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The 30-Minute City: Designing for Access
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Preface

A discussion is presented of the ways in which accessibility to employment and urban services constitute an important measure of the quality of urban living, and how accessibility might, therefore, be included as an important component of a ‘social report’ for a city or region. A conceptual framework is introduced for measuring accessibility in terms of the ease with which citizens may reach a variety of opportunities for employment and services. This framework is interpreted as an approach to evaluating transportation and regional plans which differs from approaches based upon travel volumes and travel times which are currently employed in urban transportation planning and evaluation. The use of the proposed measures of accessibility is illustrated with data on accessibility to employment and health care facilities in Los Angeles, and these data are interpreted to illustrate differences in accessibility as a function of spatial location of residence, and socio-economic status. - Martin Wachs (1973) ¹

This book started from the transcripts of a presentation I gave at the University of California, Los Angeles, the 12th Annual Martin Wachs Distinguished Lecture in Transportation. Marty Wachs is a legendary professor of transport planning, working at UCLA and the University of California, Berkeley, as well as Northwestern University early in his career, where he was a student of William Garrison, the chief ‘space cadet’ and founder of the quantitative geography movement.² His contributions to transport planning are many, but for the purposes here, we think about his development of what we now call the Cumulative Opportunities measure, which is detailed more in Appendix A, and whose abstract is replicated above.

The risk of titling a book The 30-Minute City is that it might get compared to The 4-Hour Workweek³ or 7-Minute Abs.⁴ But unlike those, the 30-minute city is not only desirable, it is feasible. We can create cities where people achieve a one-way travel time to work of 30 minutes, and satisfy all of life’s other necessities close-at-hand. This requires application of well-established knowledge, using modes of transport technology that have been around for more than a century, and doing so thoughtfully, making the millions of small

¹ (Wachs and Kumagai 1973).
² (Barnes 2004).
³ (Ferriss 2009).
⁴ I really don’t know what to cite here, but search for it online.
decisions that individuals and cities do, day after day, with this end in mind. To be clear, we do not require autonomous vehicles, hyperloops, drones, trackless trams, micromobility, or multi-copters, even if we eventually see such things widely deployed.

There are other similar types of objectives out there:

• 5 - Copenhagen is looking at a ‘5-minute city’ to achieve carbon-neutrality.5

• 10 - Satisfying the ‘pint-of-milk’ test asks whether you can purchase a pint-of-milk (or in New Zealand apparently, a pint-of-beer) within a 10-minute walk of your home, a modified version of the test asks if can you do it at some place that doesn’t also sell petroleum. 6

• 15 - Ottawa is proposing a ‘15-minute neighbourhood’.7

• 20 - The related ‘20-minute neighbourhood’ is based on the concept of ‘living locally’ by giving residents the opportunity to access all the services they need with a 20-minute walk, cycle or public transport trip.8 My colleague David King at Arizona State University is working on this in Phoenix with partners at the University of New South Wales. Twenty-minute neighbourhoods feature in Plan Melbourne.9

• 25 - I have not heard anyone serious about a 25-minute city. This is probably because unlike 5, 10, 15, and 20, 25 is not an even divisor of 60.10

While the 30-minute city tends to focus on work, the 5-, 10-, 15-, and 20-minute tests ask about life’s other activities, and while the 30-minute city tends to focus on public transport and cars, these other tests emphasise non-motorized travel, and public transport for the 20-minute threshold.

But if you can get a pint-of-milk within a 10-minute walk, you probably can get to your major services within 30, and you are doing better than the average 62-minute commute trip now experienced by public transport using Sydneysiders.11
Acknowledgements

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The text is the fifth volume in the *Access* series, and complements:

- *The End of Traffic and the Future of Access* (with Kevin Krizek),17
- *Spontaneous Access*,18
- *Elements of Access* (with Wes Marshall and Kay Axhausen),19 and
- *A Political Economy of Access* (with David King).20

As always, all errors remain the responsibility of the author.

13 http://streets.mn.
17 (Levinson and Krizek 2018).
18 (Levinson 2016b).
19 (Levinson et al. 2018).
20 (Levinson and King 2019).
1

Introduction

1.1 Why Are We Here?

Let’s start by asking a question:

Why are we here? Or perhaps, why are we here?

I am here because you are here. There is no point in writing without a reader.

And you are here because I am here. There wouldn’t be much point of you ‘sitting here’ if there weren’t words on the paper or screen in front of you.

Figure 1.1: Musical Icons in Two Sydneys.
Why do we live in cities? This is in many ways the same question as above. I am here because you are here. You are here because he is here. He is here because she is here. She is here because we are here. There would be little point to live any particular place were it not for other people. Cities are organised so that many people can be reached in a short amount of time. We reach those places by foot, bike, bus, train, ferry, or even the automobile. But we do so in a short amount of time. We don’t need airplanes or very fast trains to get between places within cities, even though airplanes and very fast trains have higher speeds than walking, bikes, buses, metros, ferries, and cars.

Cities optimise what people can reach in a given amount of time – not how fast they are going. Speed is a means, not an end. Congestion is an indicator not of transport failure, but of economic success. We see this when we compare the average speed of travel inside Sydney, about 30 km/h (18 mph)\(^1\) by car after considering traffic signals, lower speed limits, and congestion\(^2\) against the 100 km/h (60 mph) that can be regularly obtained on rural highways across Australia. This low automobile speed is not a knock on Sydney, all the great cities have congestion.

Congestion is a problem. It is not framed as an existential problem the way environmental costs are. We cannot be taken seriously when we say:

> With additional usage of the automobile, we are at risk of Global Gridlock. We see Rising Street Levels, consuming footpaths and bikepaths and buildings and all that come before it. If we don’t get Global Traffic Change under control, our cities will be inundated with asphalt, and humanity will die.\(^3\)

This is in contrast with the dire forecasts of unchecked global warming, and rising sea levels, which more and more people are taking seriously. Yet congestion is about wasting time, and your life is just the accumulation of moments in time. You won’t die from congestion \textit{per se}, but it will consume a fraction of your life. And you might die from the pollution that traffic produces,\(^4\) or from the car crashes that drivers cause,\(^5\) or the stress from driving,\(^6\) or the unhealthiness of sitting rather than walking.\(^7\)

If, like the average American or Australian, you spend 4 or 5 years of your waking life in a vehicle, and you spend much of that time in cities or suburbs, at least 1 extra year of your life is spent slowed down by traffic. You are wasting precious time, and the consequence of that is that you do less of what you want; you engage in fewer activities, or pursue otherwise less preferred opportunities.

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\(^1\) (Roads and Maritime Services 2011).
\(^2\) (RMIT/Australian Broadcasting Corporation 2016).

Though there is an amusing Dr. Who episode, \textit{Gridlock}, (Season 3, Episode 3), about a civilisation that spends its life on The Motorway, below New York, stuck in traffic, traveling at a speed of about 2.5 km/year.

\(^3\) (Künzli et al. 2000).
\(^4\) (Marshall 2018).
\(^5\) (Antoun et al. 2018).
\(^6\) (Stamatakis et al. 2019).

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Figure 1.2: Great Zimbabwe.
Cities exist as long as they can provide access to things people care about. If the environment or the economy or preferences change, that access may be valued differently. Cities rise and fall just as empires, and the important cities of yesteryear are not always dominant today. We see that with the now abandoned Great Zimbabwe (Figure 1.2), Mesa Verde Cliff Dwellings of the Anasazi People (Figure 1.3), and the Michigan Central train station in Detroit (Figure 1.4).  

1.2 A Tale of Two Sydneys

Travelers should care about what they can reach in a given amount of time, not how fast they are going.

We can think about this by comparing two different places: Sydney and Sydney, shown in Figure 1.1.

Sydney, Nova Scotia, on Cape Breton Island, was settled by Europeans in 1785. You will be forgiven for never having heard of this version of Sydney, though it has a musical icon on its shores – the Big Fiddle. From a transport perspective, people move with relatively high speeds, largely unencumbered by congestion, but have relatively few places to go. In 30 minutes, residents of Sydney, NS, Canada can reach a little more than 30,000 other people by car.

In contrast Sydney, New South Wales, settled by Europeans in 1788, also has a musical icon on its shores – the Sydney Opera House. The city as a whole is relatively slow regardless of what mode they are using. But there are so many destinations that Sydney, NSW, Australia has high accessibility than Sydney, NS, Canada. An Australian Sydneysider can reach many many things in a short amount of time; in 30 minutes, she can reach more than 300,000 workers, and over 800,000 people, by car.  

1.3 Access is Opportunity

Modern people care about access to jobs and schools and stores and shopping centres and healthcare and amenities, like the Opera House or Big Fiddle, and the outside world through ports and airports, and so on. Similarly, organisations care about access to labour and customers and suppliers and competitors and complementors and the outside world. Access is multi-dimensional.

Accessibility measures how much stuff (jobs, workers, etc.) someone can reach from a specific point in a given travel time (say 30 minutes) by a particular mode at a certain time of day.
This cumulative opportunities measure of accessibility is like the meter or kilogram in the metric system, it means the same thing regardless of where or when you are.\textsuperscript{10}

We can talk to a politician and say at a given place, your city’s 30-minute accessibility by public transport at 8:00 am is 100,000 jobs, and we can compare it with any other place, where the accessibility may be higher or lower, or we can compare Los Angeles and San Francisco, or compare Los Angeles in 2019 with Los Angeles in 1973.\textsuperscript{11}

This ability to directly compare is valuable for many reasons, and we can do this for any type of opportunity that we’re interested in, not just jobs.

1.4 Outline

The first part of the book, where we are now, explains accessibility.

We next consider access through history (chapter 2). Access is the driving force behind how cities were built. Its use today is described when looking at access and the Greater Sydney Commission’s plan for Sydney.

We then examine short-run fixes: things that can be done instantaneously, or nearly so, at low budget to restore access for people, which include retiming traffic signals (chapter 3) and deploying bike sharing (chapter 5) supported by protected bike lane networks (chapter 4), as well public transport timetables (chapter 6).

We explore medium-run fixes that include implementing rapid bus networks (chapter 7) and configuring how people get to train stations by foot and on bus (chapter 8).

We turn to longer-run fixes. These are as much policy changes as large investments, and include job/worker balance (chapter 10) and network restructuring (chapter 9) as well as urban restoration (chapter 11), suburban retrofit (chapter 12), and greenfield development (chapter 13).

We conclude with thoughts about the pointlessness of cities and how to restructure practice (chapter 14).

The appendices provide detail on access measurement (Appendix A), the idea of accessibility loss (B), valuation (C), the rationale for the 30-minute threshold (D), and reliability (E). It concludes with what should we research (F).
The 30-Minute City: Then and Now

Figure 2.1: Sydney Tram Catchment Areas, at maximum extent (c. 1923, varies by location).

Founded in 1788, Sydney’s first intercity rail network was launched in the 1850s. While designed for longer distance passenger and freight movements, it was adapted to be a commuter line, and it continues to serve these roles today.
Access was central to the design of networks. The construction of Sydney’s first public transport networks embedded accessibility.\(^1\) The spacing of stops and stations were such that 30-minute commutes were possible, and people were within 15-minute walks of train stations (and a 10-minute walk of the slower trams). Note there was also a significant amount of corruption and self-dealing by land-holding politicians along the way.\(^2\)

2.1 Trams

Sydney’s Trams, what Americans would call streetcars or trolleys, evolved over time. The first iterations were the horse-drawn trams. These were replaced by steam-powered, and a few cable-powered, trams. The network was electrified in the late 1800s and early 1900s. This network kept growing through the first few decades of the 1900s. And by the 1930s, and especially in the post-World War II era, it was phased out, getting sucked into a black hole. Like so many streetcar and tram systems around the world, it disappeared in 1961.

In contrast with Sydney, Melbourne kept its trams; there are interesting differences between the cities.\(^3\) It is important to note that Sydney’s trams, like those to the destinations in Figure 2.2, were essentially all replaced by buses, public transport service remains in those corridors. Whether people like buses better than trams and whether they’re more flexible or not is a debate for another time.\(^4\)

A map of coverage of the tram network at its peak (Figure 2.1.) shows excellent coverage within 5 and 10 minutes. Throughout the older, eastern parts of the city residents, during the tram era, many residents would have had a 5-minute walk to trams or trains, a 20-minute ride, plus a 5-minute egress time to the final destination in the city, giving a 30-minute city.

2.2 Trains

Sydney’s train system might be described by an American as a commuter rail system on steroids: today Sydney Trains runs double-decker trains on 2 to 3-minute frequencies through central Sydney. The train networks, unlike trams, did not evaporate. They grew systematically from Central Station in the east to the Blue Mountains in the West.

The mainline and then many branches spawned communities that saw their peak growth in the late 1800s and early 1900s. The harbour

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\(^1\) Sydney is hardly unique in this regard, we just use it as an example.

\(^2\) (Muir 2016).

\(^3\) (Wardrop 2020).

\(^4\) (Hensher and Mulley 2015, Levinson and King 2019).
wasn’t bridged until the 1932, before that north and south of Sydney Harbour were connected by ferry. The City Circle was completed through Circular Quay in 1956.

Infrastructure construction was quiet for a while, especially immediately after the construction splurge just before the 2000 Olympics, but more investments have been implemented in the 2010s, including a new Metro line, currently serving the Northwest suburbs, which is being extended through the City to the Southwest. Two other Metro lines are going forward at this point, a line due west from the City to Parramatta, and a north-south line serving the Western Sydney Airport.

Figure 2.4 maps the 5-, 10-, and 15-minute walk access to the train stations, the coverage is extensive in the city and the Inner West suburbs.

Figure 2.3: Map of Sydney & Suburbs showing Tramway Lines and Stopping Places. Mapmaker: McCarron Stewart & Co (1905)
2.3 **Greater Sydney Commission**

Today, the Greater Sydney Commission is the main planning organisation for Greater Sydney. It is a New South Wales state agency headed by Lucy Turnbull, who is former Lord Mayor of the City of Sydney.\(^5\)

Her team put together the plan “A Metropolis of Three Cities”\(^6\) in which the “30-minute city” is a very important aspect. A 30-minute city is, of course, an accessibility concept. The three cities in the plan divide greater Sydney\(^7\) into:

- The ‘Harbour City’ which is the eastern part of Sydney, includes the City of Sydney.
- The ‘River City’ region in the middle, where Parramatta, the early seat of government in New South Wales (NSW) before it moved east to Sydney, is a second centre.
• The ‘Parklands City’ in the west, which after 2026 will be home to a second major airport, and its associated Aerotropolis, includes many smaller, pre-metropolitan, centers such as Penrith, Blacktown, Campbelltown, and Liverpool.

The plan, and the related transport plan, describes and defines a ‘30-minute city’ differently in different places. Some relevant quotes:

• “a 30-minute city, where jobs, services, and quality public spaces are in easy reach of people’s homes.”

• “The NSW Government will enhance public transport access to strategic centres as part of the 30-minute city – that is 30-minute access by public transport to the nearest strategic centre seven days a week to improve both productivity and liveability.”

• “Establish a metropolitan transport network which reinforces the metropolis of three cities, particularly the delivery of a 30-minute city where most residents in each city can access their metropolitan centre or cluster within 30 minutes by public transport.”

• “NSW Government’s new transport strategy aims to improve public transport so that by 2056, 70 percent of people will live within 30 minutes of work, study and entertainment. – A Metropolis of Three Cities.”

Parramatta and the west are growing faster because the eastern part of the city is relatively built up, and new growth in the east would require tearing things down. This of course occurs, especially at older industrial sites, but is more expensive than building at a greenfields site (chapter 13). The Western Sydney Airport is now

Figure 2.5: A Metropolis of Three Cities. Source: Greater Sydney Commission. (Greater Sydney Commission 2018).

8 The term Aerotropolis was popularised by Kasarda (2004).

9 (Greater Sydney Commission 2018).
under construction, and the plans call for building an Aerotropolis around that, and serve that site with a new hub-and-spoke rail network, as shown in Figure 2.5. There’s already a hub-and-spoke system built around the Central Station in the ‘Harbour City’ and a similar type of network is slowly being built in Parramatta.

So the 30-minute city goal by the GSC does not mean that the people in the western Sydney ‘Parklands City’ could reach the Sydney CBD in 30 minutes. It’s that, in 30 minutes, they can reach the Aerotropolis around Western Sydney Airport by public transport. Similarly in 30 minutes by public transport, people in the central ‘River City’ could reach central Parramatta, and, people on the eastern Harbour City can reach the Sydney CBD.

The current (2016) commute time is 26 minutes by automobile in Sydney. But the average public transport commute is 62 minutes. So one might question whether Sydney can achieve even the goal of 30-minutes by public transport to the nearest centre, much less the goal of 30-minute public transport commutes.

It’s an open question. But cities need performance measures, and 30 minutes is an appropriate goal. The important point is to get the right means in place which move in the direction of achieving this outcome, rather than just asserting the outcome.

The state of New South Wales, so far is following through and building public transport networks to serve not just the high density areas of the eastern Sydney and the middle density areas of central Sydney, but the lower density (marginal electorate) areas of western Sydney, which have a few higher density nodes.

We can check back in 2056 and see how successful they were.
3

Traffic Signals

Traffic engineers don’t normally think about accessibility. They think about traffic signal timing and vehicle delay.

Figure 3.1: Pedestrian Delay on an Urban Grid. Figure by Author.

Average pedestrian wait time
= Probability of arriving on non- "Walk" * 1/2 non "Walk" Time
= 27 seconds
Probability of waiting = 54/60 (90%)

In cities, the average pedestrian spends 20-30% of their time stopped at traffic lights for the benefit of cars.
(Before cars there were no traffic lights, delays were trivial.)
3.1 Traffic lights

Everyone is familiar with traffic signals. They operate in phases, with green lights given to alternating directions (for instance north-south, then east-west). More complicated intersections may have protected phases (green and red arrows) for turns, and may have more sophisticated timing patterns. From the perspective of a traveler in a car, on an approach, they face a cycle which comprises a red indicator, a green indicator, a yellow indicator, and an all-red period (which is red in all directions). Imagine a car arrives at this intersection during a red light. It waits for the red light to change to green before it moves on. There’s a certain amount of delay associated with that.¹

For pedestrians, traffic engineers apply the same concept, but the times differ because pedestrians systematically don’t get as much green time as cars do.

The first reason is that, because pedestrians take longer to cross the street than cars do, they have a longer ‘yellow’ period where the flashing ‘don’t walk’ signal is displayed. So unless a pedestrian arrives during the very brief ‘walk’ signal, they will wait. At the traffic signal nearest my house in Alexandria, NSW (also nearest the regional Traffic Management Centre), the light indicates ‘walk’ for 6 seconds out of up to 2 minutes. So unless a pedestrian arrives during that brief 6 second window (a 5% chance), they wait, an average of 57 seconds. And that assumes the pedestrian actuator, the ‘beg button’, was depressed on time, and that it was registered by the traffic signal controller.

The second reason is that ‘adaptive’ signals give varying amounts of green time to approaching cars, which may extend a phase compared with a fixed time allocation. Pedestrian walk phases are not similarly extended because pedestrians cannot be guaranteed to clear the intersection quickly enough.

Obvious equity issues arise.

Transport for New South Wales is very proud of their Sydney Coordinated Adaptive Traffic System (SCATS), developed in Sydney and exported around the world. It is world-leading technology in many ways – if your objective is to move cars quickly through urban intersections. The technology is perfectly capable of handling pedestrians better, but that’s apparently not in the objective function in the local implementation, so the traffic managers have made the choice to not actually count pedestrians.

¹ The probability of stopping is the ratio of red time to the duration of the whole cycle. The average stopping time for cars that stop, if they arrive randomly, is one-half the red time. Traffic engineers time signals to platoon vehicles to avoid random arrivals.
3.2 Urban Grid

The idea of the green wave emerged in the traffic engineering community in the 1920s, and was deployed by Henry Barnes who served as traffic commissioner in Denver, Baltimore, and New York City. Network timing can be done with analog technology, advanced computers are not required. This urban grid (Figure 3.1) is timed for automobile speeds not for walking speeds.2

Unless pedestrians are walking at exactly an even fraction of the driving speed, they are going to get stuck at most intersections. The pedestrian will walk and then stop and walk and stop and walk and stop and walk and stop and walk and stop and walk and stop and so on.

Here the average pedestrian will stop at 6 intersections for 27 seconds each = 162 seconds (vs. 600 seconds in-motion time). In this case, $(762-600)/(600) = 0.27$ is spent waiting at signals.

At 27% delay due to signals, a pedestrian can reach in 30 minutes today what they could reach in 22 minutes 100 years ago, before traffic signals were widely deployed. Then people didn’t generally stop at intersections, at least not for a long time.

As traffic signals were steadily deployed, pedestrian conditions become significantly worse.3 Pedestrians spending 27% of their time waiting at traffic lights on a 30-minute walk lose 8 minutes. But they lose 46% of their accessibility because of traffic lights, since being able to walk 22 minutes covers much less territory than being able to walk 30 minutes.4

3.3 Designing signals for pedestrians

Cities wonder why more people drive than walk, yet design traffic signals to favour people in cars rather than on-foot. There are many things that we could do:

- Pedestrian phases could be automatic, without requiring the pushing of a button. Instead a pushed ‘beg button’ should recall the cycle so the pedestrian phase comes sooner, and so the pedestrian walk signal is lit for a longer period of time.

- Smart intersections could count pedestrians automatically. New camera technologies are available but not widely deployed. We could also make much more effective use of the actuators that are actually out there now to estimate pedestrian flows. Currently they only register that there’s a pedestrian who depressed the button, but we could use information about when the first

2To estimate the travel time for a pedestrian on an urban grid, we need to make some assumptions:
- 10 signalised intersections per km.
- A travel speed of 1 m/s when in motion. (3.6 km/h). Time to traverse 600 m = 600 sec (10 minutes) + signal delay. (Some of the distance traversal time overlaps some of the signal delay time, but we will imagine a vertical stacking queue, rather than one that has physical distance for simplicity, this is a much better assumption for pedestrians than vehicles.)
- Each intersection has only 2 phases.
- Fixed time signals at each intersection evenly distributing green time between N/S and E/W directions. So red time = 1/2 cycle length.
- 1 minute cycle length
- If a pedestrian stops, she waits 1/2 red time. That is the “walk” phase for pedestrians is as long as the green phase for cars. Strictly speaking this is not true, it is more true in cities with narrow streets than it is in suburban environments with wide streets, as narrow streets can be crossed more quickly, so the amount of “walk” time allocated can be most of the phase. This is certainly not true in Sydney, where the ‘walk’ phase is cut short so turning cars have fewer conflicts with late pedestrians.
- Pedestrians obey traffic lights. This is not as good an assumption as vehicles obey signals, pedestrian signal violation is probably higher. This is not a moral judgment one way or the other, people tend to obey authority, even when authority abuses power.
- No platooning. This is probably too severe, a quick pedestrian with some signal coordination can probably make a couple of lights in a row.

3Accessibility loss is described in Appendix B.
4Assuming a circular or square city, 

\[ 22^2 = 484\text{min}^2, \ 30^2 = 900\text{min}^2, \ (900 - 484)/900 = 46\%. \]
pedestrian pressed the button (how soon is the ‘beg button’ depressed after the walk signal ended) to estimate the rate of pedestrians arriving per hour.

- Traffic signals could prioritise pedestrians to give them the maximum rather the minimum amount of green time necessary to cross the street.
- We could give pedestrians a leading interval, so that the walk signal is lit before cars get a green light to cross their path. This increases the visibility of pedestrians.
- We could provide more all-pedestrian phases, so pedestrians can travel diagonally across the intersection.

These are sometimes referred to as a ‘pedestrian scramble’ or a ‘Barnes dance,’ in honor of the American traffic engineer who pioneered their use.

- And of course we could ban cars from busy pedestrian precincts and eliminate traffic lights.

Similarly, signals could be designed to prioritise public transport, as there are many more people in a bus than a car, doing so would reduce person delay. The signal could be held green for longer if a bus or tram is approaching but otherwise could not make the light, or the signal could change from red to green sooner, as a bus or tram approaches, so it doesn’t have to stop and start.

These are all things that we could do, but we don’t. Instead we systematically design intersections to be hostile to people on foot and in buses and trams throughout most of the United States and Australia.
Access is important for many reasons. An oft-neglected focus is environmental. Creating access while destroying the environment, and all the places worth accessing, is definitely a short-run strategy. Yet that is the outcome of auto-mobility, with its tailpipe pollution and devouring of urban space. It also makes other modes worse off by endangering pedestrians and bicyclists, and scaring people away.

Figure 4.1: Sydney Harbour Bridge hosts alternative paths, pedestrians on the left (east), buses, cars, trains, and bikes in a caged cycleway on the right (west) edge. It once served trams as well. Source: Shutterstock
from those modes. Areas with greater access have higher walk, bike, and public transport usage, and higher density development, so tend to have lower ecological footprints.\footnote{(McBain et al. 2018).} \footnote{Recognizing that urbanites also tend to travel more by airplane and consume more of other types of goods, mitigating to some extent the relatively better outcomes of their housing and urban transport choices.}

There are many techniques for \textit{making the most popular mode, the automobile, greener}. Many countries have implemented pollution control and the United States has Corporate Average Fuel Economy (CAFÉ) standards. Policy also subsidizes smaller vehicles\footnote{But not the smallest vehicles. We could subsidise single-passenger personal vehicular transport that takes up less space, because the cars are narrower, or even because they are ebikes or bicycles.} and has given privileges for electric vehicles (EVs) to ride on express lanes and park in premium spaces. All of that is better than the alternative of not reducing the automobile’s environmental impact. The costs of batteries and renewable energy are also dropping over time.\footnote{Overall we see some small progress in sales of electric vehicles. But on the other hand this number remains too low.}

We need to think more about \textit{making the greenest modes much more popular}.\footnote{And of course there’s no reason we couldn’t do both.} This chapter focuses on improving the networks for walking, biking, and public transport. The urban street space devoted to the automobile must be reigned in, and that can be achieved by creating and reinforcing paths for other modes with different design speeds.

\subsection{First Path}

In the beginning was the path. It was undifferentiated, shared by people and animals alike, and eventually wheeled vehicles pulled
by humans and animals. While dating the First Path is impossible — the very first First Path must have been a path that was reused once, and slightly better than the unimproved space around it — it operated both in early settlements and on routes connecting nearby settlements.

Today’s version of that is the sidewalk or footpath. It is now used for people walking, sometimes for people moving goods, and occasionally for people on scooters and bicycles. It should not be used for storing cars, though it is. New uses will include low speed delivery robots.

When we see a raised crosswalk as in Figure 4.2, we know the First Path and its users are given the preeminence their venerable status warrants. When we see shared spaces, we know those hearken back to the early undifferentiated path-spaces of earlier centuries. When we see pedestrian-only zones, we see a First Path that has grown up.

4.2 Second Path

The Second Path diverges from the first path with the emergence of the first street or roads with sidewalks (footpaths). Spiro Kostof (1992) dates it to about 2000 BCE in Anatolia. Many Roman and Greek cities separated sidewalks from streets, which the Romans called Semita.7

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6 Confusingly called the pavement in British English.

7 (Kostof 1992).
Post-Rome, sidewalks were rare, making appearances in London only after the Great Fire of 1666, and in Paris after the reconstruction by Baron Haussmann in the 1860s.

But to be clear, today’s sidewalk is not the second path, it is the first. The second path is the road which is largely free of pedestrians, intended for the movement of vehicles. Originally these were animal-powered vehicles, as well as human. Later fuel-powered machines took over the street and roads.

4.3 Third Path

The Third Path actually emerged well before the Second Path was colonised by motorised vehicles. It is for bicycles, and initially was paved, in contrast with the unpaved streets and roads of its time. Given the first Velocipede was only 1817, and the first bike chain (which we associate with modern bicycles) was 1885, these came relatively quickly compared with the First and Second Paths.

While the technology of the bike lane has now been around for well more than a century, throughout most of North America and Australia bike lanes are not widely provisioned. So bicyclists have the Hobson’s Choice of driving in traffic with much heavier and much faster automobiles and trucks on the Second Path, the roadbed, or riding on the First Path, the sidewalk or footpath, in conflict with pedestrians, often illegally.

Regulations in many places limit the use of bikes on footpaths. The reasons for this are clear from the pedestrian’s point of view, bikes are traveling up to 4 times faster than walkers, and collision can create injury, and near collisions result in unwanted adrenaline rushes. Shared paths, as in Figure 4.4, are designed to be wider and accommodate both pedestrians and bicyclists.
Given the disparities of speeds on the first (5 km/h) and second paths (30-120 km/h), there is a clear market niche for an infrastructure network for vehicles faster than foot and slower than cars. Physically, one imagines it generally lying between the existing kerb and removing a lane now devoted to the storage or movement of cars. And for many if not most urban places globally, this has been recognised and networks of third paths have been, or will be, built out.

This Third Path is important not just for bikes, but for electric bikes (which are becoming increasingly feasible with progress in battery technology) and electric scooters, sometimes collectively referred to as micromobility.

The good news is that this is a low cost opportunity that cities have to further the 30-minute city. The streets are already there, they just need some space reallocated. The best place to start building a new network for human-based transport is at the terminus of many short distance trips, places like train stations, schools, universities, and shops.

### 4.4 Fourth Path

A Fourth Path for rapid buses and other high-occupancy vehicles is also important, an example is Figure 4.5. The first bus lane emerged in Chicago in 1940. One reason for bus lanes lies in operational differences compared with existing road users. Buses start and stop in traffic much more frequently than cars. But a second reason is in fact the opposite, not because buses would block cars, but because cars would block buses. Buses carry more passengers than cars, and so should move faster, and can do so when they are not stuck in traffic behind cars.

High-occupancy vehicle (HOV) lanes, and their child, high-occupancy toll (HOT) lanes are widely deployed on freeways (and some arterials) throughout the United States. The hope is by separating HOV traffic, including buses, but mostly cars, the HOV traffic moves faster, and total person throughput is increased, as HOVs are more valuable than single-occupant vehicles due to the extra passenger, under the assumption everyone has the same value of time. HOT lanes relax that assumption, and recognize that value of time varies by person, and even for the same person vary by circumstance; everyone is in a hurry sometimes. The benefits of restriction to HOV lanes, compared with use as general purpose lanes, depends very much on conditions.

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10 Rapid buses are described in chapter 7.
11 (Levinson et al. 2002).
12 (Janson and Levinson 2014, Tilahun and Levinson 2009).
13 (Dahlgren 1998; 2002).
Figure 4.6: Kelly Street, Ultimo, Sydney, is a Complete Street with wide footpath, drop-off lane, movement lane, and bike lane.

4.5 Complete Streets

The complete streets movement advocates for streets with sidewalks and separated bike lanes, and which are otherwise designed to promote safety and efficiency.

Without differentiated networks for a given mode of travel, fast modes are stuck inefficiently sharing the right-of-way with slower modes, and vice versa. Bicyclists are trapped with pedestrians (and thus too slow) or cars (and thus risk life and limb). Bus passengers are stuck behind cars. In order to achieve the access potential of each mode of transport (walking, biking, public transport), each needs its own paths free of cars. A local example of this is on Kelly Street in Sydney, Figure 4.6. A regional example is the Sydney Harbour Bridge, shown in Figure 4.1.
Bikesharing has evolved quickly in the past decade. From station-based bikesharing, to stationless (or dockless) bikesharing, to e-bike sharing, to scooter sharing. One of the things all of these

Figure 5.1: 30-Minute job accessibility difference between Nice Ride and walking in Minneapolis. Source (Schoner and Levinson 2014).
technologies do is expand access by giving people the ability to reach more territory, and thus more destinations, in less time. Jessica Schoner and I first started exploring this in 2013, examining the then station-based NiceRide bikesharing system serving Minneapolis and St. Paul.\(^1\) While the exact map of access depends on the city, year, and technology, the general pattern is likely stable, more access in the CBD, and a ring around the CBD where bikesharing provides the most relative access compared with walking. We observe similar patterns for reliability (discussed in Appendix E).

Maps of Nice Ride and walking accessibility, (Figure 5.2) and the difference between the two (Figure 5.1) were produced. In the difference map, darker shades of brown indicate a larger number of jobs accessible by Nice Ride versus walking. Darker shades of pink indicate a larger number of jobs accessible by walking than Nice Ride. The Nice Ride stations provide a marginal improvement in job accessibility over walking in a small handful of blocks. Most of these are clustered around, but not in, Downtown Minneapolis, with some corridors extending into South Minneapolis. The tan blocks around the edge of the Central Business District CBD indicate the boundary where walking is no longer sufficient to reach the major job centres of Downtown Minneapolis. These are areas where the bike-share network is the most built-up, so Nice Ride has greater potential to improve accessibility conditions beyond the walking baseline.

At the the 30-minute (and longer) time threshold, a dark ring around central Minneapolis emerges where Nice Ride provides access to 100,000 to 175,000 more jobs than walking. The dark ring shows a zone where one cannot walk to the CBD within 30 minutes, but the Nice Ride system provides Downtown access, and therefore significantly improved job accessibility.

Dockless shared bikes emerged in Australia in 2017, after a few years on the road in China. Their main contribution has however not been transport (they are used about once every 3 days)\(^2\) but instead as the recipient of complaint about sidewalk clutter (unlike say cars, which are always parked perfectly). As a consequence, they have been targets of vandalism. The obvious solution will eventually get adopted, geofenced corrals for parking bikes (shared and private), taking away one car parking space per block perhaps.

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\(^1\) (Schoner and Levinson 2014).

\(^2\) (Heymes 2019).
Hao Wu and I have examined the consequences of the change of public transport timetables (schedules) on accessibility. Adjusting system components without specific consideration for accessibility does not fare well.

Major changes to Sydney’s public transport timetable implemented in November 2017 add more services, aiming to

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Figure 6.1: Change in Job Accessibility due to the Service Change (Red denotes zones with higher accessibility after the timetable change)

1 (Wu and Levinson 2019b).
increase passenger throughput to accommodate a growing patronage, forecast to increase by 21% before 2021. The new timetable incorporates more train and bus services, and higher service frequency across the system, including service improvements for southwest Sydney and Parramatta. More services increase the passenger throughput, but inevitably reduces the buffer between consecutive services and lowers the robustness of the system in absorbing any shock from unexpected disruptions. Although the lack of timetable robustness has been criticised, little attention has been given to the effect on accessibility to jobs.

While there are more services overall, there are fewer direct (no transfer) services with the new timetable. Empirically estimated mode choice models have found that people perceive transfers to be more onerous (effectively, they are perceived to take more time) than objective measures would suggest. A minute of transfer might be perceived to be the equivalent of 2 to 9 minutes of real time. For example, there were 15 trains running between Penrith and Redfern in the old timetable (7-9 am), but in the new timetable provides 7 direct trains, and 8 trains with transfers, increasing the expected wait time for those seeking a one-seat ride, and the perceived travel time for those who choose to take trips requiring transfers. The trains are also more crowded, which is especially problematic in the summer afternoons with high temperatures.

Effects of this service change on accessibility are less straightforward. On the one hand, having more services facilitates transfers, improves train frequency, and reduces waiting time on the platform and at stops; on the other hand, running more trains reduces separation distances between trains, and requires lower operating speeds to compensate. The new timetable alters the mix of express and ordinary services, changing when and how often a stop gets skipped, which produces a spatial shift in accessibility.

We find that with the new timetable, the overall person-weighted accessibility dropped by 3%, from 45,070 to 43,730, under a 30-minute travel time threshold. Within the studied area, 63.3% of the population would be adversely affected, while 36.7% would have better accessibility to jobs for their morning commute. The new timetable reduces overall accessibility, and the majority of residents were negatively affected.

2 (NSW Government 2018).

3 (Blumer and Cockburn 2018, O’Sullivan 2018b).

4 There is a trade-off between reliability of the system and capacity utilisation. As capacity utilisation increases, flexibility on the system, and the ability to recover from incidents diminishes. This is a natural trade-off that occurs in all sorts of transport systems from air travel to highways. The problem was made evident in early January 2018, when major delays were experienced by Sydney train passengers as a combined result of driver shortages, system malfunctions, and the newly introduced timetable that was unable to deal with these unexpected disturbances in the system. This led to accusations and counter-accusations between labour and management, and a threatened strike. (Graham 2018).

5 (Liu et al. 1997).

6 (O’Sullivan 2018a).
One of the lowest of low hanging fruit to improve accessibility is implementation of rapid bus systems. Rapid bus differs from the
similarly named *bus rapid transit (BRT)* in that it does not require an exclusive right-of-way. While rapid bus systems exist in various forms throughout the world, here we use an example from Minnesota.

### 7.1 Rapid Bus Lines

Minnesota’s A Line opened in 2016. As shown in Figure 7.1, it is the part of the rapid bus network running from suburban Rosedale Mall in Minneapolis’s northeast suburbs, passing by the Green Line light rail connecting downtown Minneapolis and St. Paul, to the 46th Street Station on the Blue Line light rail connecting downtown Minneapolis with the airport and Mall of America in the south.

The environment for waiting at the stops is better than your conventional post in the dirt bus stop. There is a full gamut of stop features, including shelter, accurate real-time NextBus information, pre-payment mechanism, and benches to sit. Everything you would want except maybe trees.\(^1\) Pre-pay saves time boarding,\(^2\) and all-door boarding saves time for everyone. Interestingly, the A Line stations provide more information than the local light rail stations.

National public transport critics main complaint is lack of exclusive right-of-way seems, noting that *rapid bus* does not rise to the level of full *BRT*. However neither Snelling Avenue nor Ford Parkway, the main routes the bus travels along are typically congested enough to justify an exclusive lane for only 8 buses an hour.\(^3\) A few stretches are served by other routes as well, but still not enough. It would be nice to see some more vigorous transit signal preemption, rather than mere priority.

In addition the buses have Wi-Fi, though with advanced high capacity wireless phone coverage, this feature will be increasingly moot.

Pre-pay and all-door boarding reduce the time to board 50 passengers from about 150 seconds to 50 seconds. The faster

<table>
<thead>
<tr>
<th>Threshold (Minutes)</th>
<th>Base</th>
<th>A Line</th>
<th>Percent Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>772</td>
<td>771</td>
<td>-0.1</td>
</tr>
<tr>
<td>20</td>
<td>6,217</td>
<td>6,397</td>
<td>2.9</td>
</tr>
<tr>
<td>30</td>
<td>25,485</td>
<td>26,864</td>
<td>5.4</td>
</tr>
<tr>
<td>40</td>
<td>65,528</td>
<td>69,239</td>
<td>5.7</td>
</tr>
<tr>
<td>50</td>
<td>127,815</td>
<td>134,315</td>
<td>5.1</td>
</tr>
<tr>
<td>60</td>
<td>212,100</td>
<td>220,622</td>
<td>4</td>
</tr>
</tbody>
</table>

\(^1\) (Lagune-Reutler et al. 2016).

\(^2\) MetroTransit has a very generous free transfer policy.

\(^3\) The A Line runs every ten minutes (6 buses per hour in each direction), the local 84 bus it largely replaced remained with 2 buses per hour to serve the local bus stops the A Line skipped.
### Time-saving features:

- **Prepay.** Riders tap on before boarding the bus. This saves 1.5 - 6 seconds per passenger vs. tapping on-board or paying cash. Ticket Machines at stops avoid on-board cash payments. Nevertheless, the system should be farecard only by this point in history, rather than still accepting cash.
- **All-door boarding.** Passengers can board at any door not just the front. This halves the boarding time.
- **Fewer stops.** Longer spacing between stops means less dwell time at stops and less acceleration-deceleration delay. Stop spacing increased from about 200 m to about 800 m.
- **Stopping in lane.** The bus stops in traffic at the extended curb to board and alight passengers, rather than pulling over to a bus stop and having to pull back into traffic, saving time for itself, at the expense of other road users.
- **Signal priority.** Buses can hold green lights longer or turn red lights to green sooner to reduce intersection delay.

### Time-losing features:

- **Bikes on buses.** While it seems a nice feature to allow bikes on buses, (through racks attached to the front of the bus) and may save time for the bicyclist, it added 38 seconds to one of the stops by my measurement. I saw 3 of these on my first round trip on the A Line. I don’t mean to pick on the bicyclists; they are following the rules and doing what is allowed. Now maybe with experience this gets down to 20 seconds. If it were only 30 seconds for the bicyclists, who cares, but when it is 30 seconds multiplied by the number of people on board, this gets expensive. For a fullish bus of 50 people that is 25 person minutes of delay. During peak times this can be a considerable problem.

Turnaround implies a higher frequency of service with the same number of buses and hours of driver time, so the service is more productive all-around. It’s a win-win for almost everybody, except people who have to walk a longer distance to get to the nearest bus stop. Figure 7.2 maps the change in accessibility before and after the A Line opened. There are winners and losers but there are many more winners (green) than losers (yellow) here. Overall this increased transit accessibility by 5% for people who are within a buffer around the A Line, as documented in Table 7.1.
Figure 7.2: Percentage change in number of total jobs reachable within 30 minutes (2015 A Line vs. Baseline network and 2013 land use) (Palmateer et al. 2016).

7.2 Rapid Bus Networks

The Minneapolis - St. Paul region has an alphabet\(^4\) soup of lines in their rapid bus network, shown in Figure 7.1.\(^5\)

As of present, six additional corridors have been studied for rapid bus implementation, possibly taking us to the letter ‘K’. In any case, I hope MetroTransit gets to the letter Z and has to start using Greek letters.

One corridor (the original ‘B Line’ before that letter was re-allocated) from St. Paul to the airport was dropped in favor of a future light rail or streetcar investment at the behest of the City of St. Paul. Sadly (and predictably), that rapid bus line, which would have been opened by now, is not, and the rail line that it was aborted in favor of is at least a decade away.

Since the letters in the alphabet don’t appear to have any geographical relationship to the lines they represent, there is no reason for them to be chronological either.

\(^{4}\) ALPHABET should mean mean Arterial Lines Producing High Accessibility By Efficient Transit.

\(^{5}\) The lines are expected to open in the following sequence:

- A Line on Snelling Avenue, Ford Parkway and 46th Street (open June 2016).
- C Line on Penn Avenue (open June 2019).
- D Line on Chicago and Emerson-Fremont Avenues.
- B Line on Lake Street and Marshall Avenue.
- E Line on Hennepin Avenue.
7.3 Circuitry

You may notice that the new rapid bus routes in Minneapolis are direct, not circuitous. Circuitry, as shown in Figure 7.3, is the ratio of the network distance to the Euclidean (or straight-line) distance.

It turns out that circuitry for transit networks, particularly bus networks, is significantly higher than that of road networks, illustrating how transit system operators choose to expand their spatial coverage at the expense of directness and efficiency of the passengers already on-board. The circuitry of transportation networks affects transit accessibility, and so high transit circuitry helps to explain transit’s low mode share.\(^6\)

Circuitry is not as high for long trips as short trips, express buses and trains are much more direct than local buses. But if we want people to use transit, we need the networks to be more efficient and respect user time. Even though transfers are penalised by passengers, we should consider networks that require transfers, rather than very long single-seat rides.\(^7\)

Network circuitry is at least implicitly a factor in people’s location decisions. People select home to work commute patterns with network circuitry ratios that are about 25% better than random.\(^8\)

Figure 7.3: Circuitry: The ratio of network to Euclidean distance is always greater than or equal to 1. (Levinson and El-Geneidy 2009).

\(^6\) (Huang and Levinson 2015).

\(^7\) (Walker 2012).

\(^8\) (Levinson and El-Geneidy 2009).
Stop spacing and public transport accessibility are deeply connected. Neither short nor excessive stop spacings maximize accessibility. But the right spacing depends on vehicle acceleration and deceleration, top speed, dwell time, and pedestrian walking speed. Industry has a ‘rule of thumb’ for setting distinct stop spacings for metro, streetcars, and other public transport services. Different types of transit vary in their ability to provide accessibility, slower moving streetcar (tram) type urban rails are inherently disadvantaged in that respect. Thus the type of transit service to be built should be of particular concern, if the public transport is to effectively serve its intended population.

Changing stop spacings for hardened facilities like rail lines are difficult, and definitely a long-term investment. The stop spacing along bus lines is relatively easily adjusted. Transit planners in the Minneapolis region found stops were too close together. The close stops reduced walk access time at the expense of a higher running time for the passengers already on-board.
8
Interface

<table>
<thead>
<tr>
<th>Accessibility Comparison of Redfern Station</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population Values</strong></td>
</tr>
<tr>
<td>time (min)</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td><strong>Job Values</strong></td>
</tr>
<tr>
<td>time (min)</td>
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<td>10</td>
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<td>15</td>
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<tr>
<td><strong>Added Values</strong></td>
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<td>5</td>
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<tr>
<td>10</td>
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<tr>
<td>15</td>
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<tr>
<td><strong>% of Changes</strong></td>
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<tr>
<td>time (min)</td>
</tr>
<tr>
<td>5</td>
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<tr>
<td>10</td>
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<td>15</td>
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</tbody>
</table>

Systems interface badly. It is harder to get from one mode to another than it should be. It takes longer to get from your origin to the station, and from your station to the destination than it should. The causes are several, but mainly due to the fact that the systems are separately managed, and no one is responsible for how they interact.

Figure 8.1: Redfern Accessibility Comparison. (Lahoorpoor and Levinson 2020).
This chapter examines how people walk to train stations (section 8.1), and how they change buses at train stations (section 8.2). But the transport system has numerous interfaces that should be investigated and addressed with the view of the whole trip, not just the segment.

### 8.1 Catchment

Bahman Lahoorpoor and I wrote a piece for an outlet called *The Conversation* “How to increase train use by up to 35% with one simple trick,”¹ which adapted a more formal academic paper.² The simple trick is ensuring the entrance and exit gates at train stations are at both ends of the platform.

Recall Figure 2.4, which maps the access to train stations in the Sydney Trains network. Their catchment areas are drawn such that many people live within five minutes, or about 400 meters, from the station platform. People who live nearer platforms are more likely to use public transport, and real estate nearer the platform, with fewer barriers like roads to cross, will be more expensive.³

All of the red stations on Figure 8.2 have a station entrance at only one end of the platform. The platform is effectively a cul-de-sac.

Consider the cartoon in Figure 8.3.

In the first scenario of Figure 8.3, our customer lives in the blue apartment building in the lower left and she’s going to try to take the train to her job in the green factory at the upper right. She’s going to walk two minutes to the light green entrance to the gray platform

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¹ (Levinson and Lahoorpoor 2019).
² (Lahoorpoor and Levinson 2020).
³ (Goetz et al. 2009).
catch the train ride, the orange entrances do not exist yet. When the train arrives at the workplace station, she has to walk down the platform again to get to the green exit, and then walk the black path to the factory. She walks the length of the platform three times. She does this twice a day.

In the second scenario, she has a better outcome since there are platform gates (entrances and exits) on each end of the platform, both green and orange entrances are open. She still lives on the wrong side of the platform, so must traverse it once per trip, but she’s saving time compared to the first scenario.

In the third cartoon, she moved to the red apartment building and now lives and works on the same end of the platform and does not have to walk very far.

Putting gates on both ends of the platform is well within our technological grasp. Perhaps this wasn’t done once to save staffing.
costs when people had to buy tickets from an agent, rather than using a smartcard. It may have saved construction costs when one end of the platform was undeveloped. But those rationales have largely disappeared. We could reduce people’s travel time by a few minutes every day. The random person traveling between two station with gates on only one (random) end of the platform spends an extra 3.25 minutes each way, due to the mismatch of their entry and exit locations, and origins and destinations, compared with the ideal case where everything is aligned.

Load Balancing

Two entrances provide other advantages as well. The new entrance helps disperse passengers across the platform. People aren’t especially good optimisers.

Figure 8.4: Platform Clustering. (Douglas Economics 2013)

Figure 8.4 shows where people stand on platforms at Town Hall Station in Sydney. Where it’s red, there are more people, and we observe that it’s adjacent to the stairwells. People who don’t have a good sense of train station geography at their destination (for instance tourists, or people who travel infrequently) tend to cluster at the bottom of the stairwell and get in the first train door and then exit that door and go to wherever they’re going.

But there are people who try to optimise and get onto the right car, especially when they arrive a couple of minutes before the train is scheduled to depart. These travelers can position themselves to board the car which is closest to their desired exit. Expert commuters learn these tricks. In London, one can acquire guides to train stations designed to help optimising travelers, and one imagines with advances in GPS and augmented reality (AR)-enhanced maps, we can better load trains to both reduce crowding (on- and off-board) and reduce passenger time by aligning them with their exit, improving accessibility from both travel time and user experience perspectives.

Reconfiguration

Redfern station, which sits between Erskineville and Sydney’s Central Station, serves the University of Sydney and is the sixth busiest on the Sydney Trains network. It once had a second (southwest) entrance until the 1990s (Figure 8.5(a)). It was a rickety bridge, and it was removed for safety reasons. It was not replaced because the government pled poverty, that it didn’t have enough money at the time. The good news is that it will finally see a replacement about 30 years later (Figure 8.5(b)). Modern standards
for providing accessibility for the disabled also apply now, driving up costs for the benefit of social equality, and will result in lifts being installed on each platform.\footnote{Cost estimates are in the $AU100 million range somehow.} This entrance increases the number of people and jobs within 5-, 10-, and 15-minute catchments of the station (as shown in Figure 8.1), which translates into riders, which translates into land value, which translates into real estate taxes.

This is the kind of change the other 43 stations on the Sydney Trains network (and the countless others on train networks elsewhere in the world) with similarly lopsided configurations should receive, for which authorities don’t yet have plans. The Sydney train station with the greatest potential benefits is Erskineville, the next station down down the track from Redfern. At Erskineville, there are thousands of people who live on the wrong side of the station entrance, with even more massive apartment blocks being constructed just south of the station. These new residents are semi-circumnavigating the station twice every day. This is also low-hanging fruit. To increase accessibility this should be done now.

8.2 Transfers

Just as we might add entrances to the far end of train platforms for the benefit of pedestrians, we can think better about the interfaces between bus and rail. Consider bus drop off zones near station entrances.

Figure 8.5(c,d) shows a new bus stop at Redfern Station, which happens to be my closest train station, so I pay extra attention to what happens there. You can see the distance from near the entrance to where the buses are letting people off. This is a newly remodeled entrance which used to have a door on the side (Gibbons Street) but now has a door in the front (Lawson Street) requiring people to walk farther around the building to get inside.

To maximise access, care should be taken to minimise the travel time for people walking between bus stops and trains. Accessibility increases non-linearly with reach. Due to the area accessible increasing with the square of the radius, a 1.25-minute (out of 30) increase in travel time\footnote{An increase in walking travel time is equivalent to a decrease in walking speed, and thus a smaller accessible area in a given amount of time.} is 8\% fewer jobs reachable in 30 minutes.
(a) Historically there was a pedestrian crossing of the railroad tracks south and west of Redfern station, which was removed in the 1990s.

(b) Redfern station upgrade Option 1. Source: Transport for NSW.

(c) Added distance due to bus stop relocation and station entrance reconfiguration at Redfern Station. The old entrance was about 15 metres from the old bus stop, while the new entrance is 90 meters from the new bus stop. At an average walking speed of 1 m/s, that small change adds 75 seconds of walking time every day for people who are transferring from bus to train at the station.

(d) The distance from Redfern “Gibbons Street” Entrance to the new Redfern bus stop in the distance, adjacent to buses. Photo by author.

Figure 8.5: Redfern Station Entrances.
9

Gradial: Or the Unreasonable Network

Figure 9.1: Washington DC Metro. The centre is a space, not a point. A ‘triangle’ is formed by L’Enfant Plaza (Yellow/Green with Orange/Blue/Silver), Metro Center (Red with Orange/Blue/Silver), and Gallery Place (Red with Yellow/Green). Source OpenStreetMap.

The reasonable network adapts itself to the world; the unreasonable one persists in trying to adapt the world to itself. Therefore all progress depends on the unreasonable network.¹

The physical location of network infrastructure is one of the most permanent decisions cities make. The Cardo Maximus in the old city of Jerusalem is still a main north-south shopping street, constructed when Emperor Hadrian rebuilt the city in the 130s CE.

A street right-of-way, once created is seldom destroyed. A segment of that infrastructure is designed to be optimal at a moment of time, with a particular land use (either the realised development of today or an imagined place of tomorrow),

¹ This is an adaptation of a famous George Bernard Shaw quote.

The reasonable man adapts himself to the world; the unreasonable one persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable man. (Shaw 1903)
enmeshed within a particular network context of all the other nodes and links, compatible with a particular set of technologies. That it functions at all when land use, networks, and technologies change radically, as they do over centuries, is testament to the general flexibility inherent in the fixed topology of networks. But the implication is that if it were optimal for the world in which it was designed, it is unlikely to be optimal as that world changes.

Still, it may be the best that can be done. Embedded infrastructure, the dictionary example of sunk costs, cannot adapt much to the world around them. Instead we expect the world to adapt to the infrastructure.

Following Shaw, we might say such infrastructures are ‘unreasonable’, in that they cannot be reasoned with.

Many, if not most, planned cities have been laid out with a network of streets “with the sombre sadness of right-angles,” as Jules Verne, quoting Victor Hugo, described the American grid in Salt Lake City where streets converge at 90-degree angles to each other, in his classic road trip story: *Around the World in 80 Days.* Street grids don’t plan themselves, so while all street grids were planned, not all plans result in street grids.

Organically developed cities are often more naturalistic, radial cities, with streets feeding the city from the hinterlands, allowing more than 4-directions of entry. All roads lead to Rome, as the saying goes. The Romans themselves were a bit adverse to this organic radial system once they got their own growth machine going, laying out encampments and new settlements on the grid system. The radial system leading to and from the town would bend once it reached the town gates. But as cities themselves were generally not conceived of as whole, but rather themselves emerged, often as conurbations of smaller settlements, towns, and villages, there are often radial webs centred on town A overlapping radial webs centred on town B. Rome was famously built on seven hills, which can be read as meaning Rome is a conurbation of seven earlier villages.

Each of these network typologies has its advantages and disadvantages.

We observe that radial networks optimally maximise access for many-to-one types of movements (suburbs to central city). So rail networks, which serve the high loads demanded by, and making possible, high density city centres tend toward being radial. But when they are large they are usually not so radial that all the branches meet at one junction. From a network design perspective, intersecting more than two lines at a station can lead to other types

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2 The economist’s adage that “sunk costs are sunk” means that once something has been built, and thus that money spent, it no longer factors into benefit-cost analysis about how prospective decisions should be made, except to the extent it changes the costs of various options. Logically, you shouldn’t go to a concert just because you bought tickets if you don’t want to go, though if you are considering going to a concert or a bookstore after you bought the tickets, you don’t need to account for paying for the tickets again. You might also consider the ‘opportunity cost’ of going as the loss from not scalping the tickets. You shouldn’t throw good money after bad. But the sunk infrastructure cannot be unbuilt.

3 (Verne 1999).

4 Organic development is often largely systematically unplanned, though obviously some degree of planning often goes into laying out a street, even if it is disjoint from any other decisions. When we think of ‘planning,’ we are generally referring to longer-term, more strategic, spatial plans, that consider interactions between prospective decisions, rather than short-term, tactical plans that optimise a single decision alone decontextualised from the rest of the city, assuming all else is unchanged.

5 This was discussed in Chapter 3.3 of (Levinson et al. 2018).
of conflicts, and many systems are designed with a *triangular centre* to avoid overloading a single transfer station. Washington, DC’s largely radial Metrorail system, shown in Figure 9.1, illustrates this design. As discussed in section 14.1, cities are spaces, not points.

In contrast, the 90-degree grid is reasonably well-suited to maximise access for scattered trips, what network analysts would call a many-to-many pattern. We see this especially in dispersed point-to-point (suburb-to-suburb)\(^6\) flows that are enabled by and reinforce the grid. This is the network for the automobile. The Los Angeles freeway grid,\(^7\) the famous Milton Keynes arterial grid,\(^8\) and numerous other late twentieth century cities have been designed in a grid-like way (though not so orthogonal that Victor Hugo would object). Even though the topology is not as efficient from a distance perspective as say a 60-degree mesh, by remaining out of the city core, it can keep speeds higher.

But in response to the land use landscape that emerged with the automobile, public transport planners like Jarrett Walker\(^9\) have called for more grid-like public transport networks, so people can move, via public transport, suburb to suburb without going through the city centre. This is relatively easy to reconfigure for buses, the very definition of *mobile capital*, while very difficult for the more capital intensive rail networks with their physically embedded infrastructure.

Still, core radial lines will always be the backbone of public transport systems so long as at least one important centre justifies a disproportionate amount of service, and so long as public transport systems have positive feedback effects.

So how can we grid the radial, or square the circle, so to speak?

A better network topology might be the 60-degree, hexagonal pattern.\(^10\) But remaking street grids for existing cities is tough-going, as property rights are well established, and requires efforts like those of Haussmann in 19\(^{th}\) century Paris.\(^11\)

Instead, we have overlapping network topologies, ideally which are grade-separated in some fashion, so trains are radial and don’t intersect streets or motorways, and bus services can be more grid-like, while rapid or express bus networks (see chapter 7) serve the market niche in-between.

Thus the original street level networks are still topologically grids, but the services running on that grid, while still largely parallel and perpendicular, are compressed near the centre. The bus lines, for instance, bend towards the centre, as illustrated in Figure 9.2. The regulatory layer of through streets for automobiles may be constructed to defer to the orientation of bus services.

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\(^6\) The Australian word *suburb* means a subunit of an urban area, roughly a *neighbourhood*.

\(^7\) (Bottles 1987).

\(^8\) (Walker 1982).

\(^9\) (Walker 2012).

\(^10\) (Ben-Joseph and Gordon 2000).

\(^11\) (Willms 1997).
There are no optimal network configurations independent of the enveloping land use pattern or the technological regime. Similarly there are no optimal land use allocations independent of the network pattern or technology. Finally, there is no optimal mode of travel independent of the land use or network. All three of these systems are interlocking. Moving one requires adapting the others.

The unreasonable network forces the land use pattern to adapt to it, such that relocating network elements is more costly than keeping them in place. Similarly, in many ways the network, designed for a given technology, is very hard to adapt to a different technology. That doesn’t stop people and cities from trying, the misfit we see with the automobile in the urban core is the product of failing to acknowledge this unreasonableness (see chapter 11). But as the number of European cities restricting cars in the city centre are showing, the unreasonable network wins out over technology too.

The Grid/Radial, or Gradial, network is also Gradual. These systems seldom change all-at-once, instead they gradually evolve over decades, centuries, and millennia.
Job/housing (or job/worker) balance is an important concept and it comprises very simple math. Let’s imagine a toy city where we have two places, as shown in Table 10.1.

The places \( A \) and \( B \) are 2 km apart. If all 1000 jobs are in \( A \) and all 1000 workers live in \( B \), then everybody commutes from \( B \) to \( A \). That’s 2000 person km per day of home-to-work travel.

If we add jobs to \( B \) and add workers to \( A \) we can balance the directional flows and reduce the total number of person kilometers of travel, in this case to about 1500 person km per day.\(^2\)

If we give people opportunities closer to where they are, they don’t have to travel as far. They’re not always, or even usually, going to take the job that’s closest, but they can take a job that’s closer. The important point to remember here is that jobs in a housing-rich area and housing in a job-rich area are a free lunch from a travel perspective. We don’t get many free lunches in this

\(^1\) Job/housing balance was first brought to widespread attention by Cervero (1989; 1996).

\(^2\) The numbers in the example result from application of a doubly-constrained gravity model of trip distribution that assumes 0.5 km intrazonal travel distance, with a \( d_{ij}^{-2} \) impedance function.
The 30-Minute City

It is important to acknowledge most trips aren’t work trips, and such additional population locally might increase local non-work travel. But jobs and residents do not come in a vacuum, and the additional residents and workers come with additional stores and restaurants that also decrease the average distance for non-work travel. Even if there is more travel in the larger but now more balanced neighborhood, those trips substitute for longer distances that would have been traversed elsewhere in the city.

<table>
<thead>
<tr>
<th>Jobs</th>
<th>1000</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>0</td>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>1000</td>
<td>B</td>
<td>1000</td>
</tr>
</tbody>
</table>

(a) Base Trip Table. Total home-to-work travel is 2000 person km per day.

<table>
<thead>
<tr>
<th>Jobs</th>
<th>1000</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
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<td>B</td>
</tr>
<tr>
<td>500</td>
<td>A</td>
<td>498</td>
</tr>
<tr>
<td>1000</td>
<td>B</td>
<td>503</td>
</tr>
</tbody>
</table>

(b) Alternative Trip Table. Total home-to-work travel is 1507 person km per day.

Table 10.1: Trip Tables Illustrating Job-Worker Balance

While no city is truly monocentric, Sydney is relatively focused on its Central Business District (CBD), with over 15 percent of the region’s jobs, far more than any other centre. If you include adjacent precincts, the centre is even stronger.

Figure 10.2(a),(c) shows that accessibility to jobs peaks around the harbour: from North Sydney and the CBD, south to the existing airport, and along the mainline rail corridor west towards the Blue Mountains. Access to labour is not quite as dense (Figure 10.2(b),(d)) because labour is more spread out than jobs, but it exhibits a similar pattern. Ignoring the very low density areas at the edges of the region, we see that the job/worker ratio is highest in the east and lower out west, as shown in Figure 10.2(e). And this means there are inflows into the Sydney CBD.

So the challenge for any long-run plan is to even this out, so that more areas are balanced (and yellow), and fewer areas are imbalanced (deep blue or deep red). Public transport has a similar pattern, it is even more highly radial than the road network and serves central Sydney very well. The job/worker ratio is more diffuse but it’s still highest in the centre.

Comparing the public transport to auto access ratios (Figure 10.2(f)), there are a locations within the region where it’s relatively competitive, but Sydney has the same kind of problem as US cities – people can reach many more places by automobile than by public transport in a given amount of time. Blue indicates a very low share of jobs that can be accessed by public transport versus jobs that can be accessed by auto.

While the market drives most employment and residential location decisions, the market is not operating in a fully unfettered way. The public sector steers transport investment, even when buses or motorways are operated by private firms under a concession. Zoning and other restrictions limit the type of development in certain places. The government itself is a large player in land use. Transport networks make up 30 percent of land coverage in cities. And the government controls numerous activities that use land, including schools and parks as well as government buildings and transport facilities. Some large ones in Sydney include the state government and the airport.

The now under construction Nancy Bird Walton/Western Sydney Airport (‘Aerotropolis’) would put more employment out west and that should help reduce the imbalance a bit.

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1 It is important to acknowledge most trips aren’t work trips, and such additional population locally might increase local non-work travel. But jobs and residents do not come in a vacuum, and the additional residents and workers come with additional stores and restaurants that also decrease the average distance for non-work travel. Even if there is more travel in the larger but now more balanced neighborhood, those trips substitute for longer distances that would have been traversed elsewhere in the city.

3 While no city is truly monocentric, Sydney is relatively focused on its Central Business District (CBD), with over 15 percent of the region’s jobs, far more than any other centre. If you include adjacent precincts, the centre is even stronger.

4 See section 2.3.

5 (Sarkar et al. 2019).

6 (Bertaud 2018).

7 Adopting the term used by Kasarda (2004).
(a) Access to Jobs by Auto.

(b) Access to Workers by Auto.

(c) Access to Jobs by Public Transport.

(d) Access to Workers by Public Transport.

(e) Job to Worker Ratio by Auto.

(f) Public Transport to Auto Ratio.

Figure 10.2: Thirty-Minute Accessibility in Sydney.
The state government has other opportunities within their power: they could relocate the capital out west. Government employees, and all the ancillary consultants and lobbyists and journalists and assorted government hangers-on would relocate out west with the capital in order to have access. While these transitions take time, and are costly, eventually the workforce and the jobs would be more spatially aligned. To be clear, the State of New South Wales Parliament is unlikely to move soon, even if it would be more central and closer to the people. Parliament’s existing building (Figure 10.3) is lovely, backing onto Sydney’s Domain, the local equivalent of New York’s Central Park. It will make an excellent museum someday.

Relocating jobs westward is half the jobs-housing imbalance solution. The other half is constructing more housing in the east. The market, supported by local and state government is doing some of that. The Green Square development (Figure 10.1) exemplifies this.

The building in Figure 10.1 is constructed across the street from a train station that, unfortunately, one cannot access by just crossing the street. When finished Green Square and neighbouring Zetland will have some 90,000 residents. Unfortunately, they haven’t matched the public services for this. The station as shown in Figure 10.4 serves commuting construction workers, among others, who are building new buildings holding even more commuters. Officials are talking about installing more rail service, but they have not ensured concurrency between the public transport investment with the housing investment. And of course 90,000 people are going to need other public services like schools – officials are satisfying that by building a school for 900 students. Now you can do the math on how many school-age children 90,000 people will comprise, even if the adults among them tend to be young and childless.
11

Urban Restoration

11.1 Fubar

Since World War II, many cities can be classified as by the military word *fubar* – an abbreviation of ‘f*cked up beyond all recognition’, which entered the English language around 1944 at the height of World War II and the peak of the influence of downtowns on American life.¹

In more modern language, we might simply call them f*cked up. In general parlance, the phrase means:

“*A level of status. Typically used in reference to being physically, mentally, morally/ aesthetically, performance-wise, or even theoretically damaged in some way.*” – Urban Dictionary.²

¹ (Harper 2019a).

² (Urban Dictionary contributors 2019).
American cities are damaged: physically, mentally, aesthetically, and performance-wise. They are far off their peak. While some cities have recovered from the nadir of their damage, perhaps in the 1970s, others are still falling.

My birthplace, the City of Baltimore, hasn’t been especially safe in my lifetime. I was personally held up at gunpoint at the age of 3 coming out of nursery school with my mom. As of 2018, the murder rate was 51 homicides per 100,000 people, ranking 23rd in the world among large cities, not a record to brag about. The violence has been well-documented, transformed into entertainment for the HBO audience and has many causes, not the least of which is the drug war. State-sponsored displacement due to urban renewal and freeway construction also played a role. The riots, especially those in 1968, were a major catalyst of ‘white flight’. Perhaps even the removal of the streetcars (in Baltimore, the last streetcar ran in 1963) was a cause as well as a result of the decline of the core.

Like many other older industrial cities, the City of Baltimore, due to a self-reinforcing feedback loop, has lost significant population as shown in Table 11.1. Pull factors of suburbia (more land per dollar, more exclusivity, safety from physical violence, better schools) reduce the population of the middle class in the inner city. The remaining population is poorer, less well educated, and more violent. Because people do not feel safe in the city, more people who can, leave, at least for the suburbs, but also for other metropolitan areas. While almost every US metropolitan area has a population larger than it did in 1950, almost every core city has a smaller population. Since access to other people creates wealth, the diffusion of that population diminishes productivity. Those with an automobile can sustain access over a larger distance at higher speed, and compensate for the productivity loss of lower population density and less proximity. For those without a car diffusion reduces access, and thus opportunities to build wealth. Average metropolitan accessibility may increase with population by auto as the higher speed offsets the lower density, but it has assuredly declined since 1950 for those without.


<table>
<thead>
<tr>
<th>City</th>
<th>1950</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>City</td>
<td>949,708</td>
<td>602,495</td>
</tr>
<tr>
<td>Metro</td>
<td>1,162,000</td>
<td>2,710,489</td>
</tr>
</tbody>
</table>

American cities are damaged: physically, mentally, aesthetically, and performance-wise. They are far off their peak. While some cities have recovered from the nadir of their damage, perhaps in the 1970s, others are still falling.

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### 11.2 Things Lost

A number of things have been lost in these once great cities. Some due to inevitable technological change, some due to social change, and some due to poor policy choices.

Many cities have ‘Then and Now’ books which compare what something once looked like and what it looks like today. Consider
• Transport
  – Fast intercity trains → Airplanes, Cars
  – Streetcars (Trams) → Buses, Cars.

• Land Use
  – Downtown department stores, Shopping streets, Independent retailers, → Chains, Malls, Big box stores, Strip shopping centres → Delivery.
  – Butchers, Bakers, Fruiterers, Fishmongers → Supermarkets → Delivery.
  – Single room occupancy apartments (SROs) → Homeless encampments.
  – Neighbourhood schools → Megaschools.

• Information technology
  – Movie theaters → Multiplexes → TVs → Laptops → Smart phones → Smart watches.
  – Police boxes, Telephone booths → Mobile phones.
  – Letters, Mailboxes, Post offices → Email → Messaging.
  – Records → Tapes → CDs → Online music.

Figure 11.1, Los Angeles City Hall (c. 1928) was enmeshed in a dense urban landscape. While there was a surface triangular parking space immediately above it, most blocks were covered by buildings. That is no longer the case, where green malls and surface parking and a new freeway have completely gutted the landscape.

American (and Australian) cities don’t perform as they should, it takes too long to get from here to there, they are slower than they used to be. They are less accessible on foot, by public transport, and by bicycle.

Cities are uglier than they used to be, many grand buildings have been destroyed, only a few landmarks remain. Public streets and spaces have been transformed from elegant brick to refined asphalt in the name of a smoother ride for fast moving cars.

The shaded box shows some of the things that have been lost, and their proximate replacement, organised by three main categories: change due to automobility, changes due to land use (which are not unrelated to automobility), and changes due to
information technology and mobile communications. Obviously this list is far from complete, it is just an indicator of things that were once commonplace that have now disappeared from the American city. And, to be clear, some of the things that did—in the fond remembrances of the twentieth century (TV, department stores, shopping malls, and big box stores) are themselves being undone by online retailing and online media.

The deployment of the automobile brought in changes associated with its dominance, including urban renewal and highway construction, along with accommodation of the car through excess parking (parking spaces were literally once parks for trees along the street), wide streets, taking of street space from public transport and walkers, and the like.

11.3 Getting One Thing Right

Despite all their flaws, cities persist. They may ebb and flow in the league tables, but the dominant cities of 100 years ago remain among the most important, taking their place among some new risers. The list of US cities at the top, by century, is shown in Figure 11.2. The top 5 cities in 1900 (New York, Chicago, Philadelphia, Boston, and St. Louis) remain among the top 20 in 2000, as do 4 of the top 5 in 1800 (sorry Charleston), and 3 of the top 4 in 1700 (sorry Newport). But almost all of those metropolitan areas are larger than a century ago. They are just relatively less important, not absolutely so.

How did they rise? Well, they got at least one thing right. Often that one things was just an accident of location (a great harbour, the story of many a city), or the confluence of technology and geography like Chicago, the hinge for the Great Lakes, where all the railroads serving the vast resources of the northwest passed. Sometimes it was a coincidence of history: the good luck to have a cohort of similarly minded inventors creating a new industry like automobiles in Detroit around 1900; film benefiting from the almost perfect sunlight in Los Angeles (which was smaller than Albany in 1900), supercharged by the defense industry, freeways, and an excellent harbor; integrated circuits blossoming among the orchards near San Jose mid-century; or legalised gambling coupled with cheap electricity from the Hoover Dam, as per Las Vegas in the latter half of the twentieth century. The key to remember is that a city is a ‘positive feedback system in space.’ Accessibility begets more accessibility: Infrastructure investment creates access induces development creates access induces infrastructure investment. Repeat.
Figure 11.2: Metropolitan Population Rank by Century.
Data: US Census.
But cities also make conscious choices, and sometimes they made really good choices. New York invested in the Erie Canal, Baltimore in the B&O Railroad, many cities in their airports. The Sydney trains network, shepherded through by civil engineer J.J.C. Bradfield in the first half of the twentieth century is another example.

Great investments don’t guarantee growth though, the boosters of St. Louis were no less boisterous than the boosters of Chicago. They scored an Olympics and World’s Fair\(^8\) in 1904, when they were only trailing Chicago by a small amount. St. Louis had two major league baseball teams as late as 1953. But today St. Louis is in the outer orbit of Chicago, not vice versa.

\(^8\) The Louisiana Purchase Exposition, made famous by the Judy Garland 1944 movie’s Meet Me in St. Louis.

11.4 Restoration

Can we figure out how to unf*ck America’s cities?\(^9\)

This should not be a difficult problem in a technical sense, there are wonderful cities in many other parts of the world, and even a few in the United States itself, which are not dominated by the automobile, where people want to be. We know this because people pay a premium to live there rather than leave there.

One of the defining features of many US downtowns as late as the 1940s and 1950s was their streetcar system. While mileage and ridership peaked nationally in the US in 1923, ridership saw a second peak in 1946 in the aftermath of World War II and its restrictions on car use (due to petroleum and rubber rationing).

Since the late 1980s, US cities have been constructing light rail (LRT) systems, which have many surface similarities to streetcars. The main differences are in how they are operated, and differences of degree rather than of kind. LRT usually has an exclusive right-of-way, and the vehicles tend to be wider and longer than streetcars. Sometimes LRT is grade separated. Streetcars (trams) in contrast often run in traffic, sharing lanes with cars, trucks, and buses. Obviously grade separation increases running speed. Also obviously, a faster mode of travel will generally produce more access. LRT also has a greater station spacing, which increases running speed at the cost of higher walking access and egress time, as described in chapter 7.

So one of the theories of unf*cking cities is that of reversing the streetcar removal through LRT construction. This is an issue of scale though. Streetcars were quite extensive.

Is there any city in the world that has seen its streetcars/trams largely (if not entirely) removed, and then seen them restored to

\(^9\) Other countries may have similar problems, but America’s are especially severe.
Table 11.2: Tramway Restoration, some representative cities.

<table>
<thead>
<tr>
<th>Metro area</th>
<th>Peak Year</th>
<th>Peak km</th>
<th>Peak Pax (M)</th>
<th>Current Route km</th>
<th>Current Pax (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Besançon</td>
<td>1903</td>
<td>11</td>
<td>14.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bordeaux</td>
<td>1946</td>
<td>200</td>
<td>66.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Montpellier</td>
<td>1930</td>
<td>15</td>
<td>60.5</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td>Mulhouse</td>
<td>1930</td>
<td>57</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strasbourg</td>
<td>1930</td>
<td>230</td>
<td>71.5</td>
<td>65</td>
<td>166</td>
</tr>
<tr>
<td>Tours</td>
<td>1900</td>
<td>20</td>
<td>15</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Berlin</td>
<td>1929</td>
<td>634</td>
<td>929</td>
<td>193</td>
<td>197</td>
</tr>
<tr>
<td>Bergen</td>
<td>1923</td>
<td>15</td>
<td>20</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Geneva</td>
<td>1923</td>
<td>120</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moscow</td>
<td>1940</td>
<td>280</td>
<td>949</td>
<td>181</td>
<td>214</td>
</tr>
<tr>
<td>St. Petersburg</td>
<td>2002</td>
<td>300</td>
<td>950</td>
<td>205</td>
<td>425</td>
</tr>
<tr>
<td>Shenyang</td>
<td>1945</td>
<td>25</td>
<td>6</td>
<td>97</td>
<td></td>
</tr>
</tbody>
</table>

Note: Peak year is for network extent, not passengers.

something resembling their peak length (e.g. in North America, something like 1920s era length)?

While very few cities have fully restored tram service to its previous peak, many are in process. As far as I can tell, no US city has built more light rail tracks than it previously had streetcars. But this is a difficult number to ascertain, as the results have not been previously compiled. Washington, DC’s Metro (233 km) seems to be larger than its streetcar system (160 km) once was, though the LRT and streetcar network in the region remains much smaller.

There are, however, a few European cities that have more than restored systems that were removed in the second-half of the twentieth century, as shown in Table 11.2. Besançon, France, Montpellier, France, and Bergen, Norway appear to meet that test. Overall, some of the best restoration has taken place in France. To be clear, nothing is a perfect comparison. Peak year for length is not necessarily the peak year for patronage. Current replacements are not necessarily the same lines, as cities have changed in the intervening half century. Also the technology may not be LRT or streetcar for streetcar, but may be a Metro or train service, which is better in most respects. However it is clear that urban restoration of public transport is conceivable and popular.

The pattern through much of the western world was that trams were dismantled in favor of more modern, less capital intensive

10 Surveying transport experts and verifying

11 (Boquet 2017).
buses and cars. This pattern also played out through much of Australia, including Sydney, Adelaide, and Brisbane. Unlike Sydney, however, Melbourne retained its trams for reasons that are highly localised to the particular governmental structure and personalities of the place.\footnote{\cite{Spearritt2014}}

Sydney has restored light rail to replace trams on George Street, as shown in fig:GeorgeStreetSydney. The cost of restoring a Sydney-sized (Melbourne-sized) tramway network, has been estimated to be $\text{AU} \ 45$ billion at the current cost per km of recent construction.\footnote{\cite{Davies2014}} Since this would be staged over time, this would be about $2$ billion in capital costs per year for 22 years, or about $400$ per person (in Greater Sydney or Melbourne, both with about 5 million people) per year, a not inconsiderable sum (about $1$/day/person). That cost would be borne both by users and non-users alike, and more than half the metro area would not be accessible by tram. So one of the questions would be: How much do non-users benefit?

We know accessibility provides value to real estate, so even non-users pay a premium for the additional accessibility provided when they choose to rent or buy land. The value of residential value uplift from light rail has an extensive literature, the value for new streetcar systems in contrast is far less well established, in part because most of those systems don’t actually add access compared to the existing public transport service. They don’t enable people to do more things in less time. Arguably streetcars improve the quality of the public transport experience, however, and that should not be dismissed out-of-hand, people are far from utilitarian in their preferences.

\subsection*{11.5 Revanchism}

Thomas Wolfe famously wrote \textit{You Can’t Go Home Again} and Heraclitus said “no man ever steps in the same river twice.” So we cannot simply be historically revanchist\footnote{Revanchism is from the French for revenge.} and return cities to a forlorn memory of their 1946 or 1923 peak (for the United States). So many things have changed. To try to gain anything that has been lost, we must also lose at least some of what has been gained.

The simple revanchist solution is to ban the car. And while this can be, and has been, done in places, it cannot be done everywhere. Some of the city was built before 1920 prior to the auto. Banning the car and restoring public transport, or at least making walking and biking better, is mere restoration. However, much of the metropolitan region was constructed after 1950 in landscapes designed for the automobile, and removing it from the roots in those places will be as community-damaging as removing trams.
were from areas built in the streetcar era. People will lose considerable time taking less efficient modes to get to work, stores, and other places they need to be.

The part that is difficult for boosters to understand is context. There is a harmony between a place and the technology that was available at the time it was created.

Keeping the streetcars going for cities designed around streetcars would not have been an unreasonable decision. Improving them so they had an exclusive right-of-way, stops that did not endanger pedestrians, and low floors for access would have been a smart way to exploit the long-term investments. Restoring streetcar service on those streets where the tracks were once ripped out is an expensive decision, but so long as the built form of that era also remains or can be rebuilt, will at least be rewarded with ridership.

In contrast, constructing new streetcars on short, slow circulator lines has little value. Slow light rail (or infrequent commuter rail) to low density suburbs might attract some park-and-ride passengers, but will gain far fewer riders than that same investment in a more amenable environment.\textsuperscript{15}

Setting aside all the other reasons we may dislike cars (their well-documented sins of pollution, hazard, and the like), it was perfectly appropriate for low density post-war suburbs get transport networks designed with cars in mind. The land use pattern, road network, and technology were a good fit for their users, and the market seemed to eat it up.

But it is an obvious misfit to shoehorn the automobile into cities designed prior to its conception. Rebuilding those core cities for cars was an epic disaster, transforming streets into traffic sewers, leveling functional buildings for parking lots, tearing up lively neighbourhoods for freeways.\textsuperscript{16}

\textsuperscript{15} This is a Type I design mistake, as per Table 11.3. Though unrelated to its use here, in statistics, a Type I error rejects a true null hypothesis and is called a ‘false positive.’

\textsuperscript{16} This is a Type II design mistake. In statistics, a Type II error is referred to as a ‘false negative.’
Figure 11.3: George Street, Sydney, 2019, has seen tram routes restored.
To an urbanist, America’s post-war suburbs are also fubar. They not only require people to rely on the automobile, they make it very difficult for anyone without an automobile to access anything in a reasonable amount of time, much less 30 minutes. While the houses are sometimes individually attractive, public and pseudo-public spaces are often lacking, and the center of life, the shops, are surrounded by acres and acres of asphalt.

In contrast with the idea of *restoration*, described in chapter 11, which brings back something that once worked, *retrofit* aims to change a place which is presumed to not be working satisfactorily to something new. Many suburban areas can only be *restored* to farms or wilderness, but perhaps they can be *retrofit* to be better places.
(a) Parramatta Road Turnpike (1870), near University of Sydney. Source: Wikimedia Commons.

(b) George Street, Sydney (1890) with steam tram, University of Sydney in distance. Source: City of Sydney archive.

(c) Broadway (1954), with electric trams in front of Grace Brothers Department Store. Source: City of Sydney archive.

(d) UniLodge (2017) at the former Grace Bros building. Photo by author.

Figure 12.2: Broadway over the years.
12.1 Technological Adaptation

Adaptations occur. Just as the land use adapts to the unreasonable network described in chapter 9, so too does technology.

Streets designed for pedestrians and horses were adapted for streetcars (trams) and bicycles and cars and buses and trucks, as illustrated in Figure 12.2 showing of images of the same road, in this case, Sydney’s Broadway/Parramatta Road, over time. Broadway is not finished, and Figure 12.3 shows one rendering restoring tram (light rail) service.

The idea of retrofit is indifferent to specific technologies. Cities which were built around walking and horses and later streetcars were retrofit to enable and facilitate the automobile. Urban renewal was a massive retrofit, destroying living buildings for the sake of storing cars. Buildings in downtown Minneapolis which once assumed people would enter and exit on the ground floor were retrofit to include a second-story skyway system to compete against suburban shopping malls. Schools in Columbia, Maryland were designed with the open-classroom plan, but were retrofit to insert walls. Automobile-era suburbs are sometimes retrofit to make them more urban(e), with new rail stations and high density transit-oriented development. We have proposed retrofitting train stations with additional entrance and exits to increase accessibility.

We discuss the idea of future right-of-way retrofits in The End of Traffic. Low-speed and high-speed vehicles don’t mix well, but the hierarchy of roads built for the automobile era forces vehicles onto

\footnote{Corbett et al. 2009.}
\footnote{Levinson 2003.}
\footnote{The term transit-oriented development is usually credited to (Calthorpe Associates 1990), though the idea has been around much longer, dating to the rail and streetcar (tram) suburbs of the 19th century.}
\footnote{Lahoorpoor and Levinson 2020.}
\footnote{Levinson and Krizek 2018.}
higher level (faster, more heavily used) facilities as they leave their neighborhood. Better connectivity for low-speed vehicles (sometimes called neighborhood electric vehicles, but the same idea applies to other micromobility modes like e-bikes and to bicycles themselves) so that people can travel between neighborhoods, and not simply onto a major road, will make these alternative vehicles more viable. Cities which already have a grid network can be retrofit with traffic calming measures prohibiting or discouraging through traffic or large vehicles, while permitting local traffic and low-speed vehicles. The network can be a semi-permeable filter.

Shared spaces can be retrofit onto existing streets so that speeds are slowed and many different travelers, in and out-of vehicles, can interact over the same place.

Right-of-way reallocation is also a form of retrofit in many places, whereby lanes that had been built to standards designed for cars and trucks are reallocated for the exclusive use as bike or bus lanes.

12.2 Land Use Adaptation

On the land use side, retrofit includes building transformations, such as from conversions of warehouses to loft living, or from garages to accessory dwelling units. The more interesting elements are the conversion of parking lots and otherwise underutilised spaces to structures. Suburban parking lots are in many cases intended as a form of land-banking, a temporary use until the demand is sufficient to construct high density development. For instance, in the planned community of Columbia between Baltimore and Washington, where I grew up from the age of 5, parking around the Mall (Figure 12.4(a)) was always intended to be built upon, but the developers found no reason to deny shoppers closer parking until that time arrived. About fifty years later, some of that surface parking still remains for the temporary storage of cars, but the outer edges of the mall’s parking have been replaced with office buildings (as intended) and housing (as demand patterns changed). Retrofit of shopping center parking, perhaps the best opportunity in the suburban US for a more urban town center, have occurred in many other places as well, particularly with the decline of the shopping mall.

The Mall in Columbia attracts about 15,000,000 visitors a year. As a point of comparison, California’s Disneyland attracts about 18,000,000 visitors per year. As a Columbia resident from 1972-1991, I was once one of those visitors (actually many of those visitors, perhaps 25 to 50 of them per year).

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6 This is described more thoroughly, with numerous examples in Dunham-Jones and Williamson (2008). Talen (2011) considers the question more analytically.

7 As a point of comparison, California’s Disneyland attracts about 18,000,000 visitors per year. Disneynews.us.
I would be driven to the Mall by my mom, but as a teenager I would sometimes walk. It was not something a typical middle class adult possessing a car would do, even if it were less than 1 km away, less than the amount of distance someone might have walked within the mall. There was no good footpath or sidewalk or trail at the time from the adjoining village of Wilde Lake into the Mall.

The most recent plans call for significant redevelopment and urbanisation of the precincts around the mall, now mostly parking (Figure 12.4(b)). There have even been plans for eventually replacing the enclosed Mall with a street grid (Figure 12.4(c)). Time will tell the extent to which, and when, these come to fruition.

The problem is that temporary is often indefinite, and so land-banking via parking means an auto-oriented land use is baked into the environment for decades. Due to the unreasonableness of networks (chapter 9), the world accommodates itself to the networks and buildings it finds, making change that much harder.

To apply a metaphor Kevin Krizek and I developed earlier, every step up Mount Auto is one step farther away from the peak of Mount Transit, and every investment in an automobile-oriented world makes the avoidance of an automobile that much costlier in terms of time and quality. Every additional free parking space makes walking longer (past another parking space) and less

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8 (Design Collective 2016, Howard County, Maryland 2010).

9 (Levinson and Krizek 2005).
pleasant (past another parking space), and is another weight on the balance in favour of acquiring a car. Every additional traveler arriving in a car is another weight making it difficult to take away parking spaces.
In contrast with pre-World War II places, which were once oriented around walking, trams, and trains, and were badly adapted to accommodate the car, and now should be restored,¹ and with post-War places which were mostly oriented around the car and could possibly be beneficially retrofit to be more supportive of active and public transport,² there are the yet-to-be-developed places, the greenfields, which present us with an almost blank slate.

The best sites for cities are taken. There are a few opportunities for completely new metropolises, most of them capital cities. But most of tomorrow’s cities exist today, even if some are much smaller than they will be. However the need for de novo cities may increase if sea-level rise inundates coastal metropolises. So the idea of new

¹ See chapter 11.

² See chapter 12.
metropolises, new towns, and new districts attached to existing metropolises are all worth exploring.

13.1 New Neighborhoods: Seestadt Aspern, Vienna

When planning a new community, we must think about how it fits into the larger metropolitan fabric, the opportunity to design an entire metropolis is much rarer. Usually it is at the edge of the region, new precincts inside the city are more accurately described as brownfields, as they have had previous, but now obsolete, uses that must be cleared, and in some cases may be appropriately characterized as a complex retrofit or restoration case.

On the one hand, greenfields give designers a pretty free hand at a relatively low cost. On the other, greenfields are so far from the metropolitan core that the green modes are unattractive and provide less access than the same development and modes would in an already built up place. So the first advice is to simply try to avoid greenfields until the opportunities for restoration and retrofit are fully exploited.

There is argument about whether to provide public transport infrastructure in advance of development in order to make the development more saleable, but more nobly, to set in place transit-using habits from the get-go, rather than waiting for transit to come when the demand is there, but after automobile use is common, requiring huge behavioural shifts. An example of pre-provisioning is in the planned community of Seestadt Aspern, 30 minutes by train outside Vienna, Austria. A subway line was extended in 2010, well before the population moved in, and thus it was not well used at the time I visited (2014). Presumably this changes over time, as the construction there is rapid as shown in Figure 13.1 (and now much of it is complete) but after serving the built-up areas, the infrastructure in Vienna now leads the development. Interestingly the Aspern station is also served by buses, (Figure 13.2) which were also mostly empty at the time. One would have thought they would wait on something which has a high operating cost like buses, but apparently not. Ideally the infrastructure and development would be concurrent, however the lumpiness of infrastructure and development make getting the timing perfect nearly impossible.
13.2 New Towns: Columbia, Maryland

As mentioned in chapter 12, I grew up in Columbia, Maryland. Before it was retrofit, it was planned on a greenfield of about 5,700 ha (14,000 acres) in suburban Howard County, Maryland.\(^7\)

The original plan placed the Town Center on the west side of Columbia, adjacent to US 29, which bifurcates Columbia. US 29, a major highway connecting Ellicott City (and thus Baltimore) with the District of Columbia, has (consistent with the plan) over time been upgraded to a freeway through Columbia. The placement of the major office and shopping complex on US 29 rather than I-95 sacrificed marketability and profit for planning goals. Edge cities, of which Columbia is one, are suburban activity centers that most often crop up at junctions of freeways, ensuring both maximum access and maximum visibility for corporate cathedrals.\(^8\) By nestling the Town

\(^7\) (Levinson 2003).

\(^8\) (Garreau 1992).
Center off the less-trodden US 29, and not immediately on the roadway even there, both marketing and access punch seem to have been dissipated.

From an access perspective, as shown in Figure 13.3, Columbia is on the edge of a 30-minute commute to Baltimore (by car), and as indicated by the reds and oranges auto users can reach many of the jobs between Baltimore and Washington withing that time, especially from the eastern half of the new town. Its access by public transport, shown on the right in light greens and blues, is much less. Walking is far lower, as a practical matter only jobs within Columbia can be reached within 30-minutes by walking, and so the numbers are near the Town Center and the industrial and office parks on the eastern edge. Since its initial design, Columbia has had an internal bicycle path network, which adds to the accessibility beyond the more extensive street and road network that also permits bicycles. This can be seen especially with the yellows in the bike access in the Village of Oakland Mills just east of US 29 and the Town Center, compared with the relatively low access on foot for the same area. Bicyclists can reach both job centers in 30 minutes, while those on foot might be able to reach neither.

13.3 New Cities: Canberra, Australian Capital Territory

National capitals are often new cities built on undeveloped land. One example of that is Canberra, Australia, which was founded in 1913. To the best of my knowledge, before I visited, no one had ever walked in Canberra. There were some bicyclists, they mostly ride on the sidewalks, which like the bike lanes, are an afterthought.

The plan (Figure 13.4) is lovely; from a bird’s eye view it is elegant, perhaps beautiful. It looks organic, centered on Lake Burley Griffen, named for the town’s planner, an apprentice of Frank Lloyd Wright. It is not organic however, as plans never can be. An organic town grows from a point outward. (Or in the case of conurbation, from multiple points outward.) Instead it was laid out as a whole with the scale of the motorcar in mind, even given its early date in the deployment of automotive technology.

Canberra faces many of the same scaling problems of other 20th century planned capital cities, most notably Brasilia. To be fair, it is a challenge to plan for today’s technologies, and tomorrow’s; for today’s land use needs, and tomorrow’s. But by privileging the future over the present they guarantee the present is dysfunctional and thereby discourage growth. One hates to say “design for today, for tomorrow we may be dead”, but if we don’t design for today,
where will the growth come from? Tomorrow can worry about itself. While keeping options open is a good thing, keeping all the land vacant while waiting for the future diminishes the accessibility of the present.9

A light rail line opened in Canberra early 2019. While Walter Burley Griffin’s plan called for trams, this never happened, as it was too late in history and by the time the decision was to be made, cities were already starting to remove trams in favour of buses. Figure 13.5 depicts Canberra’s access.

9 (Levinson 2016a).
Figure 13.5: Access in Canberra, Australian Capital Territory by Alternative Modes. Source: (Wu and Levinson 2019a).
We aim to come up with measures that capture the complexity of the real world, that can explain the exploits of people. To do so, we introduce a dialectic.

Mr. Engineer was trained in engineering school to “do it right.” He is trained intensively in calculations to make sure the math works out. This is very important: the structural engineer does not want to misplace a negative sign or he would build the bridge upside down.

In contrast, Ms. Planner retorts to Mr. Engineer “do the right thing.” What are the right values? And that’s really important, too.  

\(^1\) Yes, sticking with the gender stereotypes here, engineering remains predominantly male.
Our public citizens say: “do the right thing right” providing a synthesis to this dialectic. Why is this a conflict? We need to think about both strategy and tactics. We need to think about ideas and implementation.

For instance, at train stations with entrances on only one end of the platform (see section 8.1), the sub-system objective of enabling people to leave the station is enabled, but not the broader objective of enabling them to reach their destinations in the least amount of time. Traffic signals presently are timed to minimise delay for vehicles, but not for people, and fail to count vehicle occupancy (buses wait in the same traffic as cars) or pedestrians (see chapter 3).

14.1 A Nihilistic Theory

I’m going to introduce a ‘nihilistic’ theory of transport and land use: Everything is ‘pointless.’

- Cities are pointless. Planners often abstract away important details. Dots on maps represent whole communities.
- Transit facilities are pointless. A station is not a point, it is a place.
- Junctions are also pointless. A junction, or intersection, is not a point, it’s a space. It has conflict points, which are also spaces, but it takes time to traverse, and those traversing it take up space.

Everyone working in the urban sphere should recognise this ‘pointlessness.’

Just as small spatial relations matters, so too do small time elements.

A traffic engineer proposes a change that will save somebody five seconds, and someone inevitably retorts that nobody cares about five seconds. This recalls Zeno’s dichotomy paradox.\(^2\) Because we can never get to larger time savings (or accessibility gains) when we’re always talking about how unimportant the small changes are.

\(^2\) Aristotle in Physics wrote it as “That which is in locomotion must arrive at the half-way stage before it arrives at the goal.” For instance to walk from here to there, we must first walk from here to half-way there, then from half-way there to three-quarters the way there, and so on, never reaching the end.
There is no way to save 15 seconds if you don’t save 5 seconds. There is no way to save 30 seconds unless you save 15, or 1 minute unless you save 30 seconds, or 5 minutes unless you save 1 minute. Trips comprise many elements, and use many bits of the transport network, and they are not going save it all at the same place or with the same project or process. So the better practice is to take the gains that are possible, and they will accumulate over time. And by this point, anyone reading this book should agree that saving 5 minutes does matter, since it produces 30% more accessibility.³

This argument applies to all modes. The traffic signal engineers use it to justify their signal timings for automobiles. The flaw is not in saving time, but in doing so at the expense of pedestrians and the neighborhood at large.

There is the argument that time, unlike money, cannot be ‘saved’, as there is no way to store it. And of course there is an element of truth there. But I would argue that time can be used for things that are valued more highly than standing at an intersection waiting to cross, which is to say, anything else. The time not spent waiting at the intersection might be spent in a more pleasant environment, or walking or riding farther to a slightly better or higher paying job, or a shop with somewhat better goods, or from a slightly better or less expensive home. These are the tradeoffs people make all the time, and by increasing the area that can be traversed in a given amount of time, we increase opportunity and choice.

14.2 Interdisciplinary in Real Time

To achieve this synthesis, doing the right thing right, we want to forge a new profession that is interdisciplinary in real time. Planners create long-term plans covering large areas, they, at least in theory, aim to optimise for all of society. Analysts develop policies over large areas, which have a shorter-term time horizon, and also should at least consider all of society. But the local-looking professions: engineers, architects, urban designers, and technicians of various kinds, whether they are involved in building for the long-term or managing and operating the system in the short-term, by definition optimise locally, for the site, rather than the city. How the site interacts with the city is neglected.

We need a profession not of more urban planners. God bless you. Nor of more transport engineers. But urban operators – people engaged in today’s city not tomorrow’s, but who can manage to optimise for the system as a whole, (that is, thinking about accessibility) and not just their small piece of it.⁴

Table 14.1: Horizon and Scale

<table>
<thead>
<tr>
<th></th>
<th>Long term</th>
<th>Short term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro</td>
<td>Plans</td>
<td>Policies</td>
</tr>
<tr>
<td>Local</td>
<td>Blueprints</td>
<td>Operations</td>
</tr>
</tbody>
</table>

³ Saving time, or increasing speed, increases the area that can be covered in the same amount of time, and since accessible area increases with the square of the radius, time savings have disproportional effects on accessibility.

⁴ The origin of the sentiment “Think globally, act locally” is attributed to Scottish town planner Patrick Geddes.
The world is changing ever-faster. Yet strangely, today’s professionals undertake and celebrate very long-term plans where they acknowledge the existence of a problem (congestion), and technology (autonomous vehicles), but don’t acknowledge that anything changes.

Instead, we should forge new urban operators as a strong alloy of planning, engineering, economics, and design. Urban operators take ideas in real time and solve today’s problems with resources on-hand, rather than solving imagined problems bringing distant dangers near. We have enough problems today. We also have solutions available to us today, and we don’t implement them.

Today’s disciplines are excellent for admiring and nurturing today’s problems, but not nearly so adept at solving them. Engineers and planners are so focused on the long term, their jobs effectively require them to build it and then abandon it. Operating and maintaining the system is someone else’s responsibility. Once they have made their design they hand it over to a contractor for construction, who then hands it over to the client.

And then we have people who are making microscopic decisions without thinking about the big picture. Where do you put the bus stop relative to the train station? This affects accessibility, but the decision is made based on what is convenient for the bus operator rather than passengers, or worse, to minimise delay for cars.

As Bill Garrison has argued, we want people who can bridge the hard and the soft – the hardware engineering of infrastructure and vehicles – and the software of management, control, and financial systems.

Bridging or merging the soft and the hard would vastly improve policy and policy-making processes. We should be able to simultaneously think of engineering and policy, not restricted to engineering or policy.

Those of us in the field should identify as transportists - not transport engineers or transport planners or transport economists. The problem must come before the mechanism of solution.

We want people who can bridge the site and the city. People who think about what is the position of a train platform in the greater context of the metropolitan area, so that people living on the south side of the platform can easily reach it, rather than semi-circumnavigating the train station.

We want a fusion of planners and engineers who would focus on the ends not on the means, who can think in multiple scales and multiple time horizons.
The goal of the 30-minute city aligns with travel time budgets and human behavior. We know that historically land developers and the railway builders were keyed in the idea of a feasible commute, and they were keen on this idea when they deployed tram and train networks and concomitantly subdivided large tracts into lots and built homes that were within a 30-minute commute of the Central City.

14.3 Lower case ‘d’ design

Architects are famous for BIG design ideas. But cities are not amenable to big designs any more. They grow (and should grow) incrementally, not comprehensively. So instead let’s talk about what I will call “lower case ‘d’ design,” the humble design decisions about where to put bus stops relative to station entrances, and how to time traffic signals. These are small urban design decisions that don’t get sufficient attention.6

There are many things that we can do that involve rethinking the details like adding train station gates to both ends of platforms to expand catchment areas, and thus patronage. Details like stop spacing and location, practices like all-door boarding, payment before boarding, optimising timetables and frequency may just squeeze a few seconds per stop or minutes per route out of the existing configuration, but collectively they greatly expand people’s accessibility.7

More strategically, this requires thinking about transport and land use balance (see chapter 10). Offsetting today’s imbalance can give us growth without additional travel or commuting-related congestion. To achieve a 30-minute city cities need to put new jobs in housing-rich areas and new housing in job-rich areas systematically as a way of growing. This contrasts with local governments desire to focus employment in the central city,8 and developers who will tend to put more housing in the outer suburbs where there are many fewer jobs.

And we need to design for the cities we want, not ‘predict and provide’ for the city we forecast. Our future cities cannot be delivered by the same disciplinary thinking that created the cities we have.

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6 These decisions are in the spirit of Christopher Alexander’s incrementalism. (Mahy et al. 1987).

7 See chapters 6, 7, 8.

8 See Sydney CBD Plan
Appendices
A Theory

This section talks about theory, and how we quantify accessibility. There will be a few equations, but they’re all the same equation just presented in different ways.\(^1\)

Cumulative opportunity and other measures of access have been described as "having no solid basis in theory"\(^2\).

The implication is that the theory underlying actual measures of access is unsound, unlike say "utility theory". I never really understood that because I don’t really know what comprises "utility." We know that smart people have written reams about utility, and prizes\(^3\) have been awarded for their work, but we cannot compare utility between people. We don’t know how to measure it in an absolute sense. We don’t know how to directly observe it. Of course people claim to know how to model it and come up with things that are called ‘utility’. But no one outside their small modeling community understands what they are doing, can replicate it, or explain it.

But access we can observe. The theory is direct. The only reason to locate anywhere is to be near things, to be far from things, or to possess things. Otherwise there’s no reason to be in a particular place. Measuring how many things one is near or one is far from is accessibility.

It can be measured in various ways, the most basic derives from Hansen’s measure of accessibility.\(^4\) Where the accessibility at Point \(i\) is the sum of the opportunities at all of the other points \(j\), and is multiplied by some measure of the cost of interaction between \(i\) and \(j\). We often operationalise that where \(O\) is jobs and \(C\) is travel time but really that’s just a shorthand.\(^5\)

\[
A_i = \sum_{j=1}^{J} O_j f(C_{ij}) \quad (A.1)
\]

\(^1\) A more formal version of this is presented in “Towards a General Theory of Access” (Levinson and Wu 2020).

\(^2\) (Miller 2018).

\(^3\) Unlike what the economics profession would have you believe, there is no actual Nobel Prize in Economics, it is “The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel.”, and began in 1969 following a donation from the bank to the Nobel Prize foundation.

\(^4\) (Hansen 1959).

\(^5\) The word opportunity may seem a bit clunky, it derives from ob “in front of; toward” and portus “harbor” originally “entrance, passage,” as in transport - to carry across. It has no obvious antonyms, we don’t generally use the words importunities or displeasures. (Harper 2019b).
We do this because jobs used to be relatively straightforward to measure and are probably the most important of the opportunities people consider when making locational and travel decisions. We take $C$ to be travel time which is also relatively straightforward to measure. Measuring $C$ is generally more complicated than measuring $O$. Along with out-of-pocket costs, travel time is probably the most important cost in people’s decision making. But we always remember that’s just a shorthand indicator. It is not the only thing that we care about.

Waldo Tobler one of William Garrison’s academic proteges famously said:

Everything is related to everything else but near things are more related than distant things.

This is now called Tobler’s First Law of Geography.

We can use that idea to create our travel time function ($f$). One of the simplest functions we can imagine is binary, and takes the value of one if the cost of going between $i$ and $j$ is less than some threshold, say 30 minutes, and zero if the cost is greater than say 30 minutes.

$$f(C_{ij}) = \begin{cases} 
1 & \text{if } C_{ij} < t \\
0 & \text{if } C_{ij} \geq t
\end{cases}$$

That threshold can be anything, but 30 minutes is useful, as we will discuss in Appendix D.

$$A_{i,h,z,m,e,t,p} = \sum_{j=1}^{J} O_{j,h,z} f(C_{ij,h,m,e})$$

This is the same as the first equation with more subscripts.

Being specific, we are measuring Access ($A$) at $i$, for time of day $h$, and activity type $z$, by mode $m$, considering cost elements $e$, within time threshold $t$, for persons in subgroup $p$. This equals the Sum of Opportunities ($O$) at $j$, at time of day $h$, for activity type (purpose) $z$, multiplied by some function ($f$) of the Cost ($C$), from getting from $i$ to $j$, at time $h$, by mode $m$, considering cost elements $e$.

It is the same as Equation A.1, it has unpacked the shorthand notation so that we can examine each different cost categories and each of these different activity types and each of the different times-of-day. Time-of-day is important for two reasons. The first is that travel times vary by time of day. Second, the opportunities available at 8 a.m. differ from those available at 10:00 a.m. stores might not be open at 8:00 but open at 10:00, while the travel time might be shorter at 10:00 than 8:00, jobs are not available at 3:00 a.m. for most types of job categories.
So if we think about it, the accessibility varies by time and by activity and by all of these subscripts. And so we need to keep that in mind and if we want to sum it up for everything then we can just sum those opportunities multiplied by those costs. But now we need to weigh the different activity types and the different times of day and the different modes and the different subpopulations who come up with weights for this. And this is essentially the full accessibility which is what ideally we would like to measure. We might write that as:

\[
A_{*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*,*
There are different ways to think about accessibility and projects or policies. One is how much additional accessibility something will provide if it is changed. Another is how much accessibility is lost because it has not been. The difference depends on your baseline. Based on prospect theory,\(^1\) we feel losses more significantly than gains. We treat ‘wasted time’ compared to a more efficient operation as a loss in the examples in this book.

So, for 30 minutes you have 100 percent of your accessibility. It turns out that if you lose nine minutes of time out of that 30 minutes (waste nine minutes because of poor system design), you lose half of your accessibility. That is because accessibility is a non-linear function of travel time. The area of the accessibility ring (annulus) from 29 to 30 minutes is much larger than the annulus

\(^1\) (Tversky and Kahneman 1981)
from 0 to 1 minutes, or 1 to 2 minutes. Even if we lose five minutes, we lose 30 percent of our accessibility. So every minute counts. Even if the policy only costs 30 seconds, this extra delay is actually costing people not only their travel time, but access to a large number of opportunities they can reach within that travel time.
C

Access Explains Everything

Access explains it all. It really very well explains many inputs to travel behavior including commuting time and mode shares. It explains real estate prices and density. It explains personal income and productivity. It explains investment decisions. We have evidence that access explains much of the variation in:

- Commuting Time
- Employment Rates
- Mode Shares
- Real Estate Prices and Density
- Incomes and Productivity
- Investment Decisions

Accessibility is really the central feature of transport-land use interaction that ties cities and places together. So while it might seem that using a 30-minute threshold is arbitrary, we have some empirical evidence that people have travel time budgets, that a one way trip is generally not much more than 30 minutes by automobile. Note also, this threshold seems to be about 45 minutes by public transport, people are willing to make longer trips by public transport than by car.

I did some work in my childhood looking at Rational Locators, we looked at the travel time distributions in the Washington D.C. region, and in 1957 William Whyte found the average home to work time was 28 minutes by car and we observed in 1968 it was 28 minutes by car and in 1988 it was 28 minutes by car in the Washington D.C. region. That’s pretty stable. I’m not going to say it’s an unbreakable budget or a fixed anthropological constant the way some people say, but there’s a great deal of evidence that 30 minutes each way is a good benchmark.
Why 30 Minutes?

Why should we use a 30-minute threshold? Perhaps it’s because of the Babylonians, who must have had twelve fingers when they developed their base 12 (duodecimal) counting system. They gave us the 360 degrees on a circle. Perhaps because the year is almost three hundred sixty days long (which would be 12 months of 30 days, $360 = 1 \cdot 3 \cdot 4 \cdot 5 \cdot 6$). And if we think that way, we might divide the day into 24 hours: averaging 12 hours of daylight, and 12 hours of darkness. The day was probably more regular before asteroids or planetoids hit the Earth and tilted our axis, giving us different lengths of daylight in winters and summers, and the fact that we have spring and autumn at all.¹

More seriously, 12 is a much more useful number than 10 in many ways, because of the way we divide things. The number 12 is evenly divisible by 1, 2, 3, 4, 6, and 12, which beats 10 handily. And if you think 12 is good, 60 is even better.

So an hour of 60 minutes is evenly divisible into:

- whole (60 min),
- half (30 min),
- third (20 min),
- quarter (15 min),
- fifth (12 min),
- sixth (10 min),
- tenth (6 min),
- twelfth (5 min),
- fifteenth (4 min),
- twentieth (3 min),
- thirtieth (2 min),
- sixtieth (1 min).

So we have this base 12 clock system which gives us a 60-minute hour ($60 = 12 \cdot 5$) that divides nicely into a half of an hour of 30 minutes which people continue to use despite the French Revolution and its companion, the base 10-based metric system. We don’t know exactly why people prefer to think in 30 minutes increments instead of 20 minutes or 15 minutes, but perhaps $1/2$ feels a more natural fraction to an animal with bilateral symmetry than $1/3$ or $1/4$.

¹ Though that probably occurred prior to the Babylonians choosing base 12.
The upper bound: Assume people work eight hours a day and they sleep eight hours a night. That gives them eight hours a day to do other things, 4 hours of which will be daylight, on average. And if you want to travel during daylight, the maximum you can travel is 120 minutes there and then 120 minutes back. So that’s a practical upper bound.²

The lower bound: Patricia Mokhtarian, then at the University of California at Davis, now at Georgia Tech, conducted significant work in the positive utility of travel³ and she observed that people have a minimum desired travel time. On average, people want to spend at least 16 minutes traveling between home and work. This varies between people, but it represents a powerful core idea that people like to have a spatial separation between home and the workplace and they like to have the alone time in their travel mode, for instance an automobile with a stereo system, or perhaps being alone in a crowd on a public transport system with AirPods playing podcasts.

And I don’t want to be accused of being a citizen of tinfoil hat country or be thought to believe in pyramid-power, but it just turns out that the harmonic mean of the upper and lower bounds is about 28.23 minutes, which rounds to 30.⁴ So I will conclude this section and say that 30 minutes is a natural value to use, with evidence for that.⁵

² Someone may raise the issue of supercommuters, who should generally be ignored, as they are so unusual as to have newspaper articles written about them. They are obviously greater consumers (and congestors) of the transport system due to their long distance. Still they are few in number.

³ (Redmond and Mokhtarian 2001).

⁴ \(\frac{2}{\frac{1}{16} + \frac{1}{120}} = 28.23\)

⁵ Also note a 5 and 15-min Bias in Data, so people round their travel times (upwards) to the nearest 5 and 15 minutes. So even if the time is not actually 30 minutes, it is reported as 30 minutes.
When we talk about the ‘30-minute city’ we can ask ‘which
30-minutes,’ and consider unreliability. Mengying Cui and I have
examined the unreliability of auto travel from an accessibility
perspective. More needs to be done on public transport reliability.

Figure E.1 compares the 50th percentile speed, the median, versus
the 90th (slowest) percentile speed, and we see that the people who
are most vulnerable to losing accessibility live in a ring around the
city. Those near the urban core can still reach most places they might
be going within a 30-minute time-window. Those at the edge still
cannot reach most places within 30 minutes. But those in the ring
can reach many fewer places on the worst 10% of days (one weekday
every two weeks, not an unusual occurrence) than the median day.

(Cui and Levinson 2018b).
It’s a natural pattern, and does not appear just because we’re looking at 30-minute accessibility, we see the same pattern at a larger radius with higher thresholds, and in a time-weighted analysis.

We can do things to try to reduce unreliability, but the first thing on roads is to reduce congestion. The best means for that, but which too few places have the courage to do, is implement a better pricing strategy, by which we mean any pricing strategy. The more that travelers incur themselves the congestion cost they are imposing on others at a given time, the more likely they are to switch to less expensive and less congested times of day. Also reducing crashes, and then clearing crashes faster, has a significant effect.

On public transport, there are other kinds of incidents, (person under train) which not as widely publicised nevertheless have consequences. Better designs and standardised practices can reduce unreliability.
F

Research Agenda

We researchers confront a transport landscape different from the one we were raised on. New micro-mobility devices (e-bikes and e-scooters) are coming out daily. Electric vehicles are being deployed more slowly. We face a new world of ‘shared’ rides, vehicle automation, and mobility-as-a-service. There is an explosion of new modes, but our accessibility framework has been classically designed for the automobile, public transport, walking, and biking.

Traditional, privately-owned automobiles are very straightforward because they’re basic, we know where to find them, they (unfortunately) generally serve only one passenger. But now we’ve got new modes where you have to go and find a vehicle that’s often randomly distributed across the landscape, with or without a dock. There is now more significance given to taxi-like services, which have apps telling you when it will arrive. The app may say the vehicle is coming in 2 minutes, but the passenger knows better than that. So reliability of information, not just reliability, and information, needs to be considered. The time, the price, and the quality of the trip are uncertain.

This explosion of new modes and new data is an opportunity for thinking about measurement. How do we actually measure access? We want to think about time and cost perception. As engineers we try to objectively measure things, but as behaviorists we know that people subjectively perceive and remember things differently than what we measure. We know that people exaggerate the amount of travel time, and on average they tend to round up rather than rounding down. So a 28-minute commute is almost always reported as a 30-minute commute, but so is a 22-minute commute sometimes.

These time and cost perceptions are a real problem because people behave based on their perceptions, not based on our measurements. So what people think of as their accessibility is based on what they perceive their travel times to be, not what we objectively measure.

\(^1\) See Appendix E.
We can better align perception and reality with traveler information, but we really need to understand people’s time perception better. We need to understand the effects of reliability. We can think about many different types of reliability measures.

Real-time GTFS is becoming available, so we’re starting to get measurements of actual public transport system performance.

Another area of how the old models break-down is shopping versus shipping. What does it mean in terms of accessibility to order food online and have it delivered to the customer in 45 minutes? How do we compare 45-minute access to Thai-food delivery versus a 15-minute walk, or Amazon’s promise of one or two hour delivery of goods vs. a 30-minute trip to the store? Are these really the same goods, are they perfect substitutes?

Well you can’t just look at those time in the same way, because with delivery the customer can engage in other activities during the wait; in contrast the traveler has many fewer things she can do, even in an AV. She just does not have the same kind of flexibility. It is an open area of research to sort virtual accessibility from physical accessibility. While being online is not quite the same as being there, it’s getting better, and more common, all the time.

We need to think about how do we measure opportunity by time-of-day because we know the opportunities vary by daypart, yet we mostly ignore that. We need to examine equity and the differences between place-based and person-based accessibility across the place-person continuum. As we divide the world into more and more subgroups we eventually have as many subgroups as individuals.

We also need to think about full-cost and full-benefit accessibility, considering multi-modal access, and how to weight the different components. When we think about the cost function and we usually talk about perceived travel time as privately experienced. If it takes 30 minutes to travel from point A to Point B, that’s something the traveler experiences. She might also experience paying out of pocket for fuel if driving or transit fares when taking the train. However, she also imposes a large collection of costs on society because the infrastructure is not fully paid for by her out of pocket. And she is producing pollution (or she is consuming clean air) and she is producing crash risk (or she is consuming safety).

We should think about these costs when conducting social evaluations, we should include not just travel time and the other private costs but we should also include the cost of pollution and the costs of CO₂ emissions and the costs of crashes and the costs of infrastructure and so on. Accessibility can be used in social evaluation, for ranking projects, policies, developments. While

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2 Or paying for bike storage at a train station, but not car parking, for some reason.

3 (Cui and Levinson 2018a).
there are not many applications that presently do this, it is a clear research direction to consider the full costs of travel, and thus the full costs of accessibility.

But we need to do this while keeping everything measurable and comprehensible in a way that we can explain to the general public and especially public officials. When is ‘this’ is better than ‘that’. Complexity is easy. Modeling is easy. Making something that people can understand is hard.
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