

## SPACE/TIME MAPPING OF URBAN TRANSIT: Isochrones, Car-dependency and Mode-choice in Melbourne

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Everyday urban life involves multiple choices of transport mode, route path and time budgets as individuals seek to move between places and projects in various parts of any city. In this paper we map the time/space zones of accessibility from any given location (isochrones) as a means to understand the ways we make choices between modes – a space/time phenomenology of everyday mobility. Harvesting data from Google Maps and other internet sources we map four primary transport modes – car, public transport, walking and cycling – and the inevitable mix between them. Within frameworks of transit-oriented development and assemblage theory we seek to understand the morphological and infrastructural conditions under which people may choose public transport and active modes of walking and cycling over the private car. Our case studies are in the suburbs of Melbourne under conditions of high car-dependency and low public transport provision. This work has several outcomes. It shows some of the prospects and limits of harvesting the emerging range of data sources as a means of mapping capacities for urban mobility. It also demonstrates the power of mapping as a production of urban knowledge in a manner that enables us to gear rigorous urban analysis to the phenomenology of everyday life and transport mode choice. Finally, it is a form of design research in that it tests the ways in which designed infrastructural change can transform the space/time flows of everyday life.

### INTRODUCTION

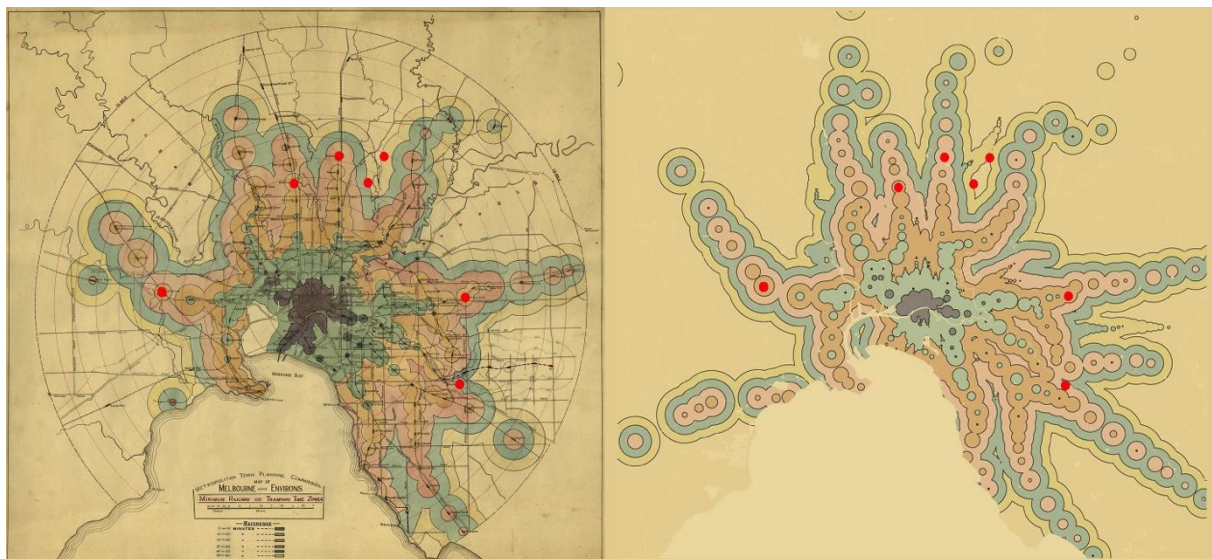


Figure 1: Melbourne Public Transport Isochrones from the central city 1925 (left) and 2015 (right).

In the 1920s the Metropolitan Town Planning Commission of Melbourne published a map entitled 'Minimum Railway and Tramway Time Zones' (Figure 1 (left)) which showed the minimum commute times to the central city by public transport. This was one of the earliest uses of isochrone mapping in urban transport history although there are earlier examples in Britain. At the time Melbourne had one of the world's most extensive urban rail and tram systems, primarily built in the 1880s and funded by public debt. The map shows a darker zone of 10 minute access surrounding the central grid and then a green zone of 20 minute access covering the extensive tram network of the inner city with fingers extending along the radial train lines into the middle ring suburbs. The 30 minute zone (orange) extends these fingers up to about 16 kilometres from the centre. This map was updated for the major 1929 urban plan of Melbourne but it had scarcely changed (Metropolitan Town Planning Commission 1929: 44). In a 21 page analysis of urban transport only a half-page was devoted to public transport with the rest devoted to road congestion – the problem was to redesign the city for cars. Public transport investment largely ceased and the result is the rapidly-expanding car-dependent city that is now such a great challenge for all Australian cities. Of course such isochrones should change over time as trains and trams become faster and lines are extended. Figure 1 (right) shows the same public transport isochrones for 2015 using the same minimum times, scale and colour scheme. After over a

century of disinvestment the similarities between these two isochrones maps should not be surprising. Over the same period Melbourne's metropolitan area has more than doubled. If we had comparable data on car access we would find that the catchment areas have expanded dramatically over the same period to vastly exceed those for public transport. This is one way of understanding what car-dependency means – that we lose time by choosing public transport.

The current public transport network has not changed a great deal with the radial structure of the train system still dominant. While it is now augmented with buses they are low-volume and infrequent with most routes being far from direct. There are vast suburban areas within the metropolitan boundary that are beyond walkable access to high volume public transport. While Melbourne's early form was driven by transit, the contemporary metropolis is largely the product of the private car. A network of arterial roads is supplemented by major roads and freeways that provide good lines of both radial and orbital movement. Much of the freeway layout follows the State's 1969 Transportation Plan, which has served as an enduring legacy.

### ISOCHRONES

Isochrones have been used in science and in transport planning to understand the relationship between movement and time for more than 130 years. Isochrone maps can include a combination of various modes of transport, or focus on a specific mode. One of the earliest examples in transport is Galton's map titled 'Isochronic Passage Chart' which showed the travel times from London to various parts of the world in 1881, by a combination of both sea and land based transport (Galton, 1881). The Atlas of the Historical Geography of the United States (Paullin and Wright, 1932) contained a series of maps showing expanding travel isochrones between 1800 and 1930. They demonstrated how travel times from New York expanded across the USA between 1800 and 1930 with the construction of new roads, extensive rail networks and then the emergence of commercial aviation. In 1912 Penck produced isochrones maps in Europe focused on regional rail travel times measured in hours rather than days (Penck, 1912). Isochrones maps of metropolitan public transport networks emerged in the same period (Manchester City Council, 1914) and may have been the precursors for the map in Figure 1 (Melbourne Metropolitan Town Planning commission, 1925).

Although there has been a tendency to focus on public transport accessibility, isochrones maps were also used for private cars. In 1972 Armstrong investigated four potential sites for a new airport in South Hampshire for their accessibility by cars. This study looked at car travel time and the number of 'air users' to identify the optimal site, assuming travel by car (Armstrong, 1972). Public transport isochrones maps are now commonly used to understand accessibility based on travel times. Websites such as Mapnificent allow users to select a point on a map and a time period to determine areas accessible via public transport based on travel time, and includes data for many Australian and international cities (Mapnificent, 2015). The website Mapumentals, which also allows users to generate isochrones, has the catchphrase 'Travel time maps: Because 'how long' means more than 'how far' and this captures the shift in perspective that isochrones maps produce. In the recent 'Plan Melbourne', a long term strategic vision for Melbourne, this idea is emphasised in one of the 9 strategic principles for the vision: 'Principle 7-'Living locally- A '20 minute' city' (State Government Victoria, 2014). Here we can see time replace distance as the key measure of accessibility, and acknowledges that movement occurs using different modes of transport and there is indeed competition between these modes.

Walking isochrones can be traced to the work of Jacobs (1961, pp.179-182) who introduced the concept of 'pools of use' to refer to the zone within walking distance of a particular urban location measured by distance or time. This later developed into the mapping of walkable catchments or 'pedsheds'. There has been a proliferation of research into walkability over the last 10 years, and pedshed mapping is a key indicator of local area walkability. At this smaller scale, pedsheds provide an insight into the permeability of the local neighbourhood, as well as an understanding of local accessibility to public transport, jobs and services.

Our interest in this paper lies in the capacities of isochrone mapping to enlarge our understanding not of single transport modes, but of the ways we make choices between modes. Everyday urban life involves multiple choices of transport modes, routes and time budgets as individuals seek to connect between home, work, recreation and shopping in various parts of any city. People make judgements based largely on trip times and we seek to use isochrones to map the empirical basis of this phenomenology of everyday mobility. The juxtaposition of isochrones for different modes can show the accessible territories and times, the basis on which we make rational choices between modes. Such mapping becomes more possible and powerful through the harvesting of GPS data that is becoming available from Google and other sources. Google Maps shows urban data for walking,

cycling and driving; public transport data needs to be accessed through public transport authorities. Our ultimate goal is to understand what forms of urban transformation are necessary to develop a walkable transit-oriented city. We suggest that one way of understanding car-dependency is the gap between a car and public transport isochrone at any given time for any particular place in the city. While there will inevitably be a range of other factors that drive mode choice, minimum time is surely primary - people will move from cars to public transport when it is the faster mode for their desired trip. We seek to understand the morphological and infrastructural conditions under which people may choose public transport and active modes of walking and cycling over the private car. To this end we have also tested how particular designs for extended public transport networks might change this equation. This is a multi-scale analysis with a focus on the interdisciplinary capacity to think across scales and to understand the relations between them – walking and cycling at smaller scales geared to public transport and cars at larger scales.

Our case studies are in the suburbs of Melbourne under conditions of high car-dependency and low public transport provision. This work has several outcomes. It shows some of the prospects and limits of harvesting the emerging range of data sources as a means of mapping capacities for urban mobility. It also demonstrates the power of mapping as a production of urban knowledge in a manner that enables us to gear rigorous urban analysis to the phenomenology of everyday life and transport mode choice. Finally, it is a form of design research in that it tests the ways in which designed infrastructural change can transform the space/time flows of everyday life.

### **THEORY**

The theoretical framework deployed here has been developed from two primary sources. The first of these is 'assemblage' theory based on the work of Deleuze and Guattari (1987) involving a focus on connections and flows rather than objects and things, on connecting objectivity/subjectivity and spatiality/sociality. This is not an attempt to prove a scientific truth but to map the empirical conditions under which these flows and mode choices take place. The term 'assemblage' here suggests a whole that is formed from the interconnectivity and flows between constituent parts — a socio-spatial cluster of interconnections between parts wherein the identities and functions of both parts and wholes emerge from the flows between them (DeLanda 2006). Transit-oriented development is not a thing or a collection of things, it is the assembled connections, alliances and liaisons between them that are crucial (Deleuze & Parnet 2007: 69). Assemblage thinking operates against any notions of place as contained or stable – transit-oriented developments are held in place by connections, tensions, flows and desires (Dovey 2010: Ch 2).

The levels of complexity, adaptability and self-organization embodied in urban assemblages suggest a second and complementary framework of resilience theory based in theory of complex adaptive systems (Gunderson & Holling 2002; Walker & Salt 2006). The task here is to understand the dynamics of complex systems where the outcome of a system depends on unpredictable interactions between parts. This is work that grows out of a mix of theories of cybernetics, chaos, complexity and resilience, much of it transferred from the study of natural systems. A complex system is one where the parts adapt to each other in unpredictable ways - they self-organise. The detailed outcomes of such a system cannot be determined in advance but rather 'emerge' from practices of adaptation and self-organisation (Johnson, 2001). Key properties of complex adaptive systems include the diversity and redundancy of different parts such that each performs a multiplicity of functions where no single part is crucial to success and the system can adapt by moving forms, functions and flows around. As with assemblage theory, there is no easy way to define the 'system' as each transit node is an interactive part of further systems at higher scales. While such theory is useful for understanding complexity and adaptation the term 'system' carries connotations of predictability and systematic control — the 'complex adaptive assemblage' is a more accurate and useful label. Understood in this way, urbanization historically shows the emergence and succession of different urban assemblages over time. In Australia, with urbanization beginning after the industrial revolution, urban morphology was linked primarily to walking, cycling and public transport. Under modernist planning and Fordist production, Australian cities embraced motorization and suburbia, firmly entrenching a car-dependent urban assemblage. The challenge now is how to replace the current assemblage with one that provides Australian cities with a new resilience in the face of climate change and population growth.

### **METHOD**

Our case studies were chosen as part of a larger research project analyzing Melbourne for potentials and capacities for transit-oriented intensification and improvements to transit at multiple scales (Ref ARC project). We were, in part, looking for sites with potential to add value to the whole network through greater network connectivity. The primary opportunities included a mix of railway stations, tramlines, shopping malls, university campuses and post-industrial zones. We selected seven primary

case studies and developed a range of urban design scenarios for each based on different levels of and designs for transport investment. These opportunities tended to emerge within a middle suburban zone outside the inner-city yet well within the metropolitan boundaries and are marked on figures 1 and 2 mostly between 20-30 minutes from the central city by public transport.

We have chosen to map isochrones of 5, 10, 20 and 30 minutes for each of four transit modes - car, public transport, cycling and walking. Five minutes (or 500 metres) has become a standard measure for walkability zones (pedsheds) at the smaller scale and while cars and public transport extend beyond 30 minutes (and beyond the city fringe) we are seeking to contain the study to scales that enable contrast between active and passive modes of transit within the city. Our walking and cycling isochrones are based on data accessible from Google Maps, car isochrones from TomTom and public transport isochrones from the transport authority (PTV). In the case of cars we compared TomTom and Google and determined that the TomTom data is more accurate. We understand that there can be problems of accuracy with this data but it has the virtue of consistency across different modes and parts of the city. There can be no truly accurate data of this kind because the average speed of walking, cycling or driving is mediated by so many contingencies. For walking and cycling these include traffic delays, topography, level of health, weather and safety; for cars they are strongly mediated by traffic delays although these are incorporated into the data in a general sense. All of the zones depend fundamentally on the permeability of the public access network, although this network will differ substantially between pedestrians, cyclists, cars and public transport.

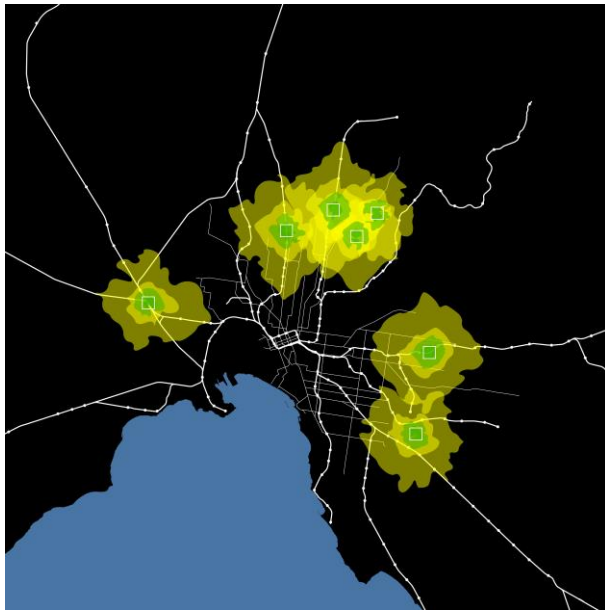
We have made a series of assumptions in order to generate a comparison between modes. For walking and cycling we have presumed that the entire trip from origin to destination is by a single mode and that there are no delays at either end (ie. that the bike is parked at both origin and destination). Car journeys, by contrast, generally involve a parking delay at one or both ends of the journey - this includes finding a carpark, entry/exit, payment and walking to the destination. While this will vary from about 0-10 minutes for different locations we have added 5 minutes total to each trip to account for this on average. While 2.5 minutes at either end may seem excessive for a car-friendly city, it can also be seen as modest during peak times and in more intensified areas.

Public transport is a much more complex mapping task since it is always multi-modal - one walks, rides or drives to and between public transport modes. We have reduced the complexity here by excluding the car and cycle connections to public transport. While such maps would be a useful addition to this work, they are complicated by being triple mode since one cannot use a car or bike at both ends of a trip (no bikes on public transport). We have simplified calculations here by choosing a public transport stop as the base point for the maps. Our public transport zones are then calculated as the sum of the average waiting time, trip time and then walking time from the transit stop. Thus a trip on a bus with a transfer to a train and then a walk to the destination will be calculated as: half the bus frequency + bus trip + walking connection + half the train frequency + train trip + walk. All of this data has been taken from the PT timetables plus walking data. Our methods here mean that 5 and 10 minute access zones for cars and public transport are insignificant. Both public transport and car access differ for different times of day and we have measured these for the morning peak (8-9am) and evening (7-9pm). We have previously measured the midday isochrones and found that they always fall between the peak and evening measures.

## ISOCHRONES

### *WALKING AND CYCLING*

Figure 2 shows the walking and cycling isochrones from 10 to 20 minutes for all of our case studies. If the local network is permeable then walkable catchments are relatively circular, or diamond shaped in the case of a regular grid. When compared to walking, the cycling zones have about 3 times the range and 9 times the accessible area for the same time limit; they are also more subject to the contingencies of topography and infrastructure – dedicated bikepaths that extend the range, steep hills that limit it, or freeways that block it. The access areas for both walking and cycling zones expand by a factor of about five with every doubling of time.



*Figure 2: Cycling (yellow) and walking (green) access zones at 10 and 20 minutes*

Both walking and cycling zones are relatively stable over time and one can predict the time of arrival for such journeys very accurately when compared to public transport and car journeys. For this reason we have represented walk and cycle zones with sharp edges while public transport and car zones are blurred. Cycling zones are a relatively consistent size for the different case studies, which perhaps reflects the relative flatness of Melbourne rather than consistent riding conditions. Both walking and cycling demonstrate capacity more than reality because such modes are mediated by weather, time of day and safety issues.

#### **PUBLIC TRANSPORT AND CARS**

Figure 3 shows the 20 minute public transport access zones for public transport from each of our case study sites. The radial pattern of the railway system is strong where sites are located on these lines; three of our case study sites are detached from tram and train lines and have smaller zones of access. Public transport access is greater during the morning peak and less during the evening due to lower frequencies. Low frequency in the evenings means that the 20 minute zones can shrink to negligible at some sites. The 30 minute access range (not shown here) covers on average about twice the range and almost 4 times the access area of the 20 minute zone. These access zones are some of the most accessible in the suburbs since our cases are based on transit nodes. Frequency of service increases for all types during peak periods; while this produces a greater access zone for trains, this effect can be more than cancelled for buses and trams that become caught in traffic jams since very few trams or buses have dedicated lanes. All public transport maps shrink during the evening due to decreased frequency.

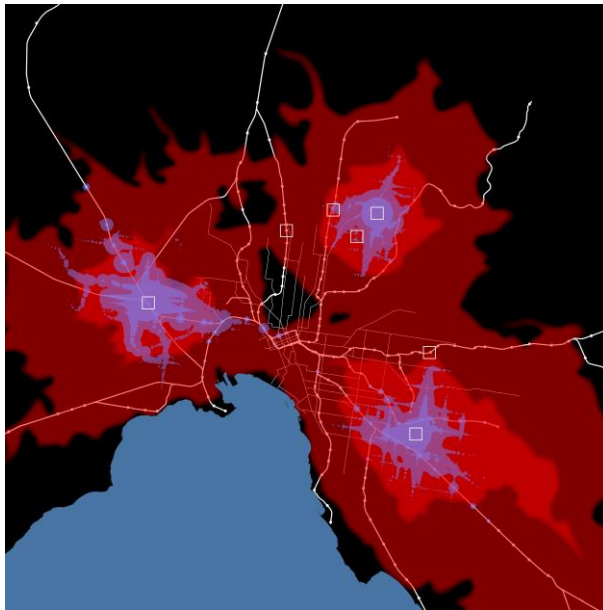


Figure 3: Public Transport and Car access zones (20 minutes, morning peak)

The similar 20 minute car access zones show protrusions are produced by freeways and arterial roads. These zones vary by about 25% across the different times of the day with the morning peak as the most constrained and evening zones as most extensive. The morning peak zone is most constrained for those driving in the direction of the city centre.

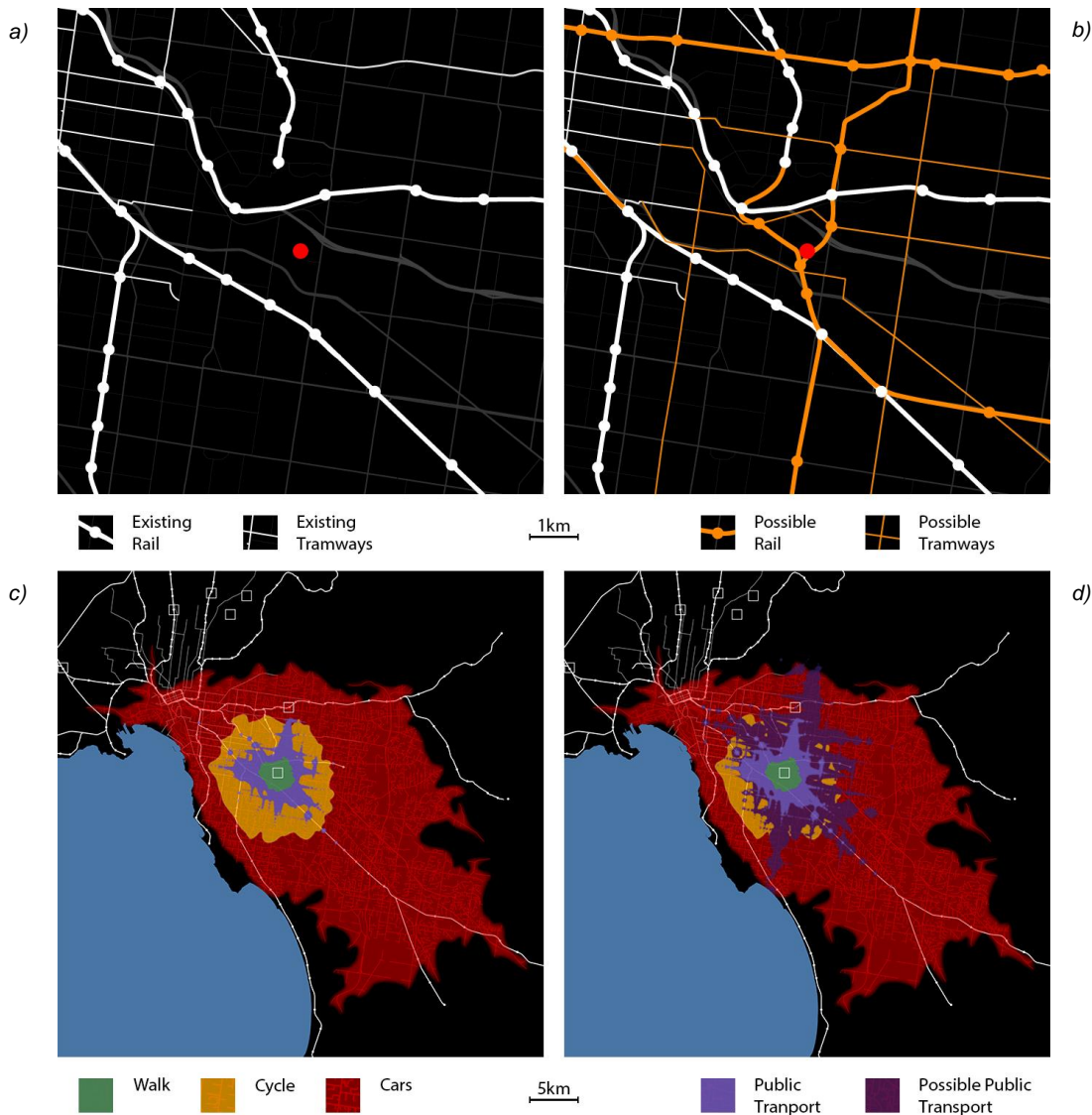
In comparing cars with public transport at this metropolitan scale it becomes clear that despite the fact that most of our case study sites are centred on public transit nodes, the choice between cars and public transport is far from competitive for most trips and at most times of day. The isochrones for these cases show that the ratio of car to public transport access zones ranges from about 4:1 to about 16:1 during the morning peak. These ratios are accentuated during the evening period when road congestion eases and public transport becomes less frequent. A resilient city is to design a city where this map would see the blue zones eclipsing the red. This gap which we will call the 'car-pt' gap is the key one that needs to be bridged in order to lure drivers out of their cars and onto public transit. During most periods of the day drivers can cover between 5-10 times the distance and between 4 and over 20 times the accessible urban area over the same time period. If one has the choice then one drives a car. One key finding here lies in the potential of cycling which has a clear advantage over cars at the 10 minute timescale and over public transport at the 20 minute timescale.

## REDUCING CAR-DEPENDENCY

In order to understand the ratio between car and public transport isochrones, and to test the ways that public transport investment might impact this ratio we focus on two of our case studies.

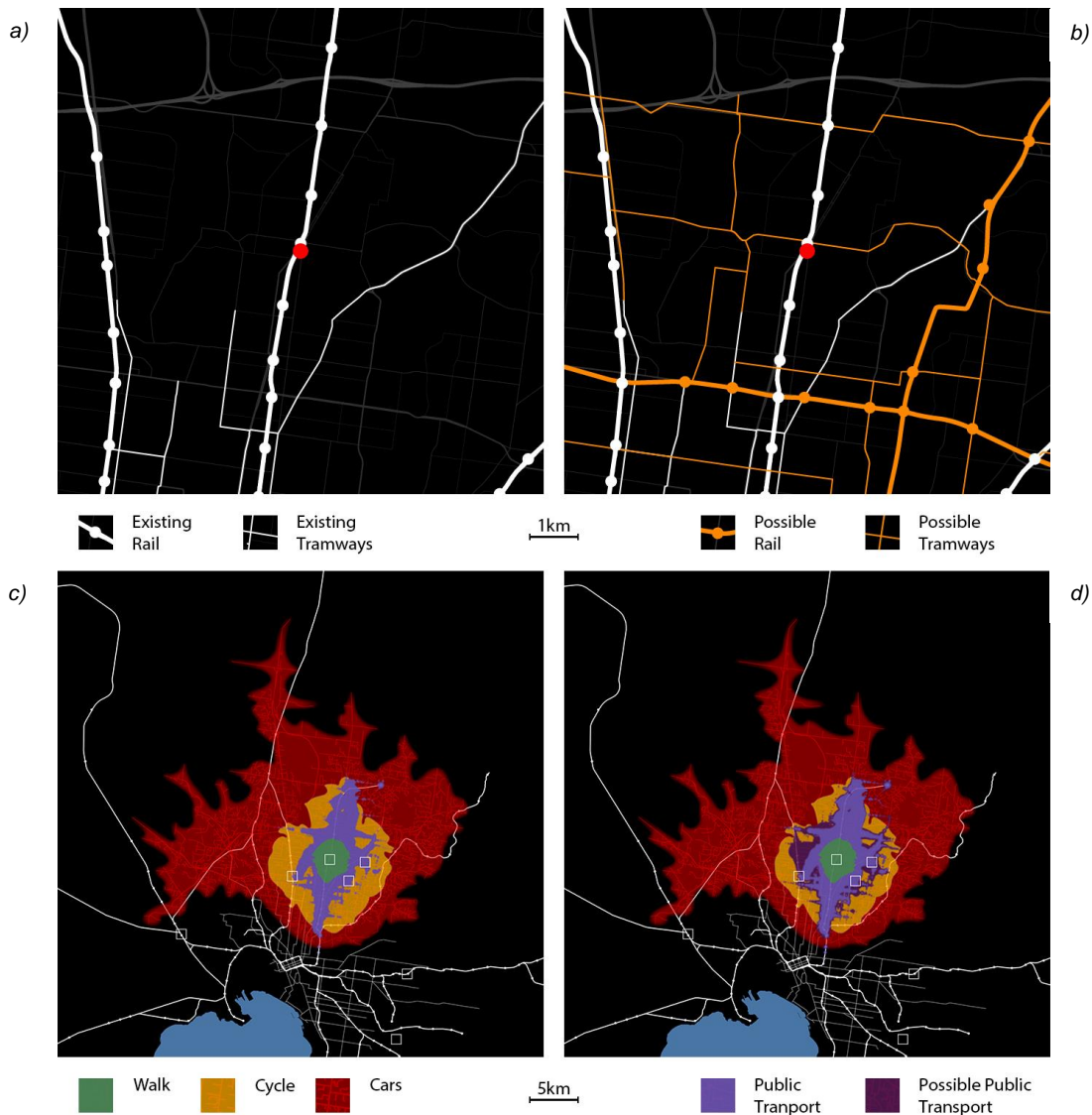
Chadstone is a shopping mall in Melbourne's southeast about 15 km from the central city. There are three tram routes and two train lines within about a kilometre (figure 4a) yet the only existing connection to public transport is by bus. We have tested the possibility of a new underground train line connecting directly to the shopping centre plus a number of new tramlines in a grid formation throughout the surrounding suburbs (Figure 4b). Figures 4c and d shows both the existing and possible car and public transport isochrones juxtaposed with the existing car zones (during the morning peak at 20 minutes). It shows how directly connecting Chadstone into the existing train network and through creating a new north-south train line in this area would have a significant impact on the public transport isochrones. In figure 4c, the public transport isochrone is considerably smaller than the associated cycling isochrone, and overwhelmingly smaller than the car isochrone. Figure 4d shows a far more competitive public transport isochrone with its reach more than doubled bringing the central city almost within the 20 minutes. In the north-south direction public transport begins to compete with the car. While there is noticeable expansion towards the southeast as a result of the new train line, it cannot compete with roads and freeways in this direction.





*Figure 4: Chadstone: Existing and possible train and tramlines (a and b) and associated existing and possible 20 minute isochrones (c and d)*

Reservoir is a large activity centre and rail station about 12 km north and 25 minutes by train from the central city. Figure 5a shows the existing situation. A major University (La Trobe) and shopping centre (Northland) lie within 3.5 km yet with only slow and low volume bus connections from Reservoir. Here we have designed a new east-west tramline linking Reservoir to both of these major attractions (Figure 5b). Figure 5c and 5d shows the existing and possible public transport isochrones contrasted with the existing 20 minute car isochrones. The addition of a new tramline here shows very little impact on public transport isochrones largely because new train lines were at such a distance from Reservoir as to have no significant impact. Reservoir is currently well serviced by buses and the new tramline largely duplicates these routes. The result would change significantly if the tramline were dedicated and not subject to traffic delays as buses are. This is a good example of the complexity of such assemblages since the development capacity of Reservoir is high and slow and any such development will increase traffic and slow down the buses.



*Figure 5: Reservoir: Existing and possible train and tramlines (a and b) and associated existing and possible 20 minute isochrones (c and d)*

La Trobe is a major university campus located about 18 kilometres northeast of the central city. Surrounded by vast carparks and with no train connections, the university struggles to attract students. A shopping centre (Northland) lies within 3km, as does the major activity centre of Reservoir, and the hospital district of Heidelberg, but there are only slow and low volume bus connections between. As shown in Figure 6a, La Trobe is located 500 metres from a tram line, however there are no train lines within walking distance. The possible connections shown in Figure 5b show a new east-west tramline and a north-south underground rail line.

Figures 5c and 5d shows the existing and possible public transport isochrones contrasted with the existing car isochrones. They show a significant impact of the new rail line which begins to become competitive with car isochrones in north-south directions. The proposed east-west tramlines had a less significant effect and remain noticeably smaller than car isochrones.



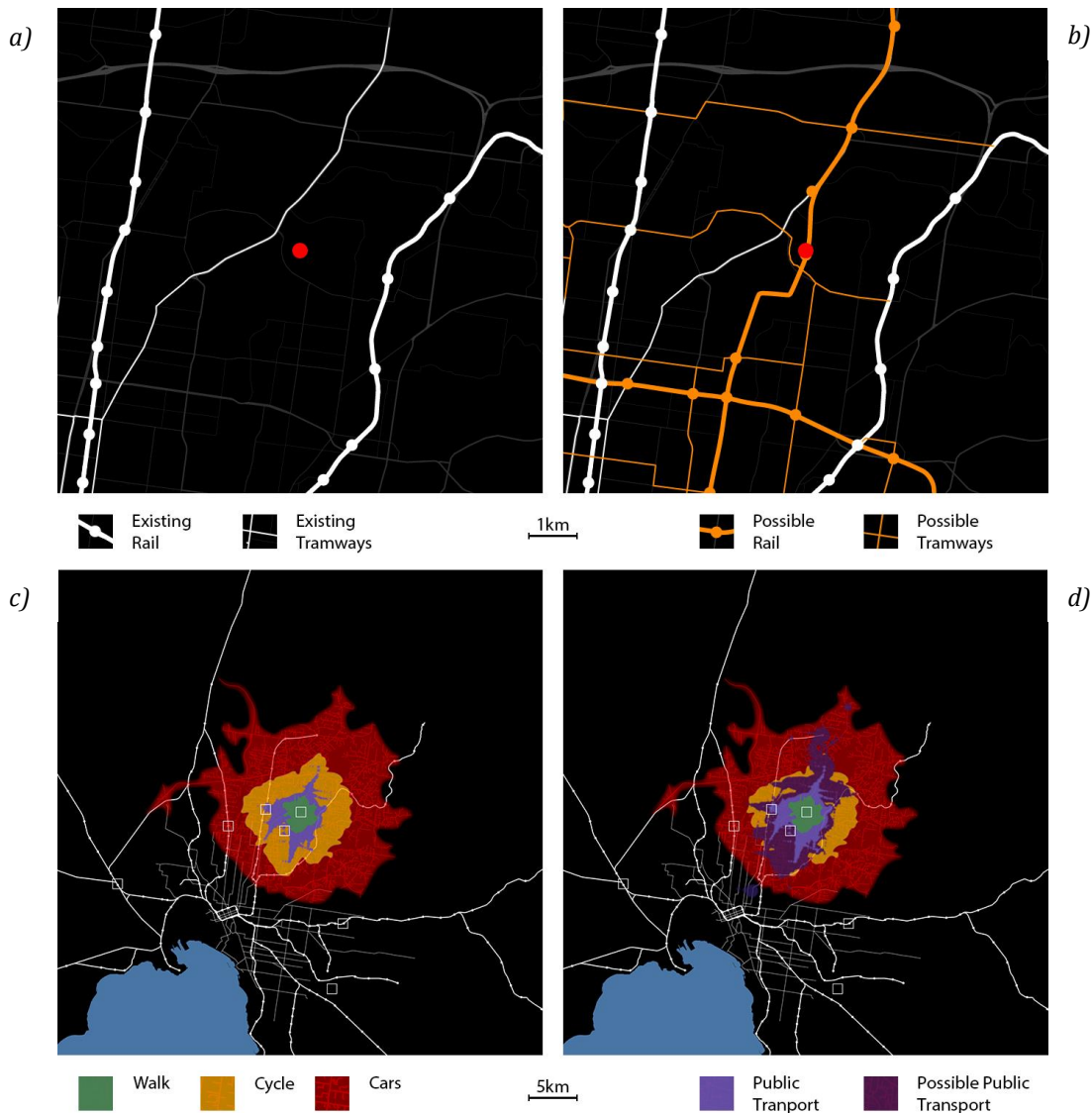


Figure 6: LaTrobe: Existing and possible train and tramlines (a and b) and associated existing and possible 20 minute isochrones (c and d)

## USING ISOCHRONES

These superimposed zones of 20 minute access are loose correlates of the cognitive maps upon which decisions about mode choice and time are based in everyday life. While one doesn't need isochrone maps in order to make such choices, we suggest that they are useful for research in three primary ways.

First, they enable us to compare levels of access using different transport modes for any given location. The map provides an empirical basis for the conditions on which people make a mode-choice for any particular trip. This is a map of potential rather than actual trips; there is no presumption that people will automatically abandon their cars when the map indicates it is rational to do so. The second use of such maps is that it enables us to compare such levels of access for different locations in the city and for different time limits. The isochrones can be aggregated to map the entire city with measures of comparative connectivity, mobility and walkability – to map inequities of access. Finally this form of mapping can be integrated with design research to enable an understanding of the ways designed change can enhance urban mobility and aid the choice between alternate designs. New public transport connections and greater frequency of service will transform the isochrones, as will investment in roads, cycle paths and pedestrian networks. The effects of such designed change can also be simulated, mapped and compared with existing conditions as a basis for investment decisions and public debate.

Such mapping is very far from a simple presentation of a set of spatial facts; it is both complex and problematic. Trips by car and public transport are inherently multi-modal – they variously involve walking, parking and waiting times (which we have incorporated). Isochrone maps will also differ over time with daily, weekly and seasonal rhythms. Car traffic slows during peak periods while public transport is more frequent. Trams, buses and cars can be delayed in traffic and by trains at level crossings. This is a particularly problematic issue because any increase in train frequency slows down all the other modes. Walking and cycling zones are normally more predictable and stable but are mediated significantly by weather, safety and ability. Mode choice may also depend on road surface, noise, cost and aesthetics. The levels of complexity and adaptation make this a deeply unpredictable system to model accurately. There are an infinite number of factors that influence potential access zones – the dilemma is that to ignore them can produce inaccuracy but to include them can paralyze the mapping process or render the maps illegible. Once the map loses legibility it also loses its potency as a form of spatio-temporal knowledge. In this context, mapping can easily become a form of propaganda. Accurate maps of urban assemblages are essentially impossible – the issue is how they enable us to see the city in new ways. Isochrone mapping enables us to see differences between modes; differences between different parts of the city; and differences between existing and future levels of mobility.

The map does not simply represent selected aspects of the city so much as it works to connect them in a conceptual manner. In doing this the mapping becomes more diagrammatic and abstract; the relations between zones reveal a set of immanent forces embodied in the urban assemblage. The maps are diagrams of dynamic relations between different modes of movement, urban morphology and regimes of access in time and space. The greatest potential of such mapping is that we can begin to model the transformations of access and equity that might be produced by infrastructure investment. Yet here again the complexities multiply because the city is a self-organizing system wherein adaptations are difficult to predict. While we are dealing with probabilities rather than certainties, we are also exploring the possibilities that are embodied in the existing city. While this paper is focused on questions of access, these possibilities cannot be properly explored in isolation from questions of density and mix; the point of access is to get where we desire to go, those parts of the city where attractions are concentrated. Different parts of the transit network have different levels of attraction and different capacities for intensification. It is the synergy of density, mix and access – the urban DMA – that builds a resilient city. Herein lies the key reason for multi-scale and multi-disciplinary thinking – density, mix and access are each very different at different scales. While the difference between the car zones (red) and all of the other zones can be read as a measure of car-dependency for that location, this will depend fundamentally on the distribution of desired locations. It simply doesn't matter if we can't get to where we don't need to go.

### **A NOTE ON DATA SOURCES**

We cannot conclude this paper without a note on the use of data sources and the degree to which this is currently such a moveable feast. Our sources, as noted earlier include Google, TomTom and Public Transport Victoria (PTV). These forms of mapping are not possible without such data access, however the data sources are not always reliable nor transparent. Public Transport Victoria publish ideal data on bus, train and tram timetables and trip times, but it would be more useful if the data were based on actual performance. In practice trains are often cancelled and buses and trams get caught in traffic, just as cars do. Google and TomTom both use GPS data but it is not clear just how accurate such data is. Most of their attention has focused on cars as a means of predicting traffic jams and much of the data for walking and cycling appears to be based on presumption rather than GPS data. There are also some discrepancies between Google and TomTom data for car isochrones with Google isochrones consistently larger by about 10% of accessible area. No doubt such data sources will become more reliable over time, however it is also the case that Google and TomTom have become more restrictive in access and Google maps is now much more difficult to use than when we commenced this project.

## THE CAR/PT ASSEMBLAGE

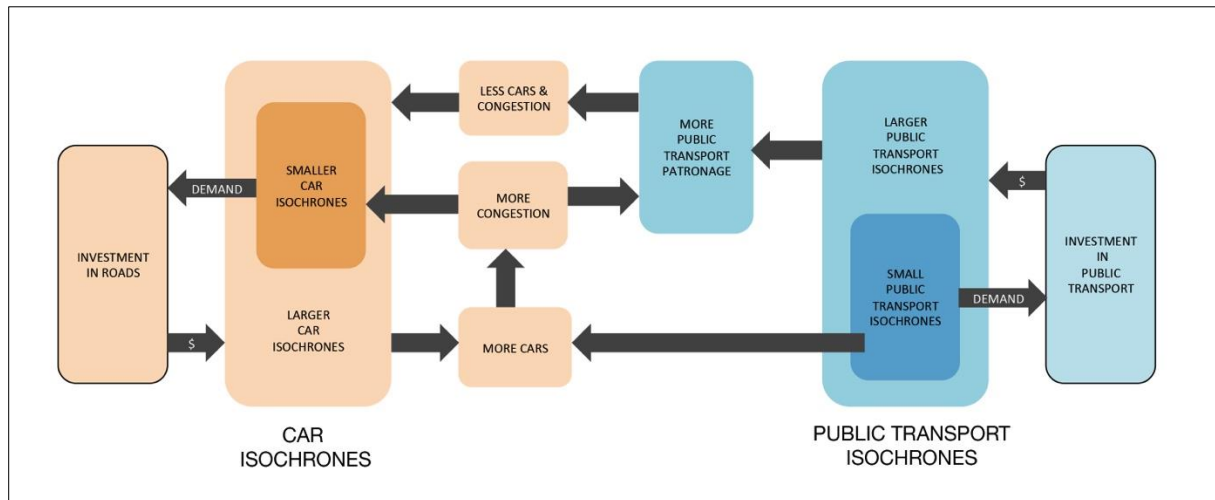


Figure 7: The Car/PT Assemblage

The public transport and car isochrones lie in a crucial relationship with each other and we conclude with a diagrammatic analysis of these interconnections that we call the Car/PT assemblage (Figure 7). Consider first (in the orange boxes) the familiar cycle whereby road congestion leads to a shrinkage of car isochrones and greater public pressure to build more roads. Investment in the road network then leads to larger zones of car access which in turn attracts more cars, which then cause renewed congestion. This is the somewhat vicious cycle we have repeated for about a century. This cycle is interconnected with a similar public transport cycle (the blue boxes) where investment in public transport expands the public transport isochrones and attracts people from cars into public transport; it thereby eases car congestion and reduces public demand for investment in roads. Ultimately, of course, the free-flowing roads will attract people back to their cars but only to the point where congestion emerges again. Increased car usage is produced both by investment in roads and by lack of investment in public transport. Demand for public transport investment is limited by the fact that those who have made the rational choice to drive become stuck in the congestion and join the roads lobby. In figure 7 each of the arrows represents a form of production and adaptation. The car cycle on the left is a vicious cycle that produces car-dependency but it can be unlocked with public transport investment because that is what makes all the modes work better. The importance of the isochrones is that they are the key slow variables that most matter in this complex adaptive assemblage. The isochrones reflect the everyday phenomenology of mode choice. It is at the point when the public transport isochrones can compete with the car isochrones that the system will begin to move to a more resilient regime. When public transport is the clearly faster mode and can be undertaken in safety and comfort, then we move beyond the car-dependent city.

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