ISOCHRONE MAPPING OF URBAN TRANSPORT:

Car-dependency, mode-choice and design research

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ABSTRACT

Imperatives to develop more walkable, transit-oriented and low-carbon cities have accentuated the need to understand the performance and possible transformation of urban access networks. Within a framework of complex adaptive systems and assemblage thinking we develop isochrone mapping of urban transport access in four transport modes: walking, cycling, public transport and cars. These isochrones can be used to compare the range and area of urban access for each of these modes, over different time limits and for different times of day. Such mapping gears urban morphology to the phenomenology of urban transport and enables us to better understand mode choice. Through design research we can also test a range of possible design scenarios for infrastructure investment and show their impact on the isochrone maps. We conclude with a focus on the relations between car and public transport isochrones as a means of better understanding car-dependency and what we call the 'Car/PT assemblage'.

KEYWORDS: isochrone mapping; assemblage; mode-choice; urban transport; walkability; design research

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Introduction

FIGURE 1: Melbourne Public Transport Isochrones from the central city 1925 (left) and 2015 (right).
Sources: Metropolitan Town Planning Commission (1929) (left); authors (right)

An 'isochrone' is defined as the line joining the equal travel time distances from any given location; it is an image of a territory that answers the question: "how far can you get from here in x amount of time?" Isochrones have been used in transport planning to understand the relationship between movement and time for more than 130

years. One of the earliest examples 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). Paullin and Wright (1932) later published maps showing isochrones from New York as access expanded across the USA with the construction of new roads, rail networks and commercial aviation. Isochrone maps of metropolitan public transport networks emerged within urban planning practice in the early twentieth century. In 1925 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. At the time Melbourne had one of the world's most extensive urban rail and tram systems, primarily built in the 1880s. The map shows a dark zone of 10 minute access surrounding the central grid and then a greenish zone of 20 minute access covering the extensive tram network of the inner city. Fingers representing the radial train lines then extended in 10 minute steps to the final 60 minute (yellow) zones that almost reach the outer circle at 13 miles (21 km) from the city centre. Despite demonstrating a level of public transport accessibility that few cities of the time could boast the great planning issue in Melbourne at that time was seen as road congestion. Public transport investment largely ceased for the next century and the result is the suburban car-dependent city that has become such a challenge to a low-carbon future. Figure 1 (right) shows the same public transport isochrones for 2015 using the same minimum times, scale and colour scheme. While Melbourne's metropolitan area has more than doubled and population has increased fourfold the public transport network has not changed a great deal with the radial structure of the train system still dominant. There are vast suburban areas within the metropolitan boundary that are beyond walkable access to frequent public transport. The modal share for public transport in Melbourne is about 11% (based on pkm) and rising (Australian Government 2013).

Although there has been a tendency to focus on public transport accessibility, isochrones maps were also used to document car access. In one of the earlier studies Armstrong (1972) used car isochrones to compare potential sites for a new airport in Britain - an early example of the use of isochrones as a basis for key planning decisions. Since the late twentieth century we have seen renewed interest in the use of GIS as a means of generating transport isochrones (O'Sullivan et al. 2000; Bertolini et al. 2005; Achuthan et al. 2010; Colclough & Owens, 2010; Drew & Rowe, 2010; Lei & Church, 2010; Delafontaine et al. 2012; Bonotti et al. 2015). Isochrones are becoming recognized as a highly useful way to show the diagrammatic forces embodied in urban transport networks. When carefully produced they are easily understood because they represent the ways people perceive travel opportunities in everyday life (O'Sullivan et al. 2000). For the locations we know well such as home and work, we organize our departure times for any journey in accordance with the knowledge of how long it will take with different choices of travel mode. In this sense isochrone maps represent the phenomenology of everyday urban life. There is now a proliferation of publicly accessible, web-based and interactive websites which allow users to select a point on a map and produce public transport isochrones for many cities instantly (Mapumental, 2015; Mapnificent, 2015). While Google maps doesn't produce isochrone maps it does enable an instant reading of transport times for walking, cycling and driving, mostly based on GPS data from mobile phones.

A key distinction made within the current literature is between 'mobility' and 'accessibility'. Mobility is primarily defined as an individual's capacity to travel, while accessibility is a systemic property or capacity of an urban network (O'Sullivan et al. 2000; Bonotti et al. 2015). Accessibility is a measure of the ease with which people can reach chosen destinations; to measure access is to measure possibilities rather than actual flows but there is no consensus on how it might be measured (Lei & Church, 2010). Some studies are focused on the accessibility of particular destinations or destination types such as libraries (Delafontaine et al. 2012), schools (Drew & Rowe 2010) and transit nodes (Achuthan et al. 2010). Some focus on a single travel mode such as the historical examples focused on public transport (Drew & Rowe, 2010) while others incorporate two or more modes (Lei & Church, 2010). The complexities of urban transport means that isochrones will differ for the same location not only by mode choice but also according to direction of travel, time of day and for different age groups (Lei & Church, 2010; Achuthan et al. 2010). There can be no standard method of isochrone mapping. The quality and readability of isochrone maps is a crucial to their usefulness; while the historic maps are generally simple and highly readable, more recent attempts to represent the complexities of time/space

accessibility have produced highly variable quality and legibility. The challenge is to break down the complexity and develop accessibility measures that are legible enough to be useful while maintaining research rigor (Bertolini et al. 2005). Isochrone mapping embodies a particular mix of epistemological issues. Mode choices are made on the basis of detailed local knowledge of travel times. Commuters know just how long a trip will take on average and they also know the range of variation because job security often depends on it. They know that trip times by car and public transport are not exact and they adapt accordingly. By contrast, pedestrian travel is much more exact; we know the minute we must leave home to be sure to catch a particular train even though we don't know if the train will be on time. While there is a need to maintain a robust empirical base for this work, some studies develop highly complex formulae that make transparency very difficult. In other cases this reduction of spatial data to numeric data is so complete that one study is entitled 'mapping' but has no maps (Colclough & Owens, 2010). Isochrone mapping is a means of rendering empirical data legible; the isochrones are forms of spatial knowledge that cannot be simply reduced to numbers (Dovey and Ristic 2015).

A key question for such research is that of scale, in terms of both space and time - an isochrone is always based on a particular time frame which will in turn produce a particular spatial scale. Bertolini et al. (2005) have argued that 30 minutes is a key time frame for urban travel in European cities where public transport predominates. While North American and Australian cities are more car-dependent, the ideal of the '20-minute city' has emerged as a sustainable ideal. The question of time scale is complicated by the fact that most urban trips are a door-to-door 'chain' of short trips where walking forms every odd-numbered link (Bonotti et al. 2015: 425). Each trip by car is walk>drive>walk and public transport is walk>PT>walk and so on. While most researchers approach such issues from a particular disciplinary perspective and at a particular scale, our study stems from a multi-scalar and multi-disciplinary analysis of transit-oriented development (Dovey and Woodcock 2014).

Walking isochrones can be traced to the work of Jacobs (1961: 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, 'pedsheds' or walkable 'buffers'. There has been a proliferation of research into walkability in recent years, and pedshed mapping is a key indicator of local area walkability. 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. Yet the literature on walkability shows little isochrone mapping, generally preferring distance measures of 400-800 metres around a given location (Frank et al. 2006; Moudon et al. 2006; Cervero & Duncan 2006; Forsyth, 2015). The use of distance (adjusted for permeability) rather than time is often based on data availability, yet any kind of multi-scale analysis of accessibility must incorporate both time and space.

There are four main goals of this paper. First is to develop methods of data harvesting and mapping that will enhance the use of isochrone mapping for our understanding of urban movement patterns. Second is to use such techniques to enable graphic comparisons between different neighbourhoods within the same city and for different modes based on the same neighbourhood. Third is to better understand car-dependency through a comparison of cars and public transport at different times of day and for different locations. The final goal is to test the impact of different scenarios for infrastructure design on these isochrones - therefore on car-dependency.

Whenever we choose to take the car, ride, walk or catch the bus we do so on the basis of a time/space conception that is represented by the isochrones. We consult loose multi-modal isochrones in our heads to judge whether it is faster to drive or use public transport and by how much. When we choose where to live, work or shop we do so within a spatio-temporal conception of what we will have access to with different travel modes. It is multi-modal isochrone maps that establish a rational basis for mode choice. The use of isochrones to compare different travel modes is relatively recent and rare. Lei and Church (2010) have mapped the ratio of bus to car times in Santa Barbara with bus times based on timetables and car times based on a survey of drivers. Their method is to map the ratio between bus and car travel time for the same journey; when the ratio is below 1 then the bus is faster. For most of Santa Barbara this ratio is well over 2 indicating a heavily car-dependent

city. Bertolini et al. (2005) have produced isochrones for cars and public transport across the regional scale of the Netherlands but these maps are not superimposed making relative judgements difficult. We seek to explore new ways of mapping that enable a comparison between different modes and at different times of day. 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, including the privacy of the car (Kent, 2014), minimum time is surely a primary criterion. 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 ultimate concern is to use isochrone mapping to compare the accessibility embodied within current urban networks with that which is possible if the city were re-designed (Lei & Church 2010). This is a form of design research that models the performance of future scenarios against each other and the status quo; it is, however in a very nascent stage. Bonotti et al. (2015) have produced isochrone maps for a proposed light rail design in Brescia at different times of day. Drew and Rowe (2010) have also developed isochrones for enhanced bus services in the UK. While such approaches are limited to public transport we explore the use of isochrones for multiple travel modes as well as contrasting existing networks with scenarios of possible transformation. 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 and Method

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).

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 (Holling & Gunderson 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. One of the central tasks of complex adaptive thinking is to isolate the 'key slow variables' that can be determinant of the ways the system crosses a threshold from one regime to another. One of our arguments here is that transport isochrones are key slow variables of the city and that the relations between car and public transport isochrones are a crucial index of car-dependency. 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.

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 (Dovey and Woodcock 2014). The case study sites include both existing transit nodes and disconnected activity centres and other 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 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 figure 1 and are 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 (Public Transport Victoria (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, 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. 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 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.

Multi-Modal Isochrones

The graph in Figure 2 shows the average isochrone area for each travel mode over 20 and 30 minutes, incorporating data from all seven case study locations. Cars and public transport are differentiated by time of day to show the average difference between morning peak and evening access zones. It shows that on average the 30 minute trip gives access to about four times the area of the 20 minute trip - much of the difference due to the start up costs of waiting and parking. During the evening the accessible area for cars expands by about 25% over 20 minutes and by 32% over 30 minutes. At the same time the area accessible by public transport contracts by 22% (20 min) and 24% for a 30 minute trip). These reverse rhythms are due to the easing of car traffic and reduced public transport frequencies in the evening.

In comparing cars with public transport 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 ratio of car to public transport access zones for any given case study 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. It is notable that on average the cycling isochrones are 3.6 times the area accessible by public transport over 20 minutes and 3.1 times larger over 30 minutes (peak periods). When compared to walking, the cycling zones have about 9 times the accessible area for the same time limit; they are also more subject to contingencies of topography and infrastructure – dedicated bikepaths that extend the range, steep hills that limit it, or freeways that block it. 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. However, they demonstrate capacity more than reality because such modes are strongly mediated by weather and safety issues.

Figure 2: Average Areas of Access Zones - 20 and 30 minutes

Figure 3: 20 minute isochrones from 3 case studies
Source: Authors

There are, of course, many differences between particular isochrones and while there is not scope here to show all sites, Figure 3 shows the 20 minute public transport isochrones for a selection of three case studies. Here we see substantial differences emerge between different locations depending on whether they are located on high volume train lines (as in the case to the west), near major road arteries (south east) or detached from all high volume networks (north). The public transport and car isochrones are each represented in both light and dark tones to depict peak hour access in the brighter tone and evening access in the darker tone. The very low frequency of public transport in the evenings means that the 20 minute zones can shrink to negligible for some sites. It is also evident that the greatest difference between peak and off-peak car access applies to those driving in the direction of the city centre. Here the particular differences between car and public transport access become apparent, regardless of time of day. There are no times or directions of travel for which public transport will be competitive with driving over 20 minutes. Here the challenge of the '20 minute city' becomes starkly visible - to enable the blue zones to eclipse the red, at least along the transit lines. This gap which we will call the 'car-PT' gap 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 access 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. Another finding here lies in the potential of cycling which, without any delays, has a clear advantage over public transport at this 20 minute timescale.

We now want to focus more on the ratio between car and public transport isochrones (the car/pt ratio), and to test the ways that public transport investment might impact this ratio. For each of the cases depicted in Figure 3 we have modeled a possible scenario for substantial public transport investment. Figure 4 maps how we have re-designed the public transport network for these cases to include new heavy and light rail lines based on principles of increasing network connectivity. These examples include a major shopping mall and a university campus that are largely disconnected from the public transport network. Figure 5 then shows both existing and possible public transport isochrones contrasted with the existing car isochrones. They demonstrate a significant enlargement of isochrones for those locations not already served by heavy rail and they show that public transport access to these locations would become competitive with the car in some directions.

Figure 4: Existing and Possible Transit Networks
Source: Authors

Figure 5: Existing and Possible Isochrones - Peak hour, 20 minutes

Source: Authors

Isochrones as Spatial Knowledge

These isochrones are loose correlates of the cognitive maps upon which decisions about mode choice 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 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); they have daily, weekly and seasonal rhythms. Walking and cycling zones are normally more predictable and stable but are mediated significantly by weather, safety and ability. 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 or accuracy it also loses its potency as a form of spatio-temporal

knowledge. In this context, mapping can easily become a form of propaganda. While accuracy of isochrone maps can be debated, what is most at stake here is how they enable us to see the city in new ways: differences between modes; between different parts of the city; and between actual and possible levels of accessibility.

Isochrone maps are empirical counterparts of the cognitive maps upon which we largely base our transport mode choices. They are also diagrams of how the city works as a complex adaptive assemblage; the relations between zones reveal a set of immanent forces embodied in the urban assemblage. 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. This is what we mean by design research - the shaping of the city becomes the basis for the research. 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.

There is an important limitation to this research in that we are dealing here with only one part of the urban assemblage - most notably excluding considerations of density and landuse mix. 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 transport is to get where we desire to go and different parts of the transit network have different concentrations and mixes of attraction, thus different capacities for intensification. It is the synergy of density, mix and access – the urban DMA – that builds the sustainable city (Dovey and Woodcock 2014). Assemblage approaches to density and mix have been explored separately (Dovey and Pafka 2014; Dovey and Pafka (in press)). 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.

We cannot conclude this section 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 the local public transport agency (PTV). These forms of mapping are not possible without such data access, however the data sources are not always reliable or transparent. PTV publish 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. 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 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.

The Car/PT Assemblage

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 6). Consider first, on the left of this diagram, the familiar cycle whereby road congestion leads to a shrinkage of car isochrones and greater public demand to build more roads. Investment in the road network then leads to larger zones of car access which in turn attract more cars (induced road traffic) and a return to congestion. This is not, however, simply a matter of the same amount of traffic being redistributed. There is evidence that better roads lead to people initiating more trips and travelling further rather than saving time (Metz, 2008). Zeibots and Elliott (2011) argue that when a road network is improved the total amount of traffic is also increased by mode shifting (from public transport) and by new traffic produced by new development attracted by increased accessibility. These effects are collectively labeled in figure 6 as 'induced road traffic'. This is the positive feedback cycle we have repeated in many car-dependent cities - building new roads creates induced traffic and therefore increased demand for new roads.

Figure 6: The Car/PT Assemblage
Source: Authors

This car cycle is interconnected with the public transport system (on the right of the diagram) where investment in public transport expands the public transport isochrones and attracts people from cars into public transport; this produces what we have termed 'induced transit traffic'. While induced traffic generally refers to roads, the principle also applies to public transport. As walking, cycling and public transit networks expand they also produce mode shifting (from cars), new trips and increased density around transit nodes. The mode shifting eases road congestion, producing larger car isochrones and less demand for road funding. Ultimately, of course, the free-flowing roads will attract people back to their cars but only to the point where congestion emerges again. In figure 6 each of the arrows represents a form of adaptation embodied in this complex adaptive assemblage. 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. This is not a new insight but can be traced to the work of Downs (1962) and Thomson (1977). As Thomson put it 50 years ago: "all efforts to improve peak hour travel by car will fail unless public transport is also improved." (quoted in Mogridge et al. 1987).

Car-dependency can be defined not only by the imbalance between car and transit isochrones, but also by the grip that the car isochrone has on logical thinking - when there is no competition we do not think about public transport. Citizens are not immune to reason when they make a mode choice based on their local knowledge of travel times to chosen destinations. The ultimate power of isochrone mapping lies in demonstrating possible urban futures; in re-designing urban transport networks with an agenda to produce competitive public transport isochrones. While this will always be an inexact science it holds the potential to become a powerful form of politics. Isochrones are the key slow variables that most matter in this complex

adaptive assemblage. The car and public transport isochrones represent the everyday phenomenology of mode choice; when public transport is the clearly faster mode then we begin to move beyond the car-dependent city.

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