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Cool Planning: How Urban Planning Can Mainstream Responses to Climate Change.

Peter Newman
Professor of Sustainability
Curtin University

Highlights

- Adaptation to climate change can be integrated into city and regional planning as illustrated in Perth's water sensitive urban design and Singapore's biophilic urban design. Adaptations such as these must be mainstreamed through planning systems as the world rapidly warms.
- Mitigation needs cities to demonstrate the decoupling of greenhouse emissions from wealth generation. This requires structural efficiencies that are mainstreamed through urban planning. Shanghai and Beijing show it is possible in emerging cities.
- Disruptive innovation is also critical to mitigation being achieved rapidly and can now be seen in power and transport through solar, wind, batteries and electric vehicles, with potential disruptive innovations such as Trackless Trams and Hydrogen (for fuel cell vehicles and industrial gas). New technologies must be part of urban policy and planning or they will become elitist and ineffectual.
- The Theory of Urban Fabrics can enable city planning to mainstream all of the above innovations by focusing different planning strategies in different parts of cities and their regions. Six tools from the paper are outlined to demonstrate how mainstreaming requires awareness of different urban fabrics.

Abstract

Climate change action requires both adaptation and mitigation. Both need urban planning in strategic and statutory processes to mainstream the innovations now appearing. Integrating adaptation and mitigation is demonstrated using two planning tools: water sensitive urban design and biophilic urbanism and both need to be mainstreamed through urban planning in a rapidly warming world.

Mitigation must be about grasping the need for decoupling fossil fuel use from GDP and data indicates this is underway. Cities like Shanghai and Beijing are showing how emerging cities can decouple wealth and car use. Disruptive innovations underway are solar and wind power, batteries, and electrifying transport but need planning tools to mainstream them. Emerging disruptive innovations include Trackless Trams that function like light rail but at significantly less cost and Hydrogen in fuel-cell vehicles for heavy transport and as an industrial fuel. The Theory of Urban Fabrics is used to show how emerging innovations can be mainstreamed in urban planning through each of the different fabrics of the city. This is illustrated using the six tools outlined in this paper to demonstrate how such nuanced and integrated urban planning responses to climate change can be mainstreamed.

Keywords: climate change, adaptation, mitigation, decoupling, disruptive innovation, urban fabrics theory

1. Introduction

Cities are critical to how the world adapts to and mitigates climate change (Solecki et al 2018; Bazzaz et al, 2018; Rozenzweig et al, 2010). Cities have always been where innovation happens and where growth is now happening hence it is also where cities have the responsibility and the opportunity to show how a new decarbonized economy can emerge (Newman, Beatley and Boyer, 2017). Climate change is now well underway and hence adaptation is firmly on the agenda of many cities (Solecki, 2015; Bai et al, 2018); mitigation of climate change is also well underway, though perhaps less obviously in much of the literature and popular press (Newman, 2017; Bazzaz et al, 2018).

This paper seeks to provide how urban planners can use their strategic and statutory tools to show how cities can mainstream emerging innovations in both adaptation and mitigation. It begins by looking at how adaptation and mitigation can be integrated using two case studies and how this can be mainstreamed through urban planning. It moves to show how cities are leading in the decoupling of greenhouse emissions from wealth generation through structural efficiencies and through disruptive innovations that are now rapidly spreading their technological tools but now must be mainstreamed. And finally, it brings together the six innovations outlined in the paper to show how the Theory of Urban Fabrics can enable planning to focus its tools into this mainstreaming process through different strategies for different parts of cities and their regions.

2. Integrating Adaptation and Mitigation into Planning

The integration of adaptation and mitigation was set out in the IPCC Special Report on 1.5^{0}C (IPCC, 2018). It showed that there were many ways to enable both processes though sometimes they conflicted. Town planning has become a major part of how cities adapt to climate change (Pelling, O'Brien and Matias, 2015). The tools of planning are needed both for short term disaster prevention from major storms, floods and fires and also long-term adaptation to 'slow moving disasters' (Brown, 2016). Two key tools for urban planners are used to illustrate: Water Sensitive Urban Design and Biophilic Design.

2.1 Water Sensitive Urban Design

Many water systems are changing due to climate change and as cities are fixed in place they must adapt or collapse as have so many throughout history as outlined by Diamond (2005). Such adaptation requires cities to change their water systems and town planning can be part of this adaptation. One such tool is now called water sensitive urban design (Mouritz, 1992) and a small case study of Perth illustrates the way town planning is playing a role in averting a slow-moving climate disaster over the city's water supply.

Perth is located on the end of a large continent rather like Cape Town is in Africa. Both cities have been seen as potential for large impact from climate change as global warming was predicted to push south the cold weather fronts known as 'roaring forties' in the sailing ship era. Both cities have Mediterranean climates with most rainfall occurring in a few months but both cities noticed a reduction in rainfall setting in over the past three or four decades. Climate change modelers informed both cities that It was not a drought, it was climate change. Adaptation was required or the cities may need to 'retreat'.

Flannery (2005) predicted in the 1990s that Perth would be abandoned because its water supplies were not sustainable. The sudden drops in rainfall coincide with what Flannery calls "magic gates," periods when there is a major shift in the climate system. In 1976 the first magic gate meant that instead of 340 gigaliters (GL) of rainfall runoff in its catchments, Perth averaged only 160 GL. Then again in 1998 another magic gate reduced the rainfall runoff to 111 GL, a reduction of about one-third from what it had been receiving. A local scientist agreed: "Climatologists tell us that [Perth] is the most profoundly affected city in the world. People have accepted that it is climate change. In other parts of the world people are thinking it's something that's going to happen to them in the next 10 or 30 years and that they've got time to adjust. We've found we've been living with it for 30 years now and we're having to adjust very quickly." (McFarlane, quoted in Newman, 2014).

Adaptation is rarely conducted without a political crisis that can generate the necessary investment to change and that has been the case in Cape Town when they ran out of water in 2018, narrowly avoiding a disaster. Perth changed earlier due to a political crisis in 2001 when the rain did not come at all. A rapid investigation was conducted, which suggested desalination might be possible. Because of the enormous energy inputs required, only a few cities in the Middle East had used desalination for their water supplies, but new German membrane technology could reduce the energy required significantly. The politicians decided to go for wind-powered desalination and now the city runs on 60% of its water supply coming from the Indian Ocean.

This is the technological part of the adaptation process needed to save a city from immediate climate change that was predicted but needed a crisis to generate the politics. The other side is how urban planning needed to step in and ensure water was recycled and was minimized; this is water sensitive urban design.

Desalination is a high energy exercise so needs to be minimized. The long-term plan is now to be much cleverer with local distributed systems and recycled wastewater, as treated sewage was historically pumped out to sea. Minimizing use means water efficiency devices need to be regulated into new developments and in particular how garden irrigation could be minimized using techniques like shared common bore water, recycled grey water and stormwater collection. Both have been regulated into a demonstration urban development called WGV (100 units of mixed medium and low density housing) and significant savings have been managed (Wiktorowicz et al, 2018). See photo 1 of a stormwater sump converted into a local park. This project is close to zero water from the mains water supply and a new larger project, East Village, is now being created with even more significant water sensitive urban design (LandCorp, 2019).

Photo 1. WGV a demonstration zero carbon water sensitive urban design in Perth, Australia

Town planning now needs to mainstream such water sensitive urban design as the public fully supported the process and have been happy to join in to projects where water saving is built into the fabric of the area. As climate change continues to destabilize water supplies for cities across the globe, similar solutions that utilize new technologies and involve citizens in determining how their water is to be provided are going to be needed. Resilient water systems can become regenerative projects that create whole new urban development approaches with positive effects on their bioregional environments and their local economies, despite continued impacts of climate change. Such mainstreaming will require urban planning to make water sensitive urban design play a central role in all future plans as water supply will become more and more disturbed by climate change.

2.2 Biophilic Design.

Biophilia was defined by E. O. Wilson (1984) as “the innate tendency to focus on life and lifelike processes”. Wilson’s special insight was that this biophilic propensity developed as part of evolutionary survival, so it remains with humans in their daily lives, even in modern cities. Biophilic design has become a major social movement within city policy and practice (Kellert et al 2008; Beatley, 2010). There is now a Biophilic Cities Network with membership across the globe as they work together showing how cities can build nature into, onto and around buildings. This inevitably involves town planning.

The city which has done most to demonstrate biophilic design is Singapore. Its special focus on requiring greenery in and on buildings that make up the city, predominantly through green roofs and vertical greenery, or green walls, has been spectacularly successful (Newman, Beatley and Blagg, 2012). They have changed buildings from being concrete and steel, designed to separate urban life from nature, to having living walls and roofs, now seen as habitat sites with a new kind of design aesthetic. As a result, a wide range of designs and methods for integrating nature into the built environment have emerged and continue to evolve (Newman, 2014). The broad elements of biophilic urbanism overlap with landscape architecture and environmental planning but mostly involve urban planning in both strategic plans that set up the natural systems an area needs to include in its design, and in statutory planning where it is possible to require buildings to include greenery. Singapore's Green Floor Plate Ratio regulates replacing the floor plate of a building with green walls, green roofs and green balconies by more than three times (Beatley, 2017).

Biophilic urbanism can help cities cope with the climate change challenge in multiple ways as it is designed first of all to cool the city (Singapore has noticed a warming trend in recent decades) due to both the urban heat island effect and due to climate change. By reducing the temperature in and around buildings there is less energy needed and there is carbon sequestration occurring in the fabric of the city. Biophilic design also makes density more appealing (with reduced car dependence) as there are extra habitat opportunities when tall buildings are landscaped and the appeal to residents is obvious (Chan and Djoghlaf, 2009). As well biophilic design helps manage storm water, reduces air pollutants, and provides multiple health advantages especially mental health (Newman, et al, 2018; Soderlund, 2018).

In both water sensitive urban design and biophilic urbanism, the policies to seek adaptation to climate change can also help to enable mitigation primarily through reducing energy use. Both slow and fast adaptation can be turned into a major opportunity if planners can grasp the chance to 'bounce forward' not just 'bounce back', to build mitigation into every building, precinct and infrastructure (Newman, Beatley and Boyer, 2017). The integration of adaptation and mitigation is explored in detail in Chapter 4 of the 1.5^0C report (IPCC, 2019). The role of urban planning to integrate adaptation and mitigation will be significant. The primary role will be when urban planners take cities like Singapore's biophilic urbanism and mainstream them into every new building and infrastructure.

The next sections of the paper show how mitigation is happening and how mainstreaming innovations in decarbonization through city planning and policy will be critical to whether the world is able to cope with this growing crisis.

3. Decoupling and Planning

On the challenge of decarbonizing our cities, Jackson (2009) and others in the 'degrowth' movement have suggested that we must reduce wealth as measured by gross domestic product (GDP) or gross national income (GNI), because they cannot see how an economy can be created that truly breaks free from fossil fuels and other damaging global impacts without reducing such measures of wealth. However, these parameters are measuring economic activity and this can change in character and quantity to improve both climate and economic opportunity. The notion that describes a change in character is 'decoupling''. Decoupling has come from the United Nations Environment Program (UNEP, 2011; 2013), but has origins from *Factor Five* by Von Weisacker et al, (2009) who suggests that wealth and greenhouse gas (GHG) emissions can be unlocked and even decoupled by a factor of five. Jackson (2009) suggests that decoupling will always be only relative and not absolute—that is, GHG emissions will continue to rise even as the economy becomes relatively more efficient per unit of GDP due to lock-in or path dependency. As figure 1 shows, worldwide GHG emissions are certainly now relatively decoupling from GDP (or GNI). The point where the world actually declined in absolute terms may have been in 2015 and possibly earlier in most developed economies (Newman, Beatley, and Boyer, 2017), though updates in more recent years are suggesting GHG has risen due to land clearing and drought in China impacting on Hydro (Tollefson, 2018). The difference between growth in wealth and plateauing or declining in GHG is still a very historic change in economic development.

Figure 1 Decoupling of global wealth and greenhouse gases. Source World Bank and IEA data

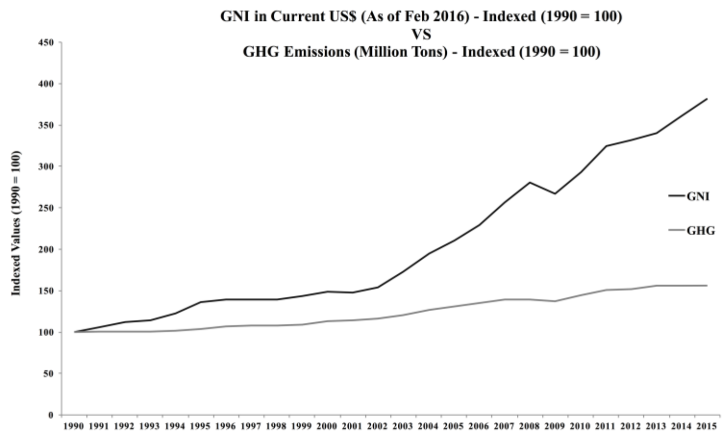


Figure 2 Decoupling of wealth and coal and oil in selected places. Source: World Bank and IEA data

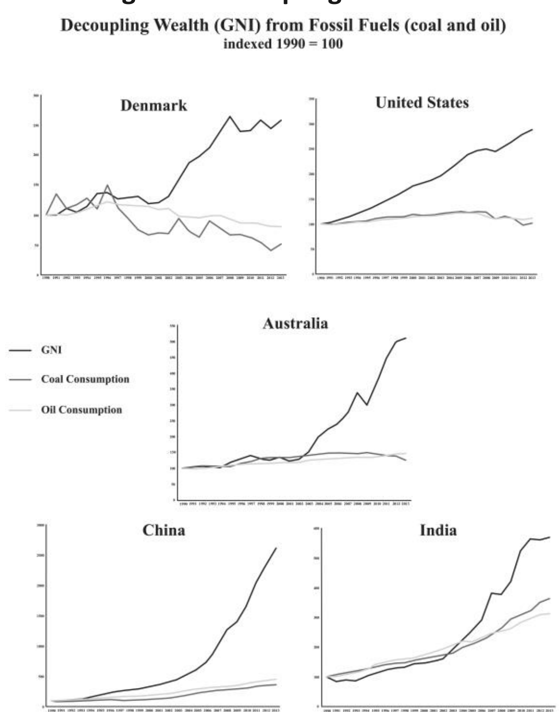


Figure 2 shows how Denmark, the United States, Australia, China, and India are decoupling (some in absolute decoupling) from the two main fossil fuels, coal and oil. In summary these data show:

A. Denmark (as a typical European country) began to reduce its use of coal and oil back in the 1990s and struggled to grow in wealth, but during the 21st century it has begun to thrive economically while rapidly phasing out coal and oil—both are decoupling absolutely.

B. The United States has been decoupling relatively since the 1990s but since 2006 has been decoupling absolutely in both coal and oil.

C. Australia has a very similar trajectory, with very strong growth in wealth while coal began declining around 2006 and oil plateauing.

D. China has decoupled with dramatic growth in wealth while fossil fuels have plateaued and coal has begun to decline.

E. India has decoupled relatively but is still growing in coal and oil, as is the case with most developing nations and cities.

In all parts of the world, it is cities that are decoupling their national economies from fossil fuels as that is where the growth is happening. In the rest of this paper decoupling will be explained in terms of its links to structural efficiencies and disruptive innovation. It will also show how urban planning can help mainstream this so that it can occur even faster as required by the 1.5^0C agenda.

4. Structural Efficiencies and Decoupling

Structural efficiencies can be seen in both building-based GHG and transport-based GHG.

4.1 Structural built environment energy efficiencies

In the period from 2000 to 2013 the OECD improved energy efficiency by a steady 0.6 per cent per year but in 2013/14 it improved 1.5 per cent and in 2014/15 it improved 1.8 per cent (OECD, 2016). This rapid growth seems to be more structural in its base as appliances and buildings are becoming significantly more efficient as shown by the IPCC (2014). This does appear to be a demand driven process involving digital smart systems in appliances and in construction and management of buildings leading to declines in electricity consumption (Nadel and Young, 2014). These changes depend on regulations. Such regulations can be made by urban planners as part of city planning as well as by provincial/state and national governments.

4.2 Structural transport energy efficiencies

Vehicle efficiency has been slowly increasing despite an increase in vehicle size washing out some of this improvement (Sivak and Schoettle, 2016). More significantly in terms of urban planning there has been growing awareness that oil is embedded in the structure of cities through 50 years of automobile dependence in the practice of town planning (Newman and Kenworthy, 1989. 1999). Figure 3 shows the large variation in transport fuel use across the world's cities and how it relates to urban density. The greatest structural efficiency in cities is when they begin to stop their urban sprawl and begin urban regeneration instead.

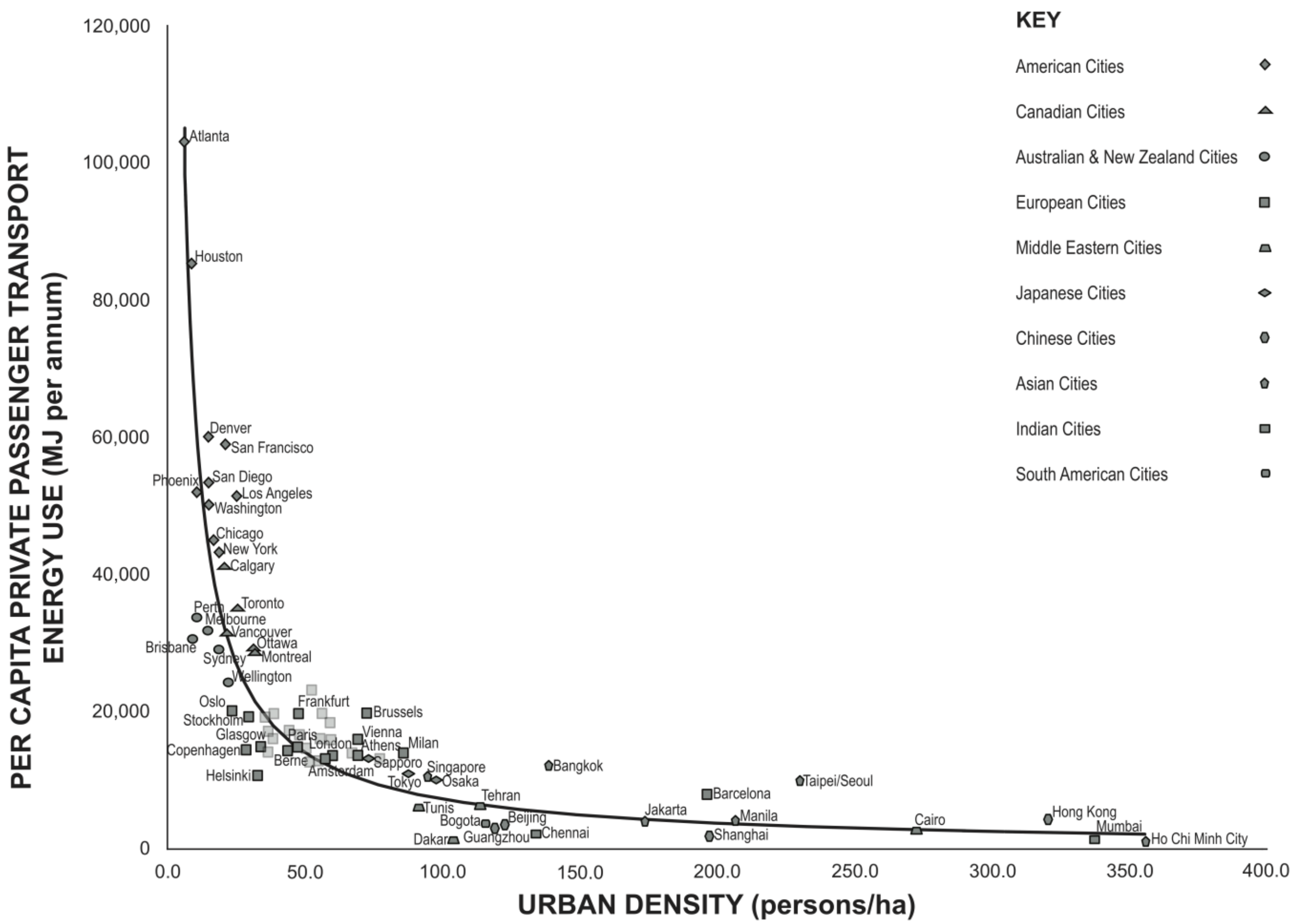


Figure 3 Urban density and transport fuel consumption per capita in global cities. Source: Author

Since 2005 a new phenomenon in the world's cities began to be seen with an unpredicted peak in car use per capita that occurred across first the world's developed cities and then even into emerging cities (Newman and Kenworthy, 2015). This appears to be driven by:

1. Increases in density that have led to exponential declines in car use;
2. Rapid growth in transit across all the world's cities as traffic congestion has led to faster rail options that by-pass the traffic; and
3. Similar trends in walking and cycling driven by health considerations and the demand for better networks.

These trends are all helping to decouple wealth generation from fossil fuels and are firmly in the ambit of urban planning as shown below in a Box with new data on how Shanghai and Beijing are entering peak car.

BOX. Beijing and Shanghai: A Case Study in Peak Car for Emerging Cities

The decline in car use per capita across most developed cities in the past decade has been attributed to a range of factors (Newman and Kenworthy, 2015) but has been generally seen as not applicable to emerging cities as they enter the phase of disposable income across the average citizen. However, the data below suggest that Beijing and Shanghai have achieved peak car (Figure B1).

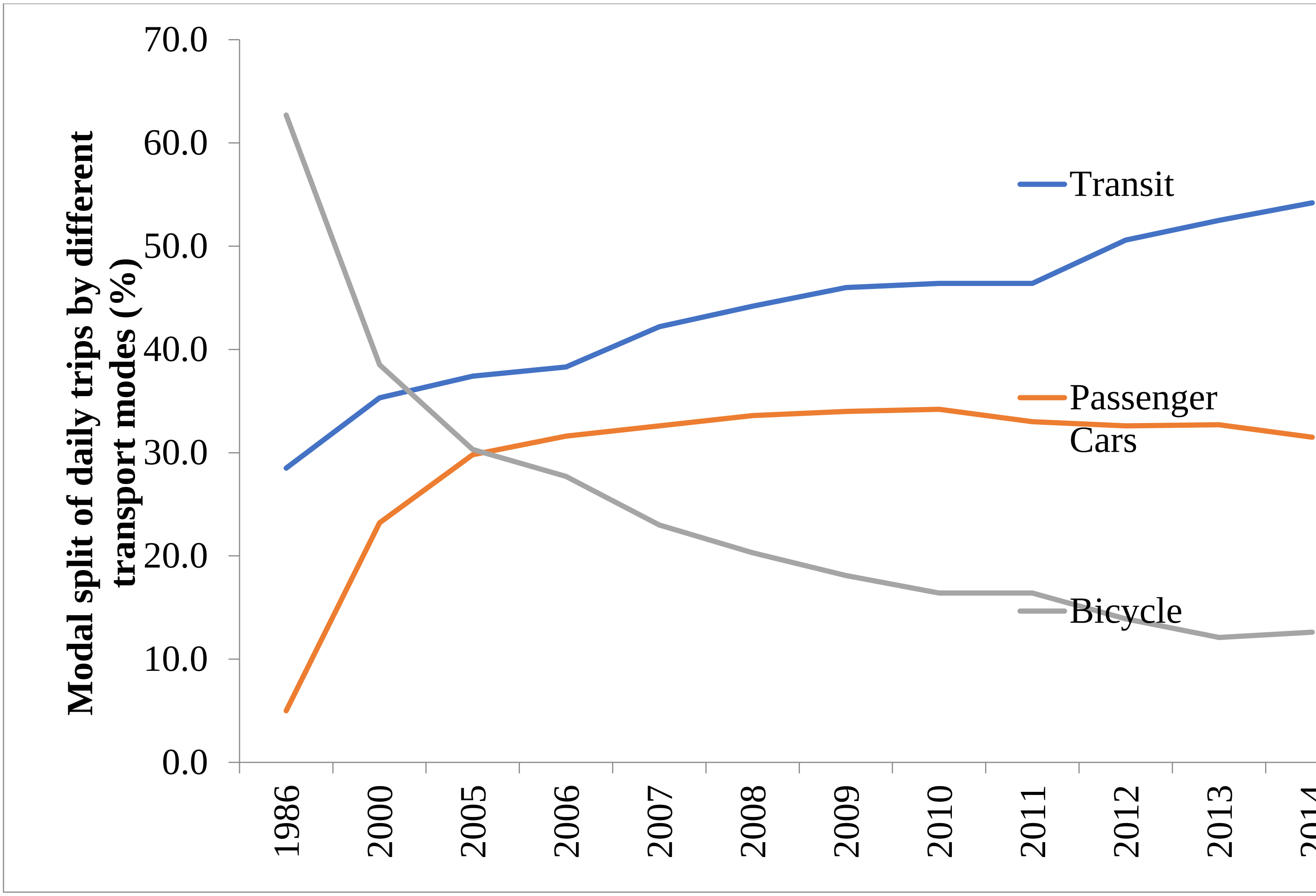


Figure B1 Beijing modal split 1986 to 2014. Source: BJTRC, 2002-15.

The dramatic decline in bicycle use has steadied at around 15% and the mirror image rise in car use has plateaued in 2010 and since then has declined. The rise in transit since the expansion of the Beijing Metro appears to be the core reason for this decline and is now over 50% and rising steadily. Similar data has been found in Shanghai (Fig B2) with even more interesting data available on walking (the highest mode and increasing) and E-Bikes (growing very rapidly to around 18%).

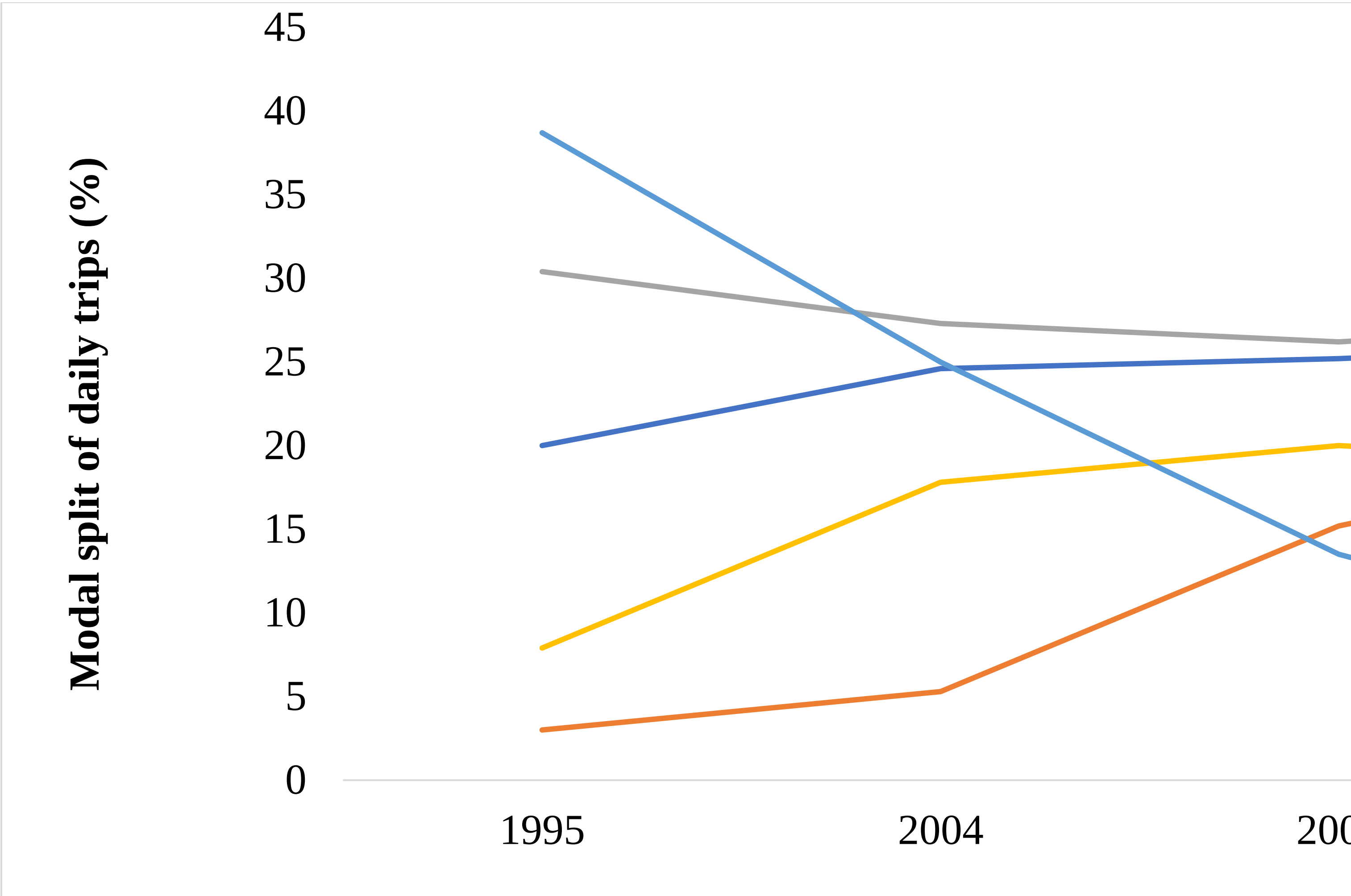
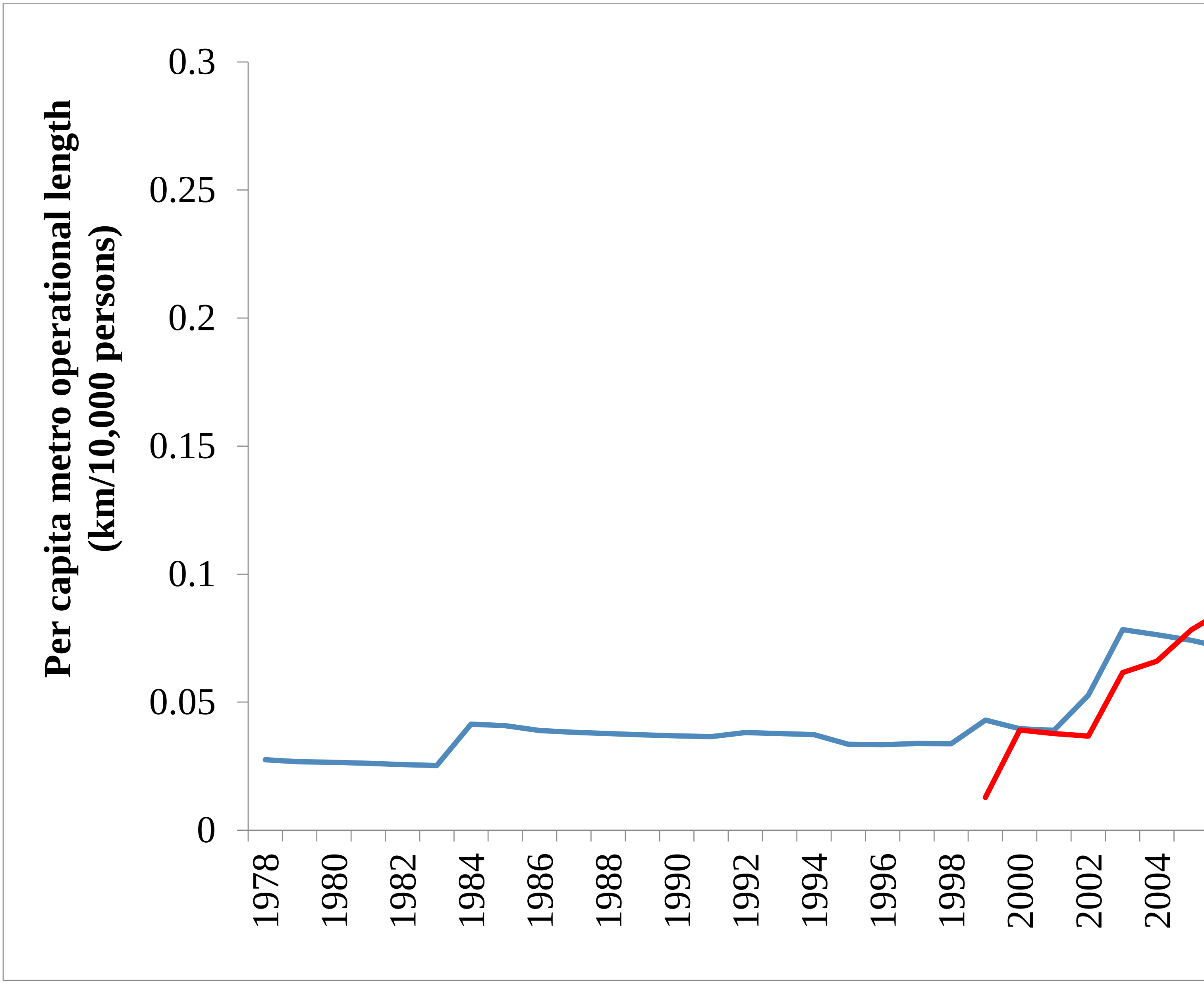
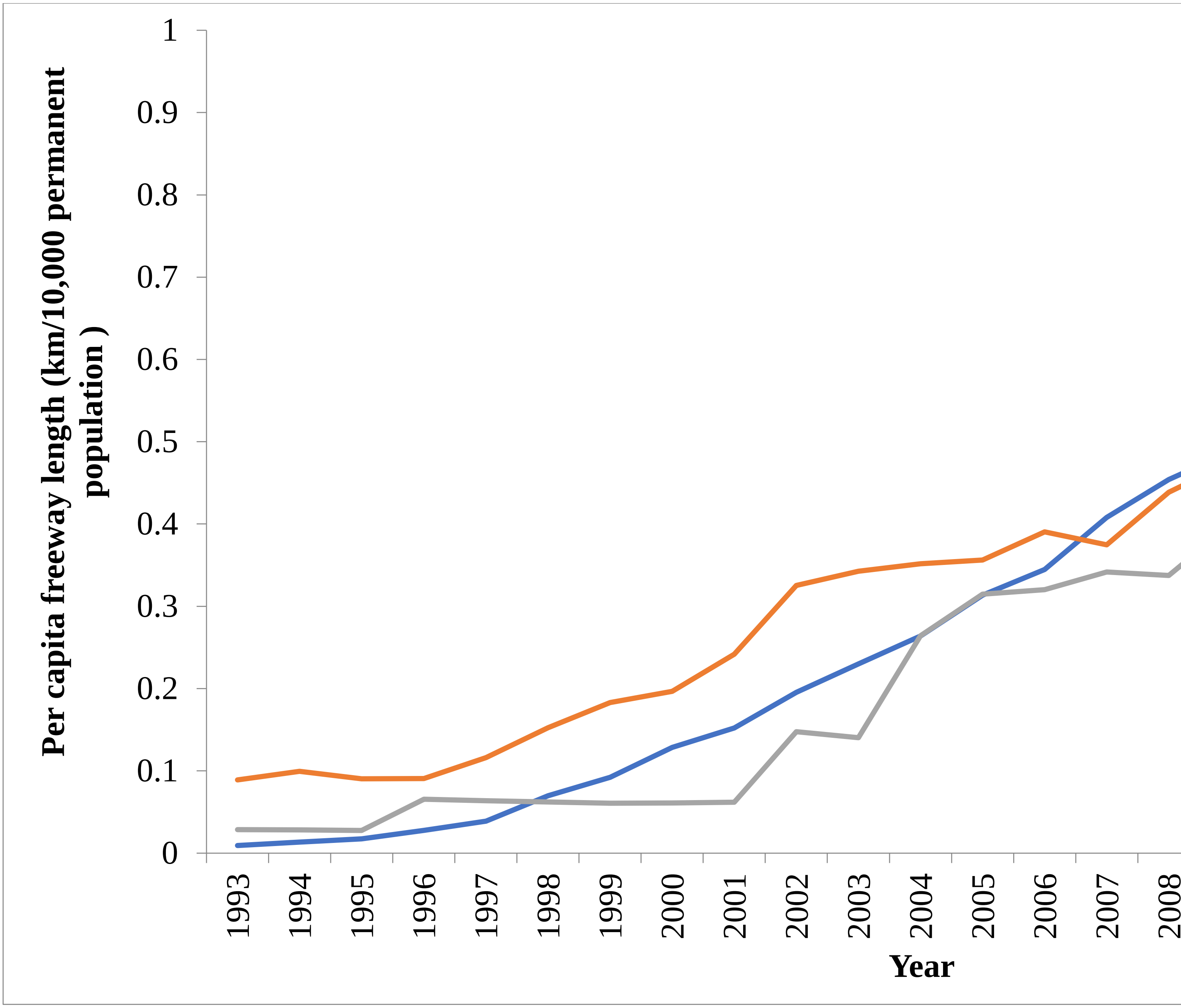


Figure B2 Shanghai model split 1995 to 2014. Source: SCCTPI, 2011; Lu and Liu, 2012

The rise in the Metro in both cities can be seen in Figures B2 and B3 as a change in priorities for spending on infrastructure with a switch from Freeway spending to Metro spending in both of these significant and large cities, compared to the rest of China.



Per capita metro operational length
(km/10,000 persons)
0.3
0.25
0.2
0.15
0.1
0.05
0
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004



Figures B3 and B4 showing Beijing and Shanghai metro length and freeway length changing in priorities from 2009. Source:

The economic implications of this transition are clear (in Fig B5 in the case of Beijing) where per capita GDP has continued to increase whilst per capita VKT decreased. This is a significant indicator that decoupling of car use from wealth generation can be done in emerging cities as it has in developed cities (Newman and Kenworthy, 2016).

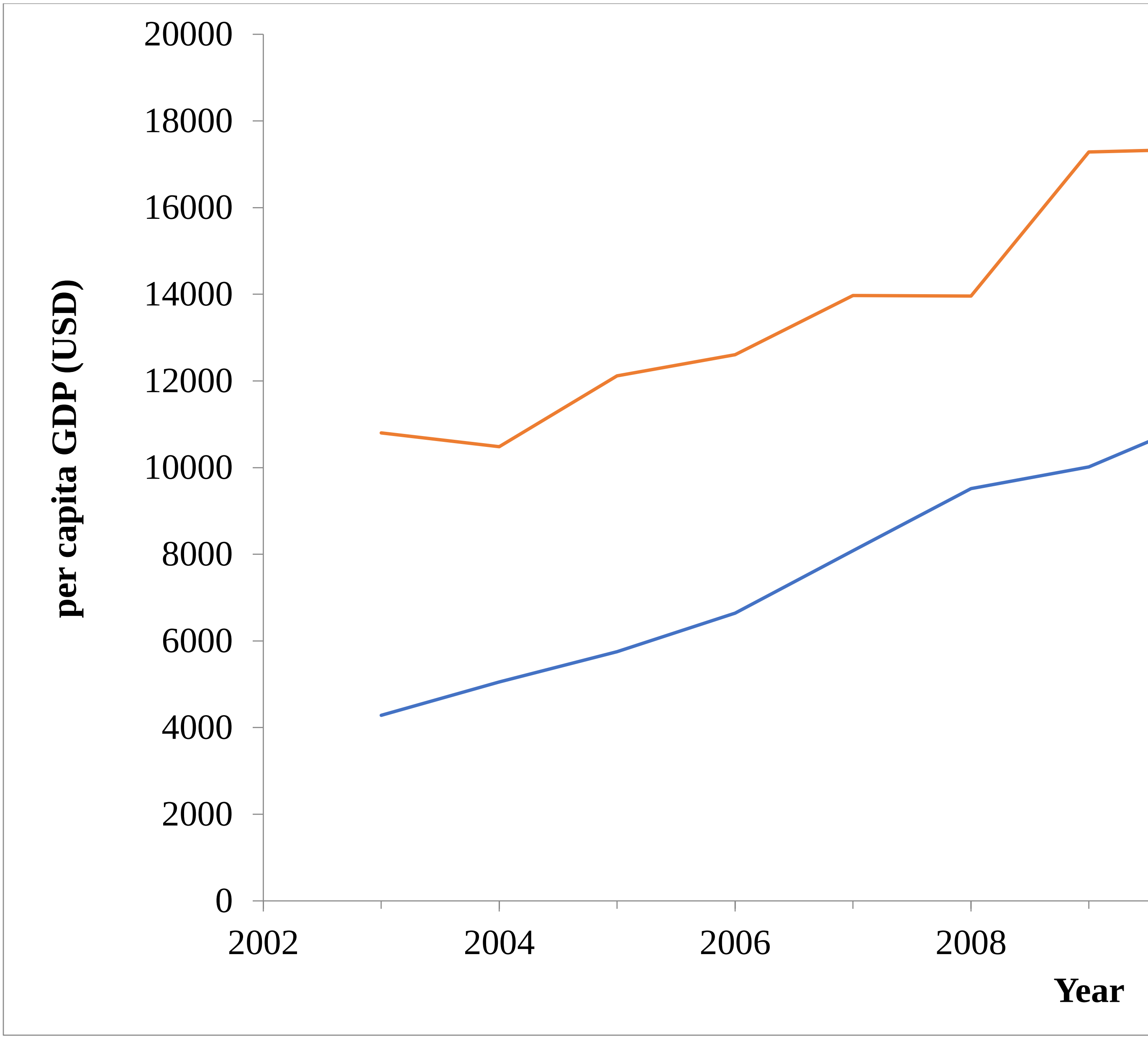


Figure B5 Relationship between economic performance (USD) and private automobile use (km) in Beijing from 2003 to 2014. Source: BBJMBS 1982-2016, BJTRC 2002-15.

……………..End of Box

The reason why such structural efficiency is improving rather than harming the economy seems to be related to the way the knowledge economy and the digital economy are related to this structural change in cities (Florida, 2010; Leinberger and Lynch, 2014). These have significance for urban planning and its role in decarbonizing the global economy (Malecki, 2007; Yigitkanlar, 2010).

The knowledge economy appears to be based around creative interactions where people work together in dense urban centres as these are where the innovative, face-to-face synergies occur between people (Newman and Kenworthy, 2015. Old central business districts and new suburban centres have been transformed back into functional walking cities and those which have done this best have attracted the most capital and young talent to work there (Gehl, 2010). The six most walkable cities in the US have 38% higher GDP and in Boston 70% of the knowledge economy workers live in walkable locations (Glaeser, 2011).

Transit systems and walking are the most spatially efficient forms of transport as well as being the most free of carbon. If one km of a lane of road was considered as a unit of travel then car traffic can fit about 800 people per hour down that lane in a suburban street, a freeway up to 2500, a busway around 5000, a light rail between 10,000 and 20,000 and a heavy rail up to 50,000 (Newman and Kenworthy, 2015). These striking differences in spatial efficiency are translating into competitive advantage based on the need to bring people together in centres. There is a strong demand for such cities because they represent the places where the new knowledge economy will most likely emerge and provide new opportunities. The data is also strong that there is demand for low carbon buildings in these new regenerating urban centres (David and Dutzik and Backandall, 2012). Indeed, cities are competing for residents and workers through the provision of new sustainability-oriented precincts and neighbourhoods; the data shows that sustainability features in buildings are a close third behind affordability and location (Glaeser, 2011; Kooshian and Winkelman, 2011)

As with many economic changes, there is a cultural dimension that perhaps explains the rapidity and the demographic complexion of the change. Young people (especially those involved in knowledge economy jobs) are moving to reduce their car use and switch to alternative transport faster than any other group (Davis, Dutzik and Baxandall, 2012). This is a cultural revolution that partly underlies the rail revolution as well as the re-urbanization of cities. This can explain why cities like Washington DC and Portland are demonstrating the decoupling of GDP from car use per capita – see Figure 4.

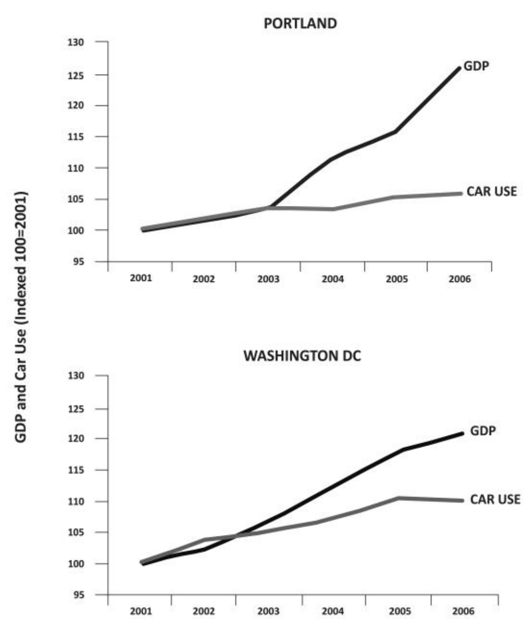


Figure 4 Decoupling GDP and Car Use in Portland Washington DC.

Source: Kooshian and Winkelman (2011)

Structural changes do bring about decoupling as the evidence suggests in both buildings and transport. However, they are quite slow and although it is imperative that cities are involved in these changes it is necessary to see the rapidity with which climate change is now happening and as suggested by the 1.5^{0}C report from the IPCC, cities must respond more rapidly (IPCC, 2019). The hopeful sign is that there are disruptive innovations happening that are enabling rapid switches in fuels that are leading to the emerging Renewable City (Droege, 2006; 2018) and which will be a major part of city decarbonization policies in the next decade. Urban planning will also play a significant role in these disruptive innovations being mainstreamed.

5. Disruptive Innovation and Decoupling

Economists who project the future based on the past have begun to see that they are no longer coping with the growth in fuel switching that is happening, especially the adoption of solar energy (Sussams and Leaton, 2017; Green and Newman, 2017a). This has led to policy being developed around the ideas of disruptive innovation as they explain change that leads to much accelerated activity (Christensen, 1997; Seba, 2014). Disruptive innovation is caused by demand more than supply. The costs of supply need to be competitive but may not be the cheapest option when people discover they want it for many reasons and this changes the whole system that the market is based around.

There is now evidence of disruptive innovation in the fuels used in buildings and in transport leading to a whole system change that some are calling the Third Industrial Revolution (Rifkin, 2011; Seba, 2012; Newman, 2018).

5.1 Renewable fuel growth

Solar and wind are disruptive innovations. Bloomberg New Energy Finance (BNEF, 2016) has made projections of the growth in renewables based on the relative costs of fuels. They suggest that from 2015 to 2040 renewables will become the dominant power source in the world; wind and solar will account for 64 percent of the new generating capacity, and globally there will be 60 percent zero-carbon power, replacing coal and gas, which will decline from 57 percent to 31 percent. These are being upgraded each year with higher growth rates. The biggest growth is predicted to be roof top solar which will drop in cost by 60 per cent. However, it may be driven at an even faster rate if it has demand driven characteristics. Carbon Tracker researchers have suggested that the changes may be even more radical than BNEF are predicting as they appear to be following more rapidly than any previous predictions as they are disruptive innovations (Schuwerk and Sussams, 2016).

The big issue with roof top solar is that it is mostly being driven from community demand rather than by utilities. Australia cities have had a remarkably rapid adoption of roof top solar at a time when little investment in power was happening in the aftermath of abandoning the Australian carbon-pricing scheme (Green and Newman, 2017b). Perth in particular showed this as the city grew rapidly in wealth over the past decade and 30% of households invested in roof-top solar PV. This happened well beyond what would have been predicted based just on supply costs and household solar is now the largest power station in the grid. Battery storage is following the same trends (Nykvist and Nilson 2015) and analysis in Perth shows solar-storage systems enable over 90 per cent grid-free electricity as well as producing more renewable energy to feed into the grid and generate income (Green and Newman, 2017b). The technology of PV and batteries seems to fit into a niche for ordinary single residential householders. The case study of WGV in section 2 on water sensitive urban design is also a demonstration showing how demand in medium density shared households to integrate PV and batteries can be achieved using Citizen Utilities and blockchain software to enable peer to peer trading (Green and Newman, 2017c).

The signs are there that demand is driving the electricity system toward a rapid decline in coal even faster than supply costs would indicate. This may involve more gas in some cities like in the US where this is significantly cheaper but the attractions of roof-top solar and batteries are more than likely going to outcompete gas when the market enables it to work as it is in Australia with simple financing, permitting and installation (Jarnason, 2016).

The integration of these innovations into grids is the next frontier. In Perth plans are being developed to phase in community batteries, end of grid individual battery systems, and regional large-scale batteries that will replace big power stations as solar grows across the grid faster than anyone foresaw. This will need to involve local planning systems as the use of community-scale batteries and regional scale batteries can be modelled and managed into grids with the potential to rapidly phase out large scale fossil fuel plants but this is a major cultural and economic change and it will need community engagement at a high level. Seba (2012) and Rifkin (2012) suggest this will accelerate even faster when electric vehicles become part of grid systems and can be recharged at home and in community-based Recharge Hubs that provide grid stabilization.

5.2 Electric mobility

Electric vehicles are growing globally at over 40% per year and are expected to reach at least 25% of the vehicle fleet by 2040 (Carlin, Rader and Rucks, 2015). Most of this growth is in China which is likely to mean cheaper exports. The demand for electric vehicles is high whether they are personal cars, buses, trains or electric bikes and certainly with cars this is happening well before the supply cost is competitive though the daily costs of operation are significantly lower and this is a strong demand factor for most consumers; some are therefore predicting even higher adoption rates (IEA, 2016) with the last diesel and gasoline new cars being produced in the 2020's.

There is another demand-based trend that will impact on the shift to electric mobility. Sprei (2018) calls this disruptive mobility. The trend in electricity to become more based on renewables means that growth in solar-powered EVs are likely to be driven by demand similar to roof top solar. EVs are already being used to fit cleverly into home PV and battery systems with the high potential for 'vehicle to grid (V2G)' - transfers of power to enable extra storage options in the grid. Electric transit is also beginning to be switched to renewable power as demand for clean transport grows across cities (Newman and Kenworthy, 2015) and new ways of financing this demand are being found (Newman, Davies-Slate and Jones, 2017). Recharging of electric cars and electric transit (buses, trains and trams) will be needed at certain parts of the city where solar collectors can be built to satisfy this demand. The obvious solution for planners is to find how Recharge Hubs can be fitted into station precincts thus mainstreaming both solar and electric transport.

Urban planning needs to participate in the development of the power grid more towards localised or community-based management of power within a broader grid system and in how electric transport fits into this. The idea of local shared mobility that is electric and autonomous which feeds into stations along a fast, electric corridor-based transit system seems to resolve many of the planning issues in this transition (Glazebrook and Newman, 2018). However, it will require detailed urban planning to enable the walkable precincts at stations to remain attractive for the knowledge economy while enabling the fast corridor service between these stations. The role of walkable design, solar design, water sensitive design and biophilic design will all be critical at stations and the commitment to transit along street corridors will need to be the highest priority for transport engineering. Bringing these approaches into an integrated plan will be the challenge that is taken on by urban planners. Without such planning the innovations can easily become elitists and ineffectual as they are not mainstreamed.

All new urban development will need to mainstream this combination of solar, EV's (both in cars and transit) along with well-positioned Recharge Hubs. This will require strategic and statutory plans to adopt these into their short and long term decision-making. The result is likely to show how solar will be able to transform cities and grids much faster than ever considered possible by utilities and by national governments.

5.3 Emerging Disruptive Innovations

There are two emerging disruptive innovations that appear to be on the horizon and could rapidly grow to achieve significant urban change: Trackless Trams (for fast street corridor access) and Hydrogen (for heavy fuel cell vehicles and industrial fuel).

5.3.1 Trackless Trams

There has been a global trend for cities to address urban public transport requirements through construction of light rail as it is known to facilitate urban regeneration (Newman, Glazebrook and Kenworthy, 2014). Light rail is effective and efficient at enabling such urban development outcomes however it is costly and can result in highly disturbed local economies during construction.

Recent technological advancements have resulted in the development of Trackless Trams that retain all the benefits of light rail (trams) combined with the flexibility of buses to create a superior product. This technology is a 3rd – 4th generation smart system being developed in Europe and more recently has been born out of the autonomous technology of high-speed rail in China. The Trackless Tram appears to be able to do all that a Light Rail can do in terms of ride quality but is significantly cheaper and less disturbing to local economies, hence it appears to be an ideal way of unlocking urban regeneration potential.

PHOTO 2 A Trackless Tram in Zhu Zhou China.

Trackless Trams are in simple terms a hybrid of a tram and a bus creating a new transport mode that retains and evolves the best characteristics of both. They have a tram like body and size with an open flexible interior layout. Battery powered electric motors provide drive without the need for a catenary and overhead wires for power associated with trams. During normal operation they follow an optically guided track (from GPS) on standard bitumen roads (however they can be manually deviated from these routes if required), using a 'train like' suspension with hard rubber wheels.

By taking innovations from high-speed rail and integrating them with the flexibility of a bus, Trackless Trams retain the positive components of light rail at significantly lower cost (approximately A$5M per km vs ~A$50-80M) and with radically speedier and simpler implementation. They are quiet and emission free, achieved through the use of electric motors with potential zero carbon if solar recharging is done. They are lighter and carry more passengers than buses and have modular functionality – enabling expansion and contraction based on demand. The standard Trackless Tram is a three-car set that can carry 200-300 passengers at a maximum speed of 70-80 kph. The use of charging stations provides the opportunity to access the 'fixed route' development benefits of light rail as well as the potential to link into other transport innovations around local shared mobility (Newman, 2018).

The value of this system is that it could potentially be funded by private investment in urban regeneration-based land development. This will require complex partnerships to be developed between government, local communities, private developers and transit operators. This is how trams and trains were first built as real estate partnerships and there are examples now appearing of how the old approach is being rediscovered (Newman et al 2018a). Evidence of its potential disruption is seen in the number of cities now being drawn into planning for Trackless Trams and the social media interest in a You Tube film with over 4 million hits in the immediate period after its release (Greenpeace, 2019).

Hydrogen

The remaining fuel that needs to be switched to renewables is the oil used for heavy transport like trucks, freight trains, shipping and aviation, and also natural gas used as an industrial fuel. These are part of all cities and there has been little confidence in any of the options being proposed (IPCC, 2019). It is possible that Hydrogen can provide a solution to both of these issues as a major reduction in the cost of electrolysing water into its constituent parts could now follow the trajectory of other disruptions like solar, batteries and EV's. Electrolysis is an expensive process where 80% of the cost is due to power however if this cost is reduced to near zero because Hydrogen is being used for storage whenever solar are wind are being produced in excess; the excess energy is used for splitting water and the Hydrogen collected for later use in either H-Fuel Cell Vehicles (which are likely to be more suitable when heavy transport switches to electric propulsion) or replacing natural gas in industrial fuel uses. Breakthroughs that reduce the cost of an electrolyser are also happening (Zhou et al, 2017).

A demonstration Green Hydrogen innovation hub is showing how Hydrogen can be created from solar electrolysis of water. This happens only while solar is producing excess power then the resulting Hydrogen is going into both fuel cell vehicles and as an industrial fuel in the gas stream (ARENA, 2019). Local Hydrogen production centres are likely to be created at industry sites and also for transport systems wherever heavy transport terminals are located. Safety issues will be a primary issue but are less obvious in practice than oil-based and gas-based systems as Hydrogen has been used for over 40 years as an industrial chemical and fuel for space exploration. During that time, industry has developed an infrastructure to produce, store, transport and utilize hydrogen safely. It will remain however a core human and social issue to be resolved, not just a technical one. As Geels (2018) suggests socio-technical systems will remain driving forces that must be considered as part of the transition to a decarbonized world. However, this is the world of urban planning and it is just a matter of putting all these issues onto the planner's agendas at all levels of city decision-making.

In the next section some suggestions are made about how to mainstream the innovations discussed in this paper using the theory of urban fabrics.

6. Urban Fabrics Theory and Planning

The theory of urban fabrics was developed by Newman, Kenworthy and Kosonen (2015) after the Australian researchers (Newman and Kenworthy, 1989, 1999, 2015) came together with Finnish planners and researchers (see UF website: urbanfabrics.fi , and Ristimaki, et al 2013), to help planners see that there are three main city types, not one as suggested by modernist city planning since the 1940's. The theory enables planners to create strategies for managing the different fabrics and especially how to see that some urban fabrics have inherently more sustainable properties that need to be optimized and extended to other parts of the city. This theory seems to offer a way of rapidly mainstreaming climate innovations.

There are three city types from history that form the basis of urban fabric theory: walking cities, transit cities and automobile cities. Most cities today have a mixture of all three urban fabrics. It is suggested that the fundamental problem with 20th century town planning has been the belief that there is only one type of city: the automobile city. As will be shown below it is the automobile city that is the most resource consumptive type of urban fabric. The rediscovery of the other city types or fabrics has been a significant factor in the reduction of automobile dependence as a paradigm in town planning and thus focuses our ability to reduce and eventually regenerate urban footprints.

The original typologies of the three city types are set out in Figure 4 (Newman & Kenworthy 1999) and are outlined in their historical development based on the average travel time budget of around one hour per person per day which has been well established in cities across the world (Newman and Kenworthy, 2015).

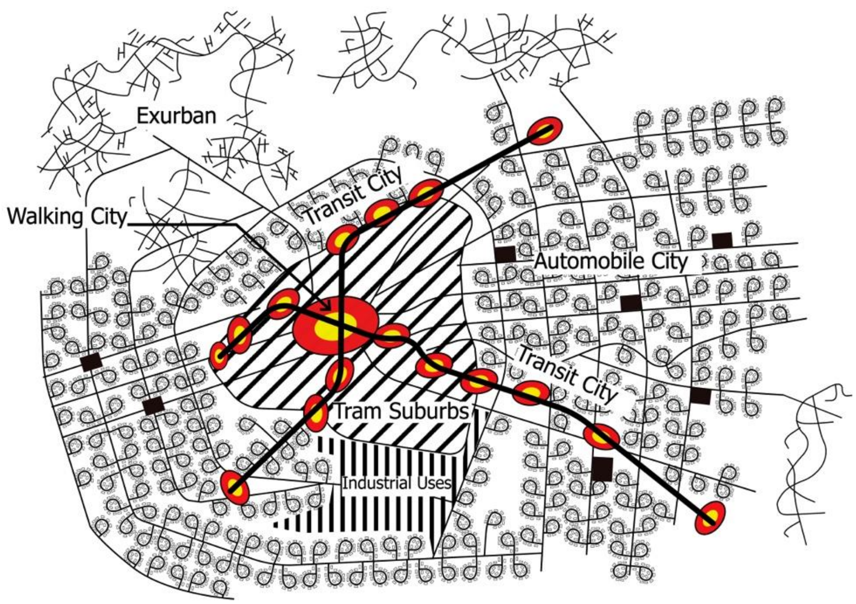


Figure 5 Automobile City, transit city and walking city, a mixture of three city types Source: Newman and Kenworthy, 1999

Walking Cities have existed for most of settlement history since walking, or at best animal-powered transportation, was the only form of transportation available to enable people to get across their cities at walking speeds of around 3-4 km/h. Thus walking cities were dense, mixed-use areas of generally over 100 persons per ha with narrow streets, and were mostly no more than 3 to 4 kilometers across, or roughly 2km in radius. The most intensive part is within a 1 km radius of some central point such as the main city square or plaza.

Walking cities were the major urban form for 8,000 years, but substantial parts of old cities retain the character of a walking city, even though today they are of course much larger than 4 km in diameter. Kraców and Venice are, even today, mostly walking cities. In squatter settlements common to many Latin American, African and South Asian urban environments, the urban fabric is usually a walking city with narrow, winding and often unsealed streets suitable only for walking.

Most modern cities have central areas that are predominantly walking cities in character, though they struggle to retain the walking urban fabric due to the competing transit city and automobile city which now overlap with it. Many cities worldwide are trying to reclaim the fine-grained street patterns associated with walkability in their city centers and they find that they cannot do this unless they respect the urban fabric of ancient walking cities (Gehl 2011). Many modern cities are trying to create new urban centers and want to make them truly walkable but often don't have the tools to do it as modernist planning manuals rarely consider them. The new NACTO manuals are an exception (National Association of City Transportation Officials, 2016).

Transit Cities from about 1850 – 1950 were based on trains (from 1850 the steam train began to link cities and then became the basis of train-based suburbs) followed by trams (from the 1890's) that extended the old walking city. Both could travel faster than walking – trams at around 10-20 km/h and trains at around 20 – 40 km/h. Such cities could now spread out forming the inner transit city 10-20 km across (5-10 km radius with an average around 8 km) and with trains forming the outer transit city 20 – 40 kilometers (10-20 km radius).

Trams created linear development (trams, being slower and with closer spacing of stops, led to strips of walking urban fabric). Trains created dense nodal centers along corridors (following faster heavy rail lines with walking urban fabric at stations like pearls along a string). Densities could be reduced to around 50 persons per ha as activities and housing could be spread out further, although they could also be significantly denser than 50 persons per ha. People still needed walking fabric around the stations.

Trains supplemented by buses are the basis of outer transit urban fabric. These can go out much further than the old tram and old subway networks and the fabric is based on corridors of dense sub-centers created by transit with an average speed of around 40 km/h. These developments now go out 20 km or more from the city center, depending on the speed of the trains. Busways and BRT are now doing the same in newer areas of many cities wherever they are freed up from traffic.

Most European and wealthy Asian cities retain this transit urban fabric, as do the old inner cores and corridors in newer cities. Many developing cities in Asia, Africa, and Latin America have the dense corridor form of a transit city, but they do not always have the transit systems to support them, so they become automobile-saturated or motorcycle saturated. Singapore, Hong Kong and Tokyo have high densities in centers based on mass rail public transit linkages and this dominates their transportation modal split. Cities such as Shenzhen, Jakarta and Dhaka have grown extremely quickly with dense, mixed use transit urban fabric but the development is based predominantly on buses and paratransit; the resulting congestion shows that their activity intensity demands mass public transit. Most of these emerging cities are now building the public transit systems that suit their urban form and Shenzhen in fact opened a metro system in 2004. China and India are building innumerable metro rail systems to support their dense transit urban fabric (Newman, and Kenworthy 2015).

Automobile cities that are looking to create transit options often are without reasonable densities around train stations and are finding that they need to build up the numbers of people and jobs near stations otherwise not enough activity is there to support such transportation options without extensive feeder systems and Park and Ride, i.e. they are building transit urban fabric and walking urban fabric to support these modes with walk-on transit users.

New fast trains can extend the transit city way beyond the previous maximum distance of about 20 km radius (McIntosh et al. 2013). When fast trains averaging 80 km/h are built across big cities then a new kind of polycentric transit city fabric emerges around each of the main stations.

Automobile Cities from the 1950s onward spread beyond the 20 km radius to some 80 km in diameter (up to 40 km radius) in all directions, and at low density because automobiles can average 50-80 km/h while traffic levels are low. These cities spread out in every direction due to the flexibility of automobiles and with zoning that separated activities.

Buses were used as a supplementary service to the automobile and hence missed the opportunity to continue creating transit city corridors, but became subservient to automobiles in the new automobile urban fabric. These cities thus provided limited public transit, mostly unattractive and infrequent bus services to support their sprawling suburbs and within a generation such areas became the basis of automobile dependence (Newman & Kenworthy 1989) and automobility (Urry 2004). Cities in the new world from around 1950 have used their growth to build automobile dependent suburbs as their main urban fabric; it is not unexpected that this growth has happened with significant increases in their urban metabolism.

Many European and Asian cities are now building some suburbs around their old transit urban fabric, though the densities still tend to be higher than in the USA or Australia and access to transit services are often still feasible but distant and require car, bus or bike connections. In Asian cities especially, the use of private automobiles is often supplemented by large numbers of motorcycles that seem particularly to thrive in transit urban fabric due to the shorter distances needed. In cities and parts of cities that are built around the automobile there is a similar need to recognize the urban fabric and respect it for what it contributes to the urban economy. However, there is also a need to see that there are real issues associated with the dominance of such automobile urban fabric, especially where it extinguishes the best features of walking and transit fabric and creates a much bigger urban metabolism. Thus, if cities are to decarbonize rapidly they need to understand how to use their different urban fabrics appropriately.

Urban Metabolism and Urban Fabrics

Thomson and Newman (2018) have produced a detailed analysis of the urban metabolism in Perth to demonstrate how it varies across the three urban fabrics. Tables 1 and 2 show the resources and wastes associated with the three fabrics. These data show the variations in energy, water, land, food, and basic raw materials in the three areas of the city as well as the wastes produced from this. There are very different metabolism flows in the three different fabrics.

INPUT (Per Person Per Year)	Automobile City	Transit City	Walking City
Resources			
Fuel in Megajoules (MJ)[1]	50 000	35 000	20 000
Power in Megajoules (MJ) [2]	9 240	9 240	9 240
Gas in Megajoules (MJ) [2]	4 900	2 940	2 940
Total Energy in Gigajoules (GJ)[2]	64.14	47.18	32.18
Water in Kilolitres (Kl)[2]	70	42	35
Food in Kilograms (kg)[3]	451	451	451
Land in Metres Squared (m^2)[4]	547	214	133
Urban Footprint in Hectares (ha)[5]	2.29	1.97	1.78
Basic Raw Materials (BRM) for New Building Types Per Person[6]			
BRM 1) Sand in Tonnes (T)	111	73	57
BRM 2) Limestone in Tonnes (T)	67	44	34
BRM 3) Clay in Tonnes (T)	44	29	23
BRM 4) Rock in Tonnes (T)	66	43	33
Total BRM in Tonnes (T)	288	189	147

Table 1 Resource input variations between urban form types (Source: Thomson and Newman, 2018))

OUTPUT (Per Person Per Year)	Automobile City	Transit City	Walking City
Waste			
Greenhouse Gas (Fuel, Power & Gas) in Tonnes (T)[1]	8.01	5.89	4.03
Waste Heat in Gigajoules (GJ)[2]	64.14	47.18	32.18
Sewage (incl. storm water) in Kilolitres (KL)[3]	80	80	80
Construction & Demolition (C&D) Waste in Tonnes (T)[4]	0.96	0.57	0.38
Household Waste in Tonnes (T)[5]	0.63	0.56	0.49

Table 2 Waste output variations between urban form types (Source: Thomson and Newman, 2018)

The fundamental structural difference in the three urban fabrics dominates the differences between the three kinds of urban systems. If cities are to respond to climate change then the tools discussed in this paper need to be applied carefully to each area with a basis of respecting their fabric and its functions.

In Table 3 below the six climate-oriented tools discussed in this paper – walkability, solar design, local shared mobility, water sensitive urban design, biophilic design, and integrated urban design – are applied to the three urban fabrics outlined. The idea is to see how they can be used to assist urban redevelopment to be more climate-based in all parts of the city. The opportunity for planners is to mainstream climate change into their urban planning. There is obviously some differences in how the different tools can be applied but in most cases it is possible to see the outcomes as being more climate resilient cities. Each of tools can vary with the fabrics but some are essential for all fabrics, especially the final tool which is an integrated approach to planning.

Climate-Oriented Urban Planning Tools	**Central City Walking Fabric (current rail-based centre)**	**Inner City Transit Fabric (old tram line area)**	**Outer Suburb Automobile Fabric (new area needing a centre)**
1. Walkability	Walkability the critical value	Walkability in station centres but fast transit corridor access also critical	Walkability in station centres but fast transit corridor access also critical
2. Decarbonization through solar design	Strong transport carbon reductions but harder to do solar on buildings	Easier to do solar on buildings and harder on transport carbon reductions	Very easy to do solar on buildings and much harder on transport carbon reductions
3. Local shared mobility	Essential but focussed on centre	Essential but needed along all stations	Essential but in sparser areas
4. Water sensitive urban design	Important but more difficult	Important but still difficult	Important and easier to achieve
5. Biophilic Design	Critical with emphasis on biophilic buildings and small pocket parks	Critical with emphasis on biophilic buildings, small pocket parks and green corridor	Critical with emphasis on small pocket parks, green corridor and landscape-oriented development
6. Integrated planning processes	Essential for delivery	Essential for delivery	Essential for delivery
7.			

Table 3. A planning framework for climate-oriented planning tools applied to three different urban fabric examples.

It is also possible to see two more urban fabrics that relate to every city: Peri-Urban Fabric and Bioregional Urban Fabric. Peri-urban and bioregional areas are not generally part of the daily commute and are therefore not considered part of the main city. However, these areas are still related to the city, as they are fundamental to its functioning in terms of its natural resources and materials as well as its waste management and ecological functions and hence need to be considered in the climate change agenda. Peri-urban areas are much more intensively used than the areas farther out. Many small villages in older areas of Europe are being drawn into cities; new kinds of settlements are emerging in such areas, offering new possibilities for resilient and regenerative outcomes.

Peri-urban areas are likely to be able to have rail access but are likely to need electric vehicle car-share or cooperative bus services to link them to it and hence to the city. Local transport can use such vehicles and also electric bikes. Peri-urban areas will grow in their usefulness to the rest of the city, as all settlements move away from fossil fuels, for the following types of functions:

- Local food production based on intensive permaculture that has short food miles and local types of food, including native food species, which are increasingly being found to have nutritional value
- Waste-recycling centres that cannot fit into the more built-up part of the city, for example, the recycling of treated wastewater to recharge groundwater systems
- Utility-scale solar and wind farms
- Plantations that help the city become carbon neutral
- Lifestyle villages for retirees and others wanting a life near the city but not on a daily basis, where experiments in regenerative design can be conducted
- Biodiversity experiments that are based on restoring native species and habitat but that need intensive manpower to manage the areas and prevent exotic and feral animals and plants from invading.

Bioregional fabric is essentially rural, but of course it still has small settlements that service the city area and thus should be seen as part of the city. Transport can still become zero carbon with electric vehicles based on solar homes, though they may also be suitable for Hydrogen based transport and in farm vehicles. The functions of bioregional areas will include all of those described for peri-urban areas but on a bigger scale, especially in relation to water and renewable energy which must be managed in a city's bioregion as well as in local communities.

The six tools demonstrate nuanced and integrated urban planning responses to climate change when considering the five different urban fabrics. Strategic planning and statutory planning needs to use these tools to enable cities to continue to lead the world in how to mainstream critical goals concerning climate change.

7. Conclusions

The evidence gathered in this paper has shown that there is a new kind of city emerging that can integrate adaptation and mitigation and which is rapidly moving to be a renewable city. This century has begun to show evidence of cities decoupling fossil fuels and economic growth. The decline of coal and oil are both caused by structural energy efficiency gains (smart technology and smart buildings for coal; smart, dense transit-oriented cities that reduce car dependence for oil) and most of all are caused by disruptive innovations enabling renewable fuels. The emerging disruptions of Trackless Trams and Hydrogen in vehicles and industrial fuel, are also potentially going to accelerate the decline of fossil fuels in a way that does not damage economies. However, in all these innovations the world is seeing mostly demonstrations that are rapidly needing to be mainstreamed. Urban planners are now needed to mainstream the demonstrations that seem to be working. It will be essential for urban planning to be completely involved in every step of this journey. Not only does urban planning have the strategic and statutory tools for managing adaptation and enabling mitigation (water sensitive urban design, biophilic design, walkable urban design, solar design, local shared mobility planning, and integrated design), but they have the ability to understand local communities who are likely to become more and more the focus of the new energy economy. These communities will need different and nuanced approaches in each of the different urban fabrics across the city.

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