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Review

Density, the Sustainability Multiplier: Some Myths and Truths with Application to Perth, Australia

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Abstract: The paper suggests that the divisive urban issue of density has critical importance for sustainability. It is particularly important to resolve for the low density car dependent cities of the world as they are highly resource consumptive. Ten myths about density and 10 truths about density are proposed to help resolve the planning issues so commonly found to divide urban communities. They are applied with data to Perth to illustrate the issues and how they can be resolved.

Keywords: city; density; multiplier; myths; sustainable; truths; urban

1. Introduction

Density is a contentious issue in most cities as it represents change and that can often be seen as threatening. There is obviously a case for designers to make density more attractive and planners to make the amenity better around denser housing. However, there are many times when the designer and planner never get a chance to show their skills as any density increases are challenged politically.

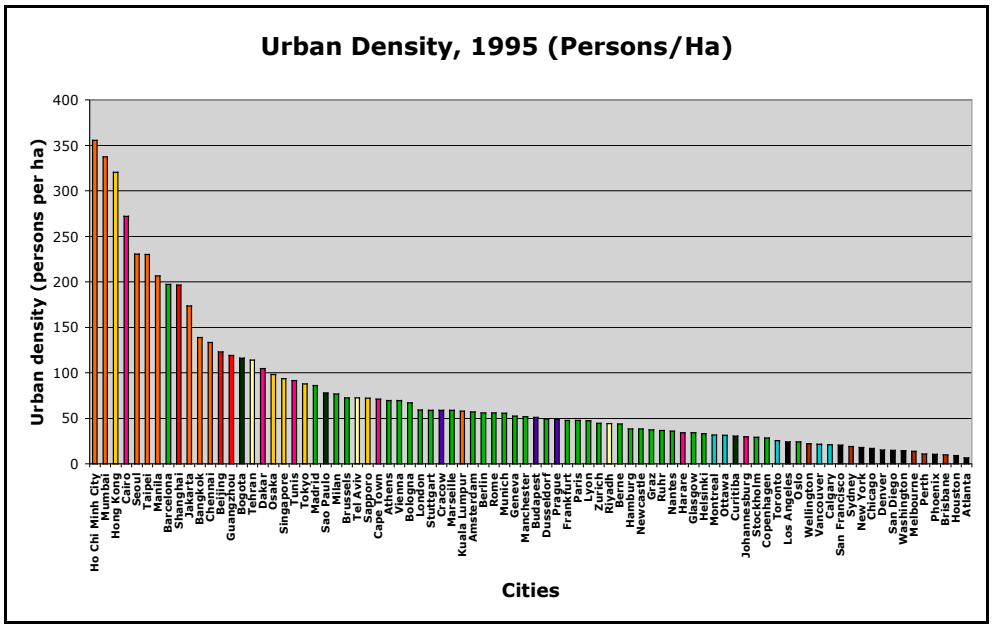
This paper tries to provide an overview of the density issue and enable the myths and truths about density to be summarized. It is hoped that the sustainability credentials of density can be better understood by seeing the broad perspective provided by the myths and truths.

2. Global City Comparisons

The density variations in cities are large. In Figure 1, the Global Cities Database is used to provide the urban density of 84 cities in 1995, the most recent year that data has been processed for these cities. Urban density is not just population divided by the political boundary of the urban region, it is defined

by the area where urban development has occurred, so large parkland, lakes and rural areas are removed. Thus, the real experienced density of the city is provided.

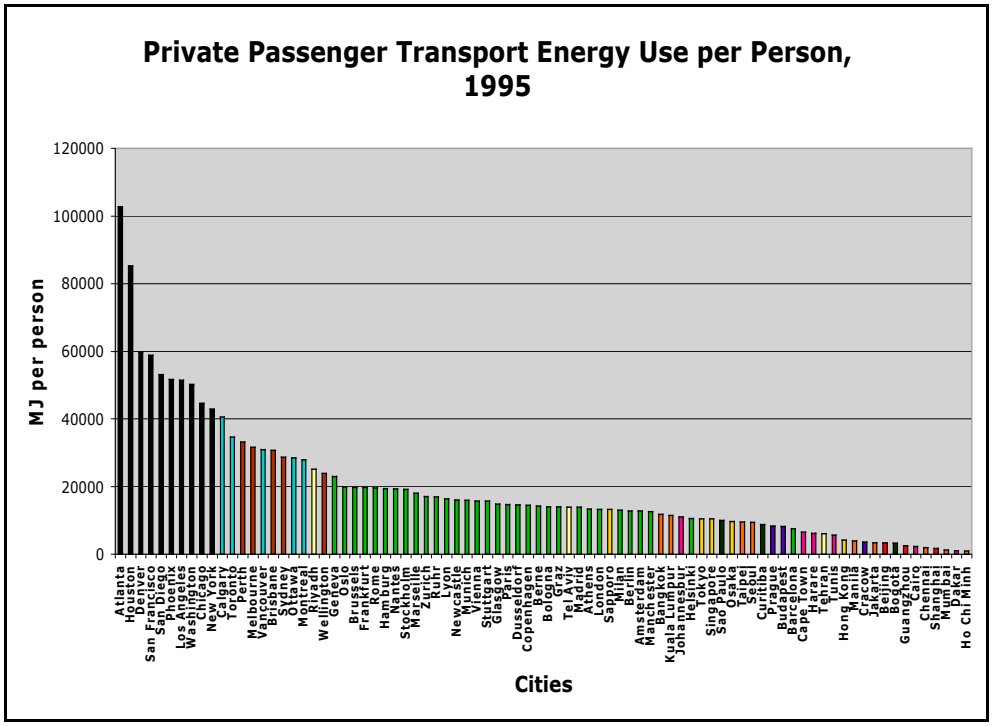
Figure 1. Urban density in global cities, 1995 [1].



The metropolitan region of Perth has a population of 1.9 million and as shown above a density of 12 per ha. It is not the lowest density city in the world but its close. Density is a major issue in Perth so the paper uses Perth in many places to illustrate the myths and truths of density.

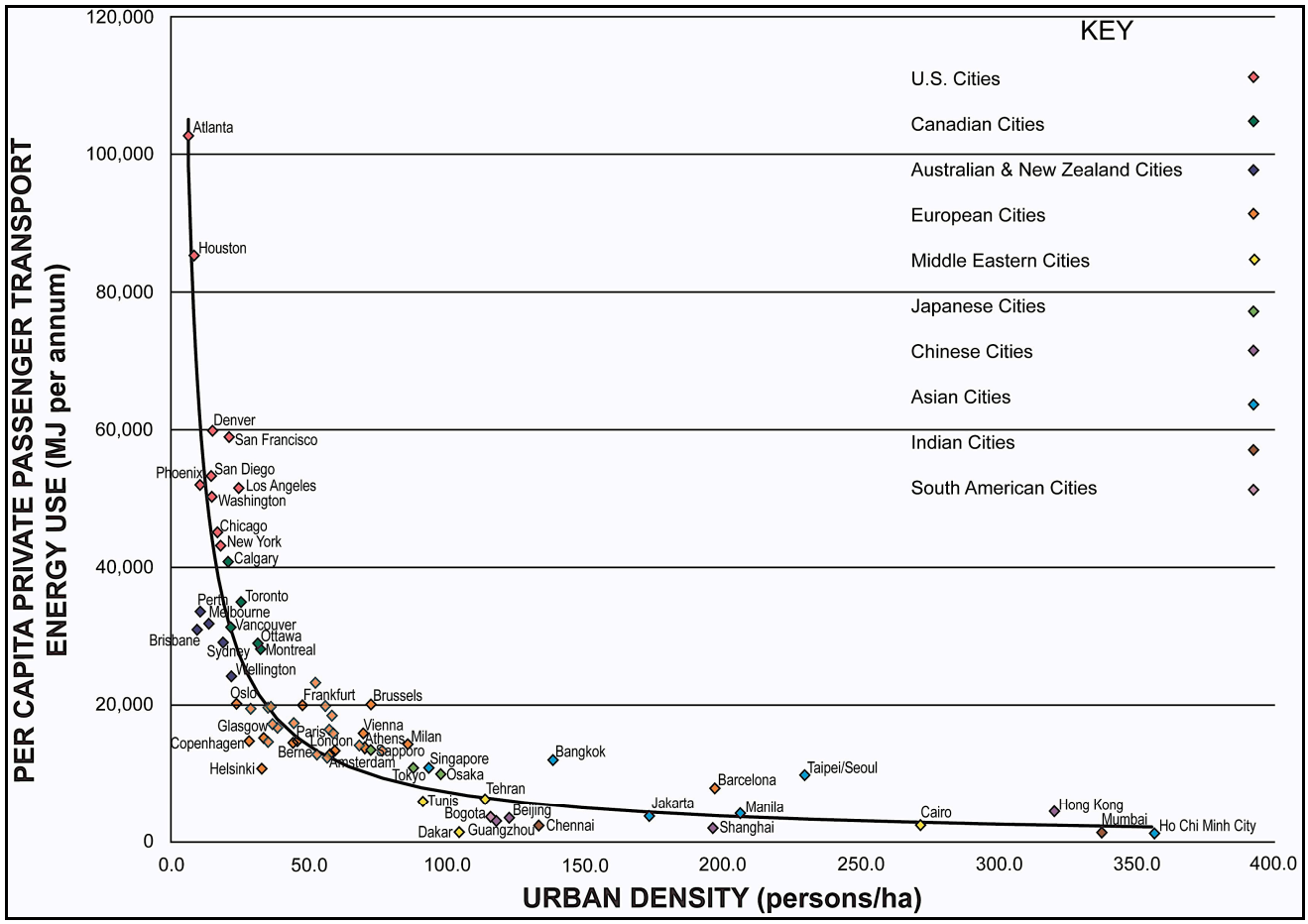
In Figure 2, the same cities are shown in terms of their transport fuel use, a critical variable in terms of sustainability with significant environmental, social and economic implications.

Figure 2. Private passenger transport energy use per person, 1995 [1].



The links between these two diagrams are obvious and so in Figure 3 the two are graphed against each other.

Figure 3. Per capita private passenger transport energy use and urban density in global cities [1].



The exponential relationship between urban density and transport fuel per person in the world's cities can be seen to be very strong. This alone should make the case for density as a sustainability multiplier: for each step in increasing density there would appear to be an exponential reduction in transport fuel. The full details of this relationship have been examined in detail both between and within cities [2–4]; there are papers suggesting the relationship is not causal and is more likely to be related to income [5,6] but that is not apparent in Australian cities where the wealthy live closer to the city and the low density suburbs are increasingly poorer and more car dependent

The most important set of cities in terms of a need for density increases is the highly automobile dependent cities of North America, Australia and New Zealand. However, there is a move to lower the density in all cities in Europe, Asia and Latin America as part of the need to accommodate different lifestyles. The reactions to density myths and truths are therefore of relevance to all cities, however the focus below tends to be on low density cities with a particular focus on Perth.

3. 10 Density Myths

The following section provides an overview of the most common myths regarding density.

3.1. Myth (1) High Density Housing is Bad for Your Health and Creates Social Problems

There is little evidence to suggest that health gets worse in dense housing. Most people in the world live in high density housing, though as shown above there are huge variations in density. There is no correlation between these levels of density and health. Health levels relate mostly to income [7–9]. Poverty is the biggest cause of ill health. Hong Kong has 300 people per ha—nearly 30 times Perth's density but has high life expectancy and low infant mortality like Perth. If industrial pollution is high then building densely within the air shed will increase respiratory issues [10] but this can be more effectively addressed directly within the industries, and if cities are sprawled to reduce exposure to pollutants it just increases the pollution due to cars.

There is little evidence social problems like crime are increased in high density areas. Crime is also mostly related to poverty [11–13]. In America, the higher the density the lower the crime rate though this is more than likely because low density cities are poorer [2]. There is some evidence that low density areas have greater obesity and depression due to less walkability and higher crime rates due to less "eyes on the street" [14–16].

Why is there such a myth about blocks of flats being bad for health and local neighbourhood security? Two reasons can be found:

(1) Because biologists suggested it was unnatural and did tests with rats and monkeys in overcrowded conditions showing how their social organisation collapsed [17,18]. None of this research seems to have been repeatable (*i.e.*, it was poorly done and others cannot see the same effects). When transferred to human conditions no evidence of density *causing* health and social problems can be found [19,20].

(2) Because from the industrial revolution cities there was a long held view that disease was spread through the air (via "miasma") and thus the early town planners in Britain sought to reduce densities to provide a "wholesome supply of good air" [21,22]. Disease was afterwards discovered to be caused mostly by water-borne germs but the myth continued. In the 1960s, poor people in the UK, Australia and America were put into high-rise public housing; the result was health problems and crime with high-rise being blamed. Now crime and health problems are higher in low density poor suburbs but we do not tend to blame the housing density.

3.2. Myth (2) High Density Housing will Lower Land Values and Create Slums

There is little evidence to support land values collapsing when higher density housing goes into an area. In most cities, land values are related to amenity—access to recreation sites, the ocean, good schools, to services like health and other employment opportunities and close to rail lines [23]. As people move to amenity areas the pressure to subdivide goes up. If zoning is increased then land values increase [24].

Even in the low density cities of America, the highest density areas like Manhattan, inner San Francisco or Washington DC, are in general, the highest value land. If anything there is a problem with density causing land values to go up so much that they cause poorer people to be displaced as they cannot pay the rates or rents become too high [25]. This gentrification is why a proportion of affordable housing is on the agenda for most planners dealing with the density issue.

3.3. Myth (3) Nobody Likes High Density Housing

There are many cultures who like dense, high-rise housing in Asia, Europe, and Latin America. There is a long tradition of living in close proximity for security and ease of access between friends and family [26]. The great cities of Europe are dense, especially in their core areas and are in great demand to live and visit. Whenever fast train or highway access is built to enable lower density fringe development then any city will begin to spread out [27] but that does not mean the general culture is anti-density. English traditional culture favours the village and rural spaciousness (in literature this is called "pastoralism"), especially after the industrial revolution with its dense, slum housing. There has however always been a more urban tradition in cities like London and Manchester with their amenity and attractions [28] and in the US from writers like Mumford, Jacobs and Gratz [29–31].

In Australia, many migrants from the UK were escaping the poverty of public housing and came seeking a suburban life. Housing markets in Australia and more dramatically in Perth in recent years, have increased in the proportion of households who favour location over housing type. *i.e.*, they choose high density because of its access to amenity [32,33]. Location has always meant a lot in cities.

Many people will want to remain in a low density house but they appreciate the benefits that higher density centres nearby can bring to their area including better transit, shops, childcare, and even aged housing options. As dense centres are built, the attitudes to them start to soften.

3.4. Myth (4) The High Density Problem is Caused by Population and this Should be Stopped or People Put in Country Towns

Population movements are mostly part of the global economy and few countries are trying to opt out of that like North Korea. Stopping participation in the global economy means that cities go into immediate economic decline. Some cities like Detroit in the US and Liverpool in the UK did not adapt to the changing global economy and so went into decline [34]. Few communities or politicians are going to accept economic decline as their policy for the future.

Perth, for example, is a boom town and its population growth is mostly caused by overseas immigration. Australia has always been a migrant country and the growth of the economy is linked to this flow of people from across the world who have followed the new jobs. Mostly, people come to Australia who have specific skills or business investments. Refugees are a small proportion and are part of International law obligations. Stopping people coming to Perth once in Australia is not legal. If the economy crashed then the population "problem" would be solved—it would transfer to somewhere else. Perth's economy is unlikely to be used as an immigration control device.

Some Australian migrant schemes require new arrivals to live in country towns. Some stay (e.g., Katanning has a multicultural mix of workers) but most move to cities like Perth where the economic opportunities, educational opportunities and health opportunities are greater. Country towns in Australia are mostly in decline and few policies have worked to reverse this decline [35]. Government incentives in terms of country town housing, grants, *etc.* have never changed Perth's overall growth. When Western Australia grows it is because Perth is growing.

3.5. Myth (5) High Density Housing Removes Trees, Places for Children to Play and Opportunities to Grow Food and Collect Rainwater

The new world cities that were built with the car after World War 2 had large allotments. Australian suburb allotment size of a ¼ acre or 1000 m^2 was a substantial area designed to cope with a septic tank's overflow, to have a rainwater tank, hopefully a vegetable garden, some trees and plenty of grass for children to play on—and of course, a large garage for several cars. This lifestyle was heavily subsidized in the post war years for returned service men and continues to be subsidized as it provides for the unique "Australian lifestyle" [36].

However, like all new world cities, Australian cities now have sewerage systems and good water supplies and the size of the houses have slowly grown so they are now four times bigger than houses in the 1960s, while the block size has reduced to around the 400 m^2 mark. Still, the campaign rhetoric of save our suburbs groups is to maintain the low density suburb as though they remained unchanged since the 1950s [37,38].

Every decade of housing reaches a point where redevelopment is necessary. The model that seems most acceptable to low density-dominated local planning systems in the US and Australia is to allow backyard infill with several small units [39]. In this way all the trees, grass and vegetable patches are replaced with brick houses, bitumen and brick pavers. Apparently, this is acceptable because it is not high rise. However, it adds very little to an area because there are no infrastructure changes or service improvements.

High-rises which enable better infrastructure and services and which can incorporate space for trees, play areas, intensive landscaping like biophilic green walls and roofs and even intensive food gardens with water collection and recycling are for some reason not acceptable [40,41].

3.6. Myth (6) High Density Housing Consumes More Energy and Produces More Greenhouse Gas

The recent arguments against high-rise housing are suggesting that these building types are dangerous to the future of the planet as they consume more energy and produce more greenhouse gases than single detached low density housing [42,43]. This is not true based on first principles of architectural design and in the scientific evaluations that are happening.

The argument depends on high-rise housing having large energy consuming areas like public lift spaces, public parking and public common areas for spas and swimming pools. The data used to support this invariably include buildings with the high energy consuming areas (mostly very wealthy) compared to the whole low density housing stock which mostly do not have such facilities as spas and swimming pools [44]. This is wrong scientifically [45,46].

The history of architecture shows that one of the key reasons for compact houses was to share walls to conserve energy for heating and cooling [47,48]. Thus, most evidence comparing high and low density housing (using similar wealth levels) shows that high density consumes less energy as heating and cooling are the biggest factors [49,50]. Commercial buildings do tend to use more air conditioning in large high rises due to the deep building spaces but there is almost no objections made to commercial high rise, just residential, for some reason.

The biggest difference between housing types is in their associated transport energy. Here, the main factor is location and in Australian cities this is easily measured by how far from the CBD the housing is [51–53]. Central/inner denser housing is between four and 10 times less transport energy consuming than low density outer/fringe suburbs [1,51–53]. There may be a congestion increase from density increases but only if the opportunities for more walking, cycling or transit are not enabled [1,54]. Energy increases due to congestion are much smaller than locational factors [55].

High density housing is attracted to areas closer in and hence most high density housing is not only lower in its building energy, it is much lower in its transport energy. As fuel and electricity prices rise, this energy factor will continue to be a major reason why high-rise housing will be needed in increasing amounts, especially if well located [56,57].

3.7. Myth (7) High Density Housing is Not Necessary as Renewable Energy and Electric Vehicles will Mean we can Drive as Much as we Like

This is also a new argument by those who concede that high density can indeed save energy, but perhaps they say this will not be needed as renewables and electric vehicles will mean we can have fossil fuel-free cities and low density.

Even with renewables and electric vehicles in our cities they are still car dependent with rapidly growing suburbs. By 2050 when the world needs to have removed 80% of fossil fuels, there will still be huge areas of American and Australian cities with low density car-dependent suburbs. To be truly sustainable, these areas will need to have totally converted to renewables and electric vehicles.

There is a bigger problem: traffic. Automobile dependent city roads are already full. It is not sensible to imagine traffic increase based on electric vehicles rather than reducing the need to use a car. This will happen if high density well-located housing redevelopment is provided around rail stations and inner/middle suburban areas with good access [58].

Future cities will need renewables, electric vehicles and transit oriented high-rise—as fast as possible [59].

3.8. Myth (8) High Density Housing Development is Destroying the Heritage Buildings of Our Suburbs

In every era of urban development there are buildings we want to keep as they are beautiful, full of history and with sensitive restoration they can be given a new life. Most cities conserve their heritage as a part of their redevelopment. However, most urban redevelopment is in newly created spaces based on redundant industries or warehouses and considerable opportunities exist for adding new houses into under-utilized urban space.

The most creative cities can do restoration and redevelopment that enables a city's economic and social life to grow [60,61]. Perth's inner areas are mostly good examples of redevelopment and Fremantle has almost doubled its housing stock while restoring its heritage.

The biggest issue facing American and Australian cities is the lack of creative higher density opportunities being enabled in other than the old brownfield sites [39]. There are many more opportunities for redevelopment in inner and middle suburbs but most housing redevelopment is either simple, dysfunctional low density infill of back yards or very wealthy high-rises. Car-based cities need to hold on to their quality heritage but add considerably more affordable high-rise housing in inner and

middle suburbs [39]. Heritage housing restoration and high density redevelopment are not incompatible—they are both needed.

3.9. Myth (9) High Density Housing Redevelopment is Wasting the Materials and Embedded Energy in Suburban Housing

When housing life is near its end the question becomes whether it should be redeveloped as part of high-rise housing or restored as a low density heritage house. The extra argument that is now being presented to stop the high-rise option is that the planet will benefit from not wasting the materials and embedded energy in a house [42,43].

The answer is that any building's materials can be recycled and thus, save most of its embedded energy. There are many ways of re-using building materials. Even a timber and asbestos house can be redeveloped (as was detailed in [62]); the building was recycled as a prefab home after the asbestos was removed.

New high-rise housing can use much lower embedded energy and low-carbon/low cost wall and roof materials, especially if constructed by off-site manufacturing (OSM) and simply joined together on site. An assessment of the reductions in embedded energy, basic raw materials and waste saved in Perth shows the huge potential for savings in basic raw materials with redevelopment using OSM, compared to business as usual (BAU) urban development on the fringe (15T using OSM compared to the 288T per person for BAU) [63].

High-rise housing is a major part of the planetary resource solution, not part of the problem.

3.10. Myth (10) High Density Housing is Not Good for the Economy

A range of markets drives the economy and it is true that much of the housing market in automobile dependent cities has become oriented to the low density project house market on the urban fringe [64,65]. However, the new high density housing market is rapidly growing and many firms are adapting to these new opportunities [33,66].

In terms of the economy, there are many benefits in this high-rise market compared to the low density urban fringe market (see Table 1 summary):

(1) Urban fringe housing is subsidized by State and Local governments. In Australia, this is around $100,000 per dwelling [51,67]. Similar data are found in American cities [68,69]. In Perth, this means $45.4 billion in the next 30 years unless redevelopment happens on appropriate sites in inner and middle suburbs [70].

(2) Urban fringe housing costs the economy hugely in extra transport costs due to the extra car travel. In Australian cities, each dwelling built on the fringe involves an additional $250 k over the lifetime of the house in travel cost. In the next 30 years, this will cost Perth $133.6 billion just in time lost to travelling. Denser cities have 5%–8% of their GDP spent on transport, low density cities have 12%–15% of their GDP spent on transport [1].

(3) Walkable high density areas have improved health due to greater walkability and improved productivity outcomes due to greater attentiveness and less days lost.

(4) Much more of the revenue from its residents is spent locally on personal services such as restaurants, childcare and entertainment rather than on cars and housing DIY, which invariably go out of the local economy.

Table 1 taken from [51–53] describes the benefits of redevelopment at higher densities over urban fringe development in Perth, expected over the next 30 years of anticipated development. It should be noted that the infrastructure savings the table describes are in fact up-front costs and other savings represent operational costs over 50 years at present values.

Table 1. Benefits of redevelopment at higher densities over urban fringe development in Perth [51–53].

Benefits of Redevelopment in Denser Centers of Low Density Fringe Development	
Infrastructure Subsidy Savings	$45,434 m
Transport Cost Savings	$133,610 m
Greenhouse Cost Savings	$13,254 m
Health Cost Savings	$2,285 m
Productivity Benefits	$18,333 m
Total Savings Due to Density	$212,916 m

High density housing will improve the economy of any low density city. In Perth, this would amount to AU $212.9 billion of savings over the next 30 years of urban development.

4. Ten Density Truths

The ten truths about density are the positive dimensions of density, the opportunities that it creates that can enable all dimensions of sustainability to be met.

4.1. Truth (1) High Density Housing Provides the Opportunity to Use Population Growth as the Way to Create New and Exciting Housing Options Rather than Continuing Urban Sprawl

Population growth is not a bad thing if its growth imperative is used to generate more sustainable cities [71]. Every city needs to see its growth plan as an opportunity to create a better city—one that has reduced footprint and a better liveability. If low density sprawl characterises the development it will simply be a wasted opportunity.

If continuing low density housing patterns are enabled in Perth then by 2050 the urban region will be over 271 km long, stretching from Myalup to Lancelin (See Figure 6). However, if new high density precincts, urban villages, are created that have a significantly higher range of opportunities, then significant gains in sustainability can be made.

The opportunities in high density urban villages should be taken to provide:

- better locations close to urban amenity,
- walkable urban design,
- affordable housing as well as top end apartments,
- aged peoples' housing with universal access features, and
- views.

As well, the opportunity can be provided for innovative developers and local councils to pursue eco-precincts or eco-villages with many sustainability features such as:

- renewable energy,
- co-generation,
- automated waste collection,
- greywater recycling,
- biophilic urbanism, and
- low embedded energy construction materials.

Though solar cells and ground sources for renewables do need extra space than is often available in high rise development [72] most of these work better in higher density precincts [45].

4.2. Truth (2) High Density Housing Provides Architectural Diversity Opportunities in an Urban Townscape

The market for well-located high rise living is now proven and growing based on people's desire to get out of traffic, long commutes and the heavy financial burden of car dependence [33,73,74]. Fuel prices are likely to keep rising bringing more opportunities for high density redevelopment [58,75].

However, increasingly the high-rise market is seen as preferable because of the culture of urbanism: living near amenity is better than having to drive there. Younger people are not buying cars and need more housing opportunities that support this choice [76]. Older people who want to downsize and not drive need to be supported in this choice as well. People from more urban cultures and backgrounds need support with dense urbanism choices [77,78].

The pressure for density should be taken to enable a greater diversity of architectural forms. There are many ways of doing density. Glass or masonry boxes will not any longer satisfy architectural tastes and will be just as boring as the endless "little boxes" of much low density suburbia [79–81]. The benefits of new materials and high density off-site manufacture is that interesting shaped buildings can be created [82].

4.3. Truth (3) High Density Housing Contributes to Solving the Big Problems of Oil Vulnerability and Climate Change

Large sprawling low density cities like Perth are not sustainable. They use transport fuel two to three times as much as medium density European cities and five to ten times as much as high density Asian cities of similar levels of wealth (see Figures 1–3 above).

The shared walls of high density housing generally means lower energy in the home as well as in transport. New technology in lighting, appliances, construction materials and design can also be very low carbon [83].

The irrevocable global trend is to move to a world where low fuel, low carbon cities, are the norm. This will mean that the economic benefits of being part of low carbon, low cost housing will grow as fuel and power based on oil and coal will be phased out. New high density precincts that allow such low carbon opportunities will be increasingly needed and are likely to be the dominant market in years to come.

4.4. Truth (4) High Density Housing is the Only Way to Provide Affordable Housing in Good Locations that Enable Affordable Living

Affordable housing can be built by going out (to cheap land) or going up (to enable the unit price of a development to be lowered.) However, only high density can provide both cheap housing (if sufficient density is allowed) and the location that can enable cheaper living due to lower transport costs.

Like many automobile dependent cities, Perth is becoming highly unaffordable [74]. Well located housing is now extremely costly because the provision of high density affordable housing in these areas is not allowed. In new suburbs on the fringe, families are purchasing cheaper homes but have to pay larger and larger transport costs. The average annual cost of car-based transport in outer suburbs is now more than a mortgage [84]. Wealthy inner suburbs have around half the car ownership of poor outer suburbs and the wealthy, in well located inner areas, have much greater use of public transport, cycling and walking than in poorer areas [84]. More high density affordable housing in well located areas is an important priority for cities like Perth. If present trends continue, the city will be highly divided into "eco-enclaves surrounded by mad max suburbs" [58].

4.5. Truth (5) High Density Housing is Necessary to Enable New Distributed Small-Scale Green Technologies

There is an emerging new model for how the footprint of cities can be dramatically reduced which I have called the Urban Sustainability model [71]. It consists of new urban infrastructure, new urban form and new urban management and is based around neighbourhoods or precincts.

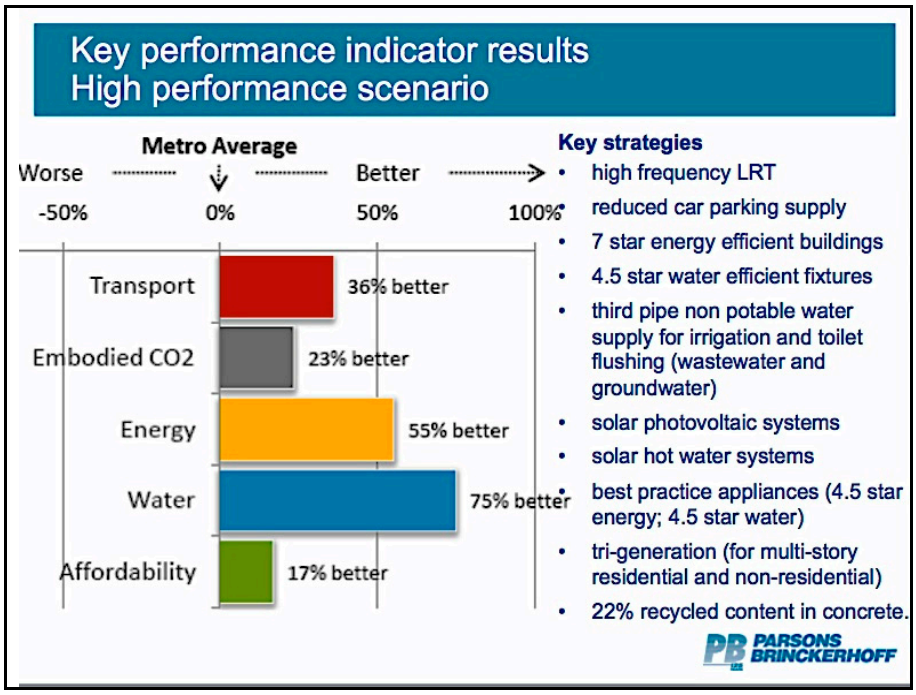
The kind of infrastructure required will enable significant reductions in fossil fuels, water, other materials and waste (thus reducing the footprint) whilst enabling cost-effective urban areas that are better places to live. The technologies to achieve this are set out in [85] and some are listed in Figure 4 below.

The kind of solutions to producing this set of outcomes can now be modelled in the design process using such sophisticated models as CCapCity produced by Kinesis, building on work done by Landcom in NSW [45]. In a recent study of the Cockburn Coast for Land Corp in Perth, we used the model to determine the best footprint reductions for the least cost. The results are set out in Figure 4 below. The list of infrastructure provided is set out on the side of the figure and the result was a cost of just $5600 per dwelling. The rapid growth and deployment of these technologies in the future will continue to reduce this already very low cost.

The need to adopt the new urban infrastructure of decentralised energy, water and waste systems is rapidly becoming mainstream policy [86]. The massive gains in decarbonising a city in a short period of time are appealing to urban policy makers across the globe.

However, they really only work when sufficient density is available and in the case above it required medium to high density buildings to make sufficient quantity for the infrastructure to work. Normal low density suburbs would not work with such infrastructure. Different management will be required also as local governance of the infrastructure is needed [87].

Figure 4. Precinct scale urban redevelopment and outcomes of new technology infrastructure [85].



4.6. Truth (6) High Density Housing Creates Opportunities for More Community and Creativity

After studying all the evidence on density and social impacts, Freedman [87] concluded that "crowding is not generally negative and it does intensify human reactions to other people." It stimulates human interaction which means the human effects of density are up to us. Higher density can produce negative effects if we do not design it well to encourage good human interaction, but it can also make beautiful and human cities.

There are cases where the dark side of human interaction has been enabled, perhaps through poor public-housing where people with social problems were concentrated. However, at the same time the most creative cities with intense human community are usually the densest places. Manhattan has both Harlem and Greenwich Village, London has both Brixton and Chelsea, Sydney has both Redfern and Paddington. Indeed, in these cases the regeneration of Harlem, Brixton, and Redfern has happened rapidly in recent years making highly desirable, trendy locations, especially for creative people. Most planners and housing providers now stress the need for mixed housing/mixed incomes/mixed cultures as well as good urban design in shared spaces that facilitates face-to-face interactions [88,89].

There is also substantial evidence that having good governance, good management systems in high-rise, can avoid social problems and create many opportunities for the growth of community [79,90].

4.7. Truth (7) High Density Housing Creates Better Economic Outcomes through Agglomeration Economics, Local Economic Benefits, Reduced Avoidable Costs and Less External Costs

Some high density housing is costly to build due to a range of factors including extra labour and safety requirements as well as the inability to build densely enough to cover costs in expensive areas [66]. New technology, off-site manufacture of high-rise buildings is now showing how low cost, low carbon houses can be put together on-site in around one week. This saves local disruption as well as enabling high-quality designed housing to be highly competitive.

The wider economic benefits of high density housing are strongly demonstrated with:

- Agglomeration economies—Bringing more jobs together, bringing more people together in a city creates economic benefits due to greater face-to-face interactions, more sharing of skills and greater social capital [91]. This is a major reason why high value jobs are mostly available where there is high density urbanism.
- Local economic benefits—when money earned locally is spent locally creating many more jobs in restaurants, entertainment and other local services [92].
- Reduced avoidable costs—when money is saved on fringe suburban development through using established infrastructure, services and transport (see Myth 10).
- Less external costs—less traffic, less pollution, less climate change, less rural land loss, less biodiversity threats... All end up as an economic cost in some way [1].

4.8. Truth (8) High Density Housing Provides Greening Opportunities through Biophilic Urbanism

A new approach to building high-density housing is being pioneered in some cities like Singapore, Berlin, Toronto and Chicago where there is a commitment to providing more greening—not just between buildings but on them with green roofs, green walls and green balconies. These cities have introduced a Green Plot ratio where the footprint of the building is replaced by an equal amount of greening. In many cases, buildings have been able to replace three times their space with green roofs and walls. Singapore is moving from being a garden city to a city in a garden or even a forest [40,41,93].

Requiring urban greening to replace urban building space has so far only happened in high density areas with the extra height to enable multistorey gardens like a forest. The different dimension of height enables very different greening structures and habitats to be created, more like a forest than a grassland or steppe. The results are stunning and at least demonstrate that high density need not mean less green.

4.9. Truth (9) High Density Housing Provides Cultural and Economic Diversity Opportunities in an Urban Townscape

Most low density cities are known for particular cultural activity but due to the distances involved in bringing people together it is often much less intensive (as suggested by [94]). Thus, writers like Jacobs [30] have documented the more intense life of dense cities. Landry and Florida [89,95] have similarly examined the need for cities to come back in if they are to create more cultural diversity and creativity. Creativity is now the basis of many new business opportunities in cities [96].

Perth was labelled "Dullsville" in the past as it was mostly a CBD surrounded by low density suburbs. In the past 20 years, there has been a dramatic shift in the city center as 30,000 extra people have moved into high density housing, mostly to the Eastern end of the city. Together with the new electric train (or perhaps because of it for some) the city center has become less and less built for cars and more and more built for people. It is no longer "Dullsville".

There has been some high density housing also built in inner suburbs like South Perth, Northbridge, East Perth and Subiaco. However, places in Perth like Fremantle, Cottesloe, Nedlands and Scarborough have actively prevented high density from happening. These local authorities have zoned it out. The decline that sets in when this happens is clear evidence that density must be taken much more seriously; the decline of Fremantle and its turn around to accepting higher density has been documented in film by Blagg [97].

Low density cities that do not see the benefits in density are likely to begin to decline culturally and economically.

4.10. Truth (10) High Density Housing Provides the Best Opportunities to Build Connected City Fabric, without Car Dependence, Especially with Urban Rail

Sustainable transport options such as trains, buses, bicycles and even car sharing, need density to work properly. Trains work best when there are dense centers being linked together like pearls on a string. Buses, bikes and walking are much slower than cars and trains. They will only be used if distances are short otherwise the time lost in transport is just too great and people will switch to a car. Density shortens distances, especially when well located.

Walking and cycling cannot be useful options in a city if distances beyond a few kilometres for walking or 5–10 km for cycling are needed. Thus, to enable more sustainable walkable environments you must have higher densities. The numbers have been scientifically assessed at 100,000 people and jobs within a 1 km radius for a center to be mostly walkable, and 10,000 people and jobs within a 1 km radius if it is to be a viable transit oriented sub center or station area [7].

The Northern and Southern rail lines in Perth are now attracting denser development to their station precincts, as more people want to live or work near this fast, quality transport option [98]. To stop this density increase or to slow it down simply means more people will use a car instead of the train. If a city is just made up of low density sprawl it is inherently car dependent.

The best way to reduce car dependence is to create focused density in centers linked by quality transport, especially rail. Figure 5 below sets out a vision for redevelopment of the Perth region using just transit oriented developments around new and old rail stations [68].

Density increases of 5–8 storeys have been designed into each of the TOD areas and it has been found possible to fit enough residences and jobs for the next 30 years of urban growth into an area of 15 km radius around the city center. This compares with Figure 6 below which shows that Perth stretches 271 km north and south based on low density growth.

Figure 5. A visualization of a regional transit oriented development (TOD) approach in Perth [99].

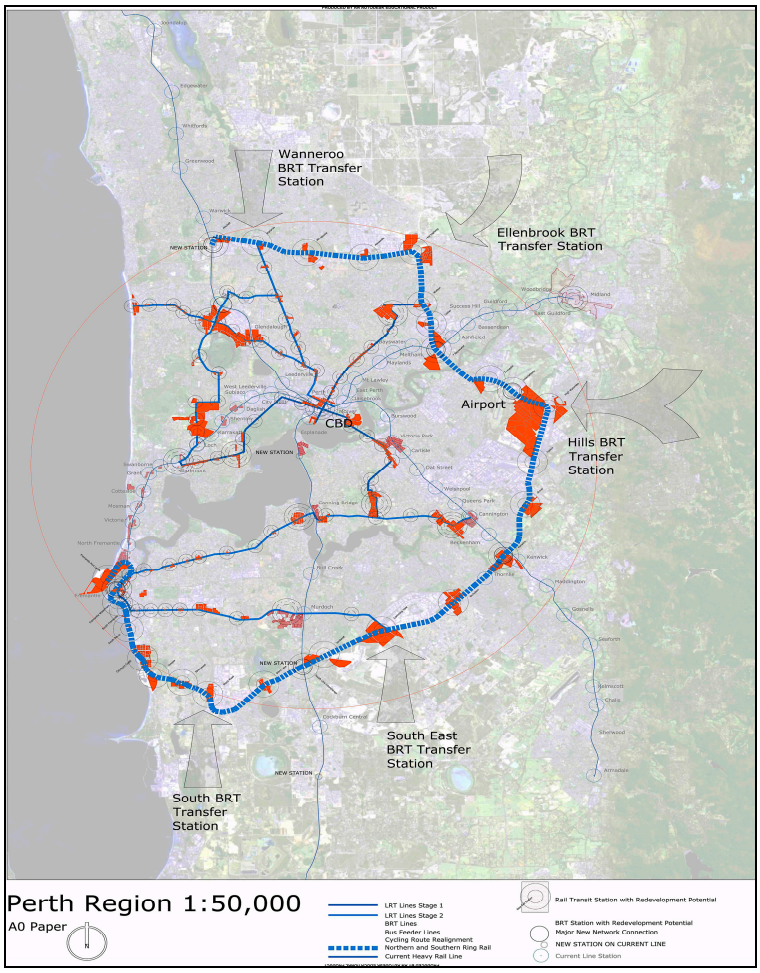
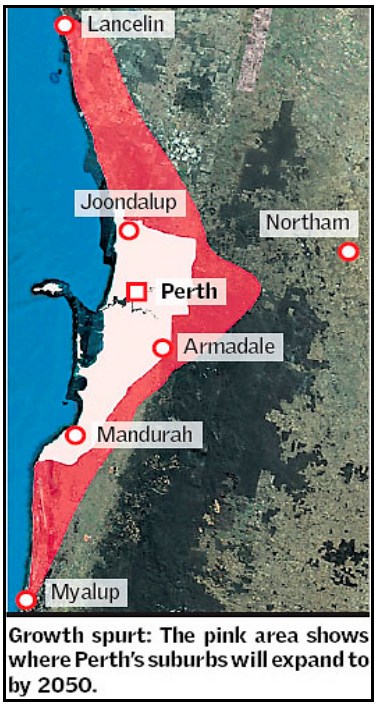


Figure 6. Perth's predicted north-south expansion to 2050 based on current low density development patterns [99].



The result in transport terms, for the vision in Figure 5, is that transit patronage triples and other sustainable transport modes increase substantially. Car use per capita will reduce by about 50%. The other data on the cost savings in this strategy are set out in Table 1.

The vision shows how a city could be significantly reduced in its footprint and be substantially improved in its livability at the same time. Density, oriented around quality transit, is the multiplier for these sustainability gains.

5. Conclusions

The 10 myths and 10 truths about density have been applied with data and qualitative understandings to a low density car dependent city, illustrated here by Perth. The evidence is powerful but so are the forces that want to stop density at all costs. The myths and truths are hopefully able to address some of these issues that cause such fear of change towards higher density.

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Conflicts of Interest

The author declares no conflict of interest.

References

1. Kenworthy, J.; Laube, F.; Newman, P.; Barter, P.; Raad, T.; Poboon, C.; Guia, B. *An International Sourcebook of Automobile Dependence in Cities 1960–1990*; University Press of Colarado: Boulder, CO, USA, 1999.
2. Newman, P.W.G.; Kenworthy, J.R. *Cities and Automobile Dependence: An International Sourcebook*; Gower: Aldershot, UK, 1989.
3. Newman, P.; Kenworthy, J.; Vintila, P. Can we Overcome Automobile Dependence? Physical Planning in the Age of urban Cynicism. *Cities* **1995**, *12*, 53–65.
4. Newman, P.W.G.; Kenworthy, J.R. *Sustainability and Cities: Overcoming Automobile Dependence*; Island Press: Washington, DC, USA, 1999.
5. Gordon, I. Densities, Urban Form and Travel Behaviour. *Town Country Plan.* **1997**, *66*, 239–241.
6. Gordon, I. Density and the Built Environment. *Energ. Policy* **2008**, *36*, 4652–4656.
7. Newman, P.W.G.; Kenworthy, J.R. Urban Design and Automobile Dependence: How much development will make urban centres viable? *Opolis* **2006**, *2*, 35–52.
8. Eckersley, R. *The Social Origins of Health and Well Being*; Dickson, J., Douglas, B., Eds.; Cambridge University Press: Cambridge, UK, 2005.
9. Marmot, M.; Wilkinson, R.G. *Social Determinants of Health*; Oxford University Press: Oxford, UK, 2006.
10. Schweitzer, L.; Zhou, J. Neighbourhood Air Quality, Respitory Health and Vaulnerable Populations in Compact and Sprawled Regions. *J. Am. Plan. Assoc.* **2010**, *76*, 363–371.
11. Kelly, M. Inequality and Crime. *Rev. Econ. Stat.* **2000**, *82*, 530–539.

12. Knox, P. Regional inequality and the welfare state: Convergence and divergence in levels of living in the United Kingdom 1951–1971. *Soc. Indic. Res.* **1982**, *10*, 319–335.
13. Fischer, C.S. *The Urban Experience*; Harcourt Brace Jovanovich: New York, NY, USA, 1976.
14. Frumkin, H.; Frank, L.; Jackson, R.J. *Urban Sprawl and Public Health*; Island Press: Washington, DC, USA, 2004.
15. Haigh, Y. *Promoting Safer Communities through Physical Design*, *Social inclusion and Crime Prevention through Environmental Design: A Developmental Study*; Centre for Social and Community Research, Murdoch University: Perth, Australia, 2006.
16. Newman, P.; Matan, A. Human health and Human Mobility. *Curr. Opin. Environ. Sustain.* **2012**, *4*, 420–426.
17. Lorenz, K. *On Aggression*; Methuen Publishing: York, UK, 1966.
18. Morris, D. *The Naked Ape*; Dell: New York, NY, USA, 1968.
19. Baldassare, M. *Residential Crowding in Urban America*; University of California Press: Berkeley, CA, USA, 1979.
20. Wilson, P. *Public Housing for Australia*; UQ Press: Brisbane, Australia, 1976.
21. Jefferson, M. The Anthropography of Some Great Cities: A Study in Distribution of Population. *Am. Geogr. Soc.* **1909**, *41*, 537–566.
22. King, A.D. Exporting Planning: The colonial and neo colonial experience. *Urban. Past Present* **1978**, *5*, 12–22.
23. Newman, P.; Matan, A.; McIntosh, J. *Urban Transport and Sustainable Development: Routledge International Handbook on Sustainable Development*; Routledge: London, UK, 2014.
24. McDonald, J.F.; McMillen, D.P. *Urban Economics and Real Estate Theory and Policy*, 2nd ed.; Wiley: Hoboken, NJ, USA, 2007.
25. Sassen, S. *Cities in a World Economy*, 1st ed.; Sage: New York, NY, USA, 1994.
26. Newman, P.; Hogan, T. A review of urban density models: Towards a resolution of conflict between populace and planner. *Hum. Ecol.* **1981**, *9*, 269–303.
27. Portas, N.; López de Lucio, R.; Pellicer, F.; Sánchez, J.E.; Monclús, J.; Dematteis, G.; Rueda, O.N.-L.S.; Domingues, A. *La Ciudad Dispersa: Suburbanización y Nuevas Periferias*; Centre de Cultura Contemporània de Darcelona (CCCB): Barcelona, Spain, 1998.
28. Williams, R. *The Country and the City*; Hogarth Press: London, UK, 1985.
29. Mumford, L. *The Culture of Cities*; Secker and Warburg: London, UK, 1938.
30. Jacobs, J. *The Death and Life of Great American Cities*; Vintage: New York, NY, USA, 1961.
31. Gratz, R.B. *The Living City: How Urban Residents are Revitalizing American Neighbourhood and Downtown Shopping Districts by Thinking Small in a Big Way*, 1st ed.; Simon & Schuster: New York, NY, USA, 1989.
32. Kelly, J.-F.; Hunter, J.; Harrison, C.; Donegan, P. *Renovating Housing Policy: Report*; Grattan Institute: Melbourne, Australia, 2013.
33. Government of Western Australia. *The Housing We'd Choose: A study for Perth and Peel: Report May 2013*; Department of Housing & Department of Planning: Perth, Australia, 2013.
34. Newman, P. Lessons from Liverpool. *Plan. Adm.* **1986**, *1*, 32–42.
35. Newman, P. The city and the bush- partnerships to reverse the population decline in Australia's Wheatbelt. *Aust. J. Agric. Res.* **2005**, *56*, 527–535.

36. Gleeson, B. *Australian Heartlands: Making Space for Hope in the Suburbs*; Allen and Unwin: Sydney, Australia, 2006.
37. Recsei, T. Pipe Dreams: The Shortcomings of Ideologically based Planning. *People Place* **2005**, *13*, 68–81.
38. Newman, P. Pipe dreams and Ideologues: Values and Planning. *People Place* **2005**, *13*, 41–53.
39. Newton, P.; Newman, P.; Glackin, S.; Trubka, R. Greening the Greyfields Unlocking the Development Potential of Middle Suburbs in Australian Cities. *World Acad. Sci. Eng. Technol.* **2012**, *71*, 138–157.
40. Newman, P. Biophilic Urbanism: A Case Study of Singapore. *Aust. Plan.* **2014**, *1*, 47–65.
41. Newman, P.; Matan, A. *Green Urbanism in Asia*; World Scientific Publishing Company: Singapore, Singapore, 2012.
42. Troy, P.; Halloway, D.; Pullen, S.; Bunker, R. Embodied and Operational Energy Consumption in the City. *Urban Policy Res.* **2003**, *21*, 9–44.
43. Low, N.; Gleeson, B.; Green, R.; Radović, D. *The Green City: Sustainable Homes Sustainable Suburbs*; University of New South Wales Press: Sydney, Australia, 2005.
44. Myors, P.; O'Leary, R.; Helstrom, R. Multi-unit residential building energy and peak demand study. *Energy News* **2005**, *23*, 113–116.
45. Beattie, C.; Newman, P. The Density trade-off: Does High Rise Construction contribute more than Single Dwellings to Greenhouse Gas Emissions? In Proceedings of the Fifth State of Australian Cities Conference, Melbourne, Australia, 29 November–2 December 2011.
46. Perkins, A.; Hamnett, S.; Pullen, S.; Zito, R.; Trebilcock, D. Transport Housing and Urban Form: The Life Cycle Energy Consumption and Emissions of City Centre Apartments Compared with Suburban Dwellings. *Urban Policy Res.* **2009**, *27*, 377–396.
47. Wilson, A.; Boehland, J. Small is beautiful—US house size, resource use, and the environment. *J. Ind. Ecol.* **2005**, *9*, 277–287.
48. Anderson, W.; Kanaroglou, P.; Miller, E. Urban form, energy and the environment: A review of the issues, evidence and policy. *Urban Stud.* **1996**, *33*, 7–35.
49. Breheny, M. *Sustainable Development and Urban Form*; Pion: London, UK, 1992.
50. Thormark, C. A low energy building in a life cycle—Its embodied energy, energy need for operatuion and recycling potential. *Build. Environ.* **2002**, *37*, 429–435.
51. Trubka, R.; Newman, P.; Bilsborough, D. Costs of Urban Sprawl (1)—Infrastructure and Transport. *Environ. Des. Guide* **2010**, *83*, 1–6.
52. Trubka, R.; Newman, P.; Bilsborough, D. Costs of Urban Sprawl (2)—Greenhouse Gases. *Environ. Des. Guide* **2010**, *84*, 1–16.
53. Trubka, R.; Newman, P.; Bilsborough, D. Costs of Urban Sprawl (3)—Physical Activity links to Healthcare Costs and Productivity. *Environ. Des. Guide* **2010**, *85*, 1–13.
54. Echenique, M.; Hargreaves, A.; Mitchell, G.; Namdeo, A. Growing Cities Sustainably: Does Urban Form Really Matter? *J. Am. Plan. Assoc.* **2012**, *78*, 121–137.
55. Newman, P.W.G.; Kenworthy, J.R. The transport energy trade-off: Fuel-efficient traffic *versus* fuel-efficient cities. *Trans. Res. A* **1988**, *22*, 163–174.
56. Curtis, C.; Renne, J.L.; Bertolini, L. *Transit Orientated Development: Making it Happen*; Ashgate Publishing Company: Surrey, UK, 2009.

57. Rodrigue, J.-P. *The Geography of Transport Systems*, 3rd ed.; Routledge: New York, NY, USA, 2013.
58. Newman, P.; Boyer, H.; Beatley, T. *Resilient Cities Responding to Peak Oil and Climate Change*; Island Press: Washington, DC, USA, 2009.
59. Newman, P. Imagining a Future without Oil in Car Dependant Cities and Regions. In *Transport without Oil*; Renne, J., Fields, B., Eds.; Island Press: Washington, DC, USA, 2013.
60. Florida, R. *Cities and the Creative Class*; Routledge: New York, NY, USA, 2005.
61. Baycan, T.; Girard, L.F.; Nijkamp, P. Chapter 1: Creative and Sustainable Cities: A New Perspective. In *Sustainable City and Creativity*; Baycan, T., Girard, L.F., Nijkamp, P., Eds.; Ashgate: Surrey, UK, 2012.
62. Josh's House. Available online: http://joshshouse.com.au/ (accessed on 5 May 2014).
63. Gardner, H.; Newman, P. *Reducing the Materials and Resource Intensity of the Built Form in the Perth and Peel Regions*: *Report*; Australian Government, Department of Sustainability, Environment, Water, Population and Communities: Perth, Australia, 2013.
64. Brueckner, J.K. Urban Sprawl: Diagnosis and Remedies. *Int. Reg. Sci. Rev.* **2000**, *23*, 160–171.
65. Ewing, R.H. Characteristics, Causes and Effects of Sprawl: A Literature Review. *Environ. Urban Stud.* **1994**, *21*, 1–15.
66. Rowley, S.; Phibbs, P. *Delivering Diverse and Affordable Housing on Infill Development Sites: Final Report*; Australian Housing and Urban Research Institute (AHURI): Melbourne, Australia, 2012.
67. Dowling, J.; Lucas, C. Suburban Sprawl Costs billions More. The Age Online Edition. Available online: http://www.theage.com.au/national/suburban-sprawl-costs-billions-more-20090716-dmxj.html (accessed on 5 May 2014).
68. Chatman, D.G.; Noland, R.B. Transit Service, Physical Agglomeration and Productivity in US Metropolitan Areas. *Urban Stud.* **2014**, *51*, 917–937.
69. Burchell, R.B.; Lowenstein, G.; Dolphin, W.R.; Downs, A.; Seskin, S.; Still, K.G.; Moore, T. *Transit Cooperative Research Program (TCIP) Costs of Sprawl-2000: TCIP Report 74*; National Academy Press: Washington, DC, USA, 2002.
70. Hendrigan, C.; Newman, P. *A Three Mode Plan for Perth: Connecting Heavy Rail*, *Light rail and Bus with Urban Development to Achieve 21st Century Goals: Report*; Curtin University Sustainability Policy (CUSP) Institute: Perth, Australia, 2012.
71. Newman, P. Sustaining our future: Resolving the conflict over population models. In Proceedings of the Nineteenth International Congress on Modelling and Simulation (MODSIM) Conference, Perth, Australia, 12–16 December 2011.
72. Mckay, D.J.C. *Sustainable Energy—Without the Hot Air*; UIT: Cambridge, UK, 2009.
73. Rowley, S.; Ong, R. *Housing Affordability*, *Housing Stress and Household Wellbeing in Australia: Final Report*; Australian Housing and Urban Research Institute (AHURI): Melbourne, Australia, 2012.
74. Committee for Perth (CFP). *The Rising Cost of Living in Perth: Report*; CFP: Perth, Australia, 2014.
75. Organisation for Economic Co-operation and Development (OECD). *Towards Green Growth*; OECD: Paris, France, 2011.

76. Davis, B.; Dutzik, T.; Baxandall, P. *Transportation and the New Generation: Why Young People Are Driving Less and What It Means for Transportation Policy: Report*; Frontier Group & U.S. PIRG Education Fund: San Francisco, CA, USA; Boston, MA, USA, 2012.
77. Sandercock, L.; Lyssiotis, P. *Cosmopolis II: Mongrel Cities in the 21st Century*; Continuum: London, UK, 2003.
78. Hass, T., Ed. *Sustainable Urbanism and Beyond: Rethinking Cities for the Future*; Rizzoli International Publications, Inc.: New York, NY, USA, 2012.
79. Gehl, J. *Cities for People*; Island Press: Washington, DC, USA, 2010.
80. Wells, W., Ed. *Blueprint for Greening Affordable Housing*; Island Press: Washington, DC, USA, 2007.
81. Katz, P., Ed. *The New Urbanism: Toward an Architecture of Community*; McGraw-Hill Inc.: New York, NY, USA, 1994.
82. Blismas, N., Ed. *Off-Site Manufacture in Australia: Current State and Future Directions: Report & Case Studies*; Cooperative Research Centre (CRC) for Construction Innovation, Icon. Net Pty Ltd.: Brisbane, Australia, 2007.
83. Beattie, C.; Bunning, J.; Stewart, J.; Newman, P.; Anda, M. Measuring Carbon for Urban Development Planning. *Int. J. Clim. Chang.* **2012**, *3*, 35–52.
84. Royal Automotive Club (RAC). *Vehicle Running Costs 2013 Guide*; RAC: Queensland, Australia, 2013.
85. Rauland, V.; Newman, P. Decarbonising Australian cities: A new model for creating low carbon, resilient cities. In Proceedings of the Nineteenth International Congress on Modelling and Simulation (MODSIM) Conference, Perth, Australia, 12–16 December 2011.
86. Bunning, J.; Beattie, C.; Rauland, V.; Newman, P. Low-Carbon Sustainable Precincts: An Australian Perspective. *Sustainability* **2013**, *5*, 2305–2326.
87. Freedman, J.L. *Crowding and Behaviour*; W.H. Freeman and Company: Oxford, UK, 1975.
88. Bay, J.H. Towards a Fourth Ecology: Social and Environmental Sustainability with Architecture and Urban Design. *J. Green Build.* **2011**, *5*, 176–197.
89. Landry, C. *The Creative City*, 2nd ed.; Earthscan: London, UK, 2008.
90. Conway, J.; Adams, B. The social effects of living off the ground. *Habitat Int.* **1977**, *2*, 595–614.
91. Glaeser, E.L.; Gottlieb, J.D. The Wealth of Cities: Agglomeration Economics and Spatial Equilibrium in the United States. *J. Econ. Lit.* **2009**, *47*, 983–1028.
92. Florida, R. *The Rise of the Creative Class: Revisited*; Basic Books: New York, NY, USA, 2012.
93. Beatley, T.; Newman, P. Biophilic Cities are Sustainable, Resilient Cities. *Sustainability* **2013**, *5*, 3328–3345.
94. Henderson, W.D. *The Unredeemed City: Reconstruction in Petersburg, Virginia: 1865–1874*; University Press of America: Lanham, MD, USA, 1977.
95. Florida, R. How and Why American Cities are Coming Back. *The Atlantic Cities Online Magazine*. Available online: http://www.theatlanticcities.com/jobs-and-economy/2012/05/how-and-why-american-cities-are-coming-back/2015/ (accessed on 5 May 2014).
96. Storper, M.; Scott, A.J. Rethinking human capital, creativity and urban growth. *J. Urban Geogr.* **2009**, *9*, 147–167.

97. Blagg, L. The Sustainable Revitalization of Fremantle, Vimeo. Available online: http://vimeo.Com/51896517 (accessed on 5 May 2014).
98. McIntosh, J.; Newman, P.; Glazebrook, G. Why Fast Trains Work: An Assessment of a Fast Regional Rail System in Perth Australia. *J. Transp. Technol.* **2013**, *3*, 37–47.
99. Weller, R. *Boomtown 2050*, 2nd ed.; UWA Publishing: Perth, Australia, 2009.