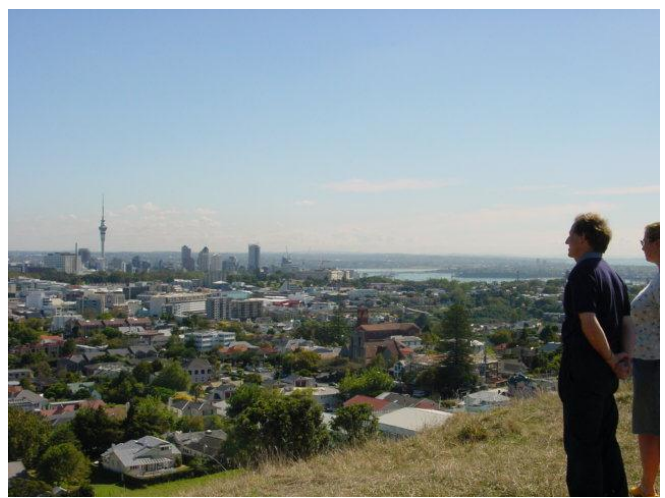


Auckland's Density

Introduction

The issue of Auckland's density is often raised in discussion about the city's development. Reference is made to studies of cities and their density. Is Auckland's urban density too low or too high in comparison?

On the one hand we have those who argue that Auckland is already relatively intensively settled and so doesn't need to become more compact. On the other hand others argue that Auckland is not densely settled enough to support a decent public transport system, and as a result any investment will be wasted. Housing affordability might be improved by a less densely settled city or it might be improved by more urban redevelopment.



I want to explore Auckland's urban density and the implications for its future planning. In this paper I set out data on Auckland's density, different ways of measuring it and how it compares to our neighbours. In a next paper I will explore what urban economics tells us about cities and their density before turning to what it all means for the future.

Is Auckland Already Too Dense?

This is not a dumb question and the answer is not simple. You might say that the answer to the question of whether Auckland is too dense is quite thick!

As a starting point, let's look at the often quoted Demographia World Urban Areas study¹. The data set out in Figure One below is taken from their 2013 report. Listed are New Zealand, Australian and Canadian cities with more than 300,000 people and their urban area density, as calculated by Demographia. The measurement of density is people per square kilometre.

I took Australian and Canadian cities as being broadly comparable in socio-economic terms to Auckland (although of course Australia and Canada have higher incomes than us, amongst other differences).

¹ Sourced on 12 December 2013 from: <http://www.demographia.com/db-worldua.pdf>

Figure 1: Density of NZ, Australian and Canadian cities

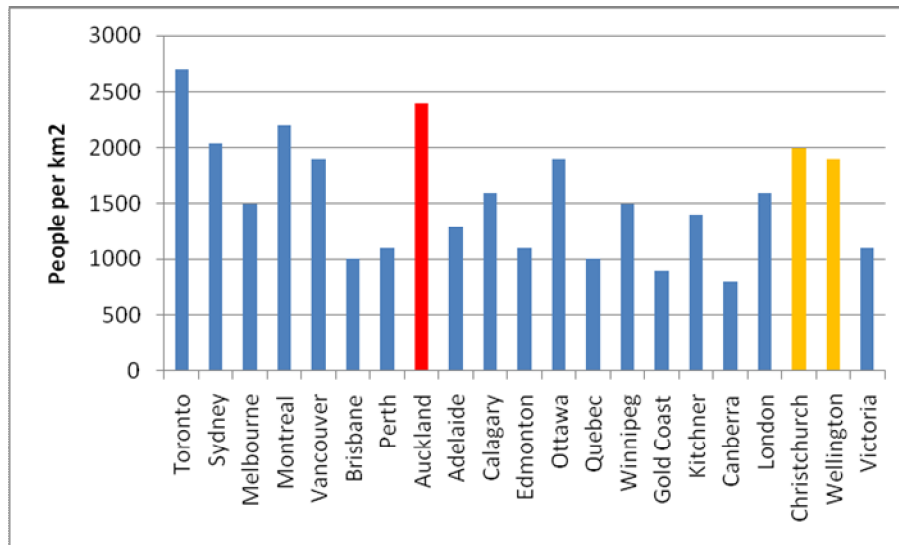


Figure One shows Auckland sticking out like a proverbial sore thumb. It is much more densely peopled than its similarly sized peers like Perth, Adelaide and Calgary. Whacky Auckland - something strange must be going on.

Notice, however, that Christchurch and Wellington are also more densely settled than cities of similar size. (Note: London is London, Ontario).

The fact that all kiwi cities seem to be more intensively developed is a clue that its not just Auckland that is different. Demographia figures show that even Hamilton (in New Zealand) has a population density of 2,200 people per square kilometre, higher than Sydney. Really?

Often a direct link is made between these densities and policies of urban containment. From this viewpoint, Auckland's high density relative to its peers is a result of artificially imposed growth management policies that restrict the outward spread of the city beyond what might be reasonable from an infrastructural management or natural environment protection stand point. What is left off this argument is that the same policies also restrict the upwards expansion of the city, but more about that later.

But does the density of the city just reflect the result of planning policies?

There are a wide range of influences on a cities density, not least of which is topography and lifestyle choices, as well as incomes and household types. Transport systems also play a big role. If transport

costs are high, then densities are likely to be relatively high too. The alternative of low transport costs usually sees cities spread out.

Before looking at Auckland's density in more detail, it is useful to first consider its context.

Firstly, Auckland lies on an Isthmus. Developable area is limited by harbours and hills. If Auckland sat in the middle of a flat plain, then there would be much more developable land within a given radius. For example, if we take a 20km radius around the centre of a city in the middle of a plain we get a land area of 1,256km². One million people spread over that area would equal 795 people per km². If that city sat on the coast and half of the radius was sea, then the land area is 628 m² and density rises to 1,590 people per km². In the case of Auckland, a 20km radius from the CBD results in a developable land area of around 470km².

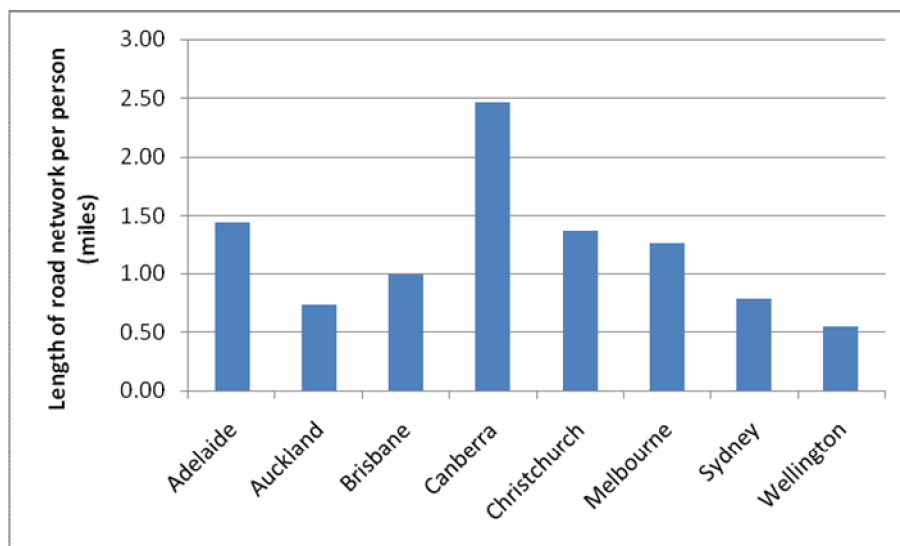
Topography squeezes Auckland up into a north-south shape. It's narrow shape increases transport costs. Auckland congestion is often said to be worse than other cities. A recent survey by Tom Tom² - using data from in car GPS systems - suggested that the average delay per hour driven in peak periods was 47 minutes in Auckland, compared to 28 minutes in Brisbane and 31 minutes in Perth. Is this the result of Auckland's density, or is Auckland's density a response to its higher transport costs, which in turn reflects its geography?

The Tom Tom survey of congestion levels in Australia and New Zealand cities contains information about total road network, as measured by Tom Tom. When you compare that network length with population³, then it's clear that Auckland has a more limited road network than comparable cities. See Figure Two.

² Sourced on 12 December 2013 from <http://www.tomtom.com/lib/doc/trafficindex/2013-1101%20TomTomTrafficIndex2013Q2AUNZ-mi.pdf>

³ It is not clear what part of the urban area the Tom Tom survey covers, and as a result what population figures to use. For example, for Christchurch I took the population for Christchurch City, not the wider urban area. Likewise for Wellington I used the figures for Wellington City and Lower Hutt, but not Porirua and Upper Hutt, as this seemed to better approximate with the area shown in the survey report.

Figure 2: Per capita road network length (as recorded by Tom Tom), for NZ and Australian cities



Now this is not a definitive measure of overall transport accessibility. It may be that other cities have wider roads, not just a longer network; or better public transport systems.

Here are the figures used to create the above graph.

Table 1: Road network length and city population

City	Road Network (miles)		Total network (miles)	2011 population	Length of road network per person
	Highways	Other roads			
Adelaide	373	1,301	1,674	1,161,668	1.44
Auckland	162	782	944	1,297,929	0.73
Brisbane	275	1,577	1,852	1,866,794	0.99
Canberra	96	767	863	350,917	2.46
Christchurch	54	413	467	341,000	1.37
Melbourne	718	4,099	4,817	3,832,366	1.26
Sydney	429	2,889	3,318	4,225,278	0.79
Wellington	40	119	159	289,000	0.55

These figures do not mean that Auckland is "under roaded" and it needs more roads. It may just mean that topography limits what we can fit in. When you compare Tom Tom's measure of congestion with the per capita length of road network then there looks like there is a relationship.

Auckland's congestion level is much the same as Sydney, for example, at 34% and 35% respectively⁴. Canberra has the least congestion at 28%. Wellington gets by with a 28% congestion level, despite having fewer roads per person but makes up for it by higher use of public transport.

So may be in the case of Auckland, topography limits transport options which sees higher transport costs which results in higher densities overall. Another explanation maybe that we have invested less in roading than other cities, and not enough in public transport. If it is lack of investment in transport infrastructure which pushes up costs, then we can still expect higher intensity of development than might otherwise be the case.

Finally, the fact that per capita incomes are much less in New Zealand than in Australia and Canada and that that may affect city density is not mentioned when the above Demographia density figures are quoted. Look at the figures in Table Two of per capita GDP.

Table 2 Per Capita GDP, 2011⁵

Country	Average city density (people per km2)	Per Capita GDP (2011 - \$US, current PPPs)
Australian	1,342.1	\$45,016
Canadian	1,931.9	\$41,559
New Zealand	2,216.1	\$32,898

This table suggests a relationship between incomes and density.

Do we just have less money to spend on housing, and therefore need to bunch up more than might otherwise be the case?. It is people density that is being measured after all. At 2013, the Auckland Region had 473,442 occupied dwellings for a population of 1,415,172, or 3 people per household. In 2011, greater Perth had 2.6 people per dwelling, Brisbane 2.7 people per dwelling. This means that for every 100 houses in the same land area, Auckland accommodates 15% more people. This doesn't explain all of the differences in population density between Perth, Brisbane and Auckland, but again is an example of many things influencing one number.

⁴ Tom Tom says that the percentage figure is the difference between travel times during peak and off-peak periods, based on their records of in-car use of GPS systems. It covers travel on local roads, arterials and highways.

⁵ <http://stats.oecd.org/index.aspx?queryid=558>

These are all points that I will return to later when we look at models that attempt to explain city density. The important point at this stage is that context is important.

Measuring City Density

Back to cities and their densities. Urban density can be calculated in a number of ways. Common is total population divided by urban area in square kilometres, as used above by Demographia. Sounds simple, but what is the urban area - is it the area actually built over, is it the administrative area, or is it a statistical area?

For example, the Auckland Council area is 5,600 km², Statistics NZ's Auckland Urban Area covers 1,100km², while the urbanised area is variously measured between 550 and 600 km².

Further complexity arises when looking at the urbanised area - is it just the area with houses, or is it houses, plus business areas and large open spaces?

Later on I raise some questions about the data on city area used in the Demographia study in comparison to other data on urbanised area. Of much more interest than city-wide measures of density is how density varies across the city. This tells us much more about urban patterns and how households make choices about locations.

Population weighted density is one way of gaining an indication of how density varies. This is based on how many people live at different densities. Take a simple city of 3 areas, each of 10ha, containing 50, 50 and 200 people. Simple urban density is $50+50+200 = 300$ people, divided by 30ha, which equals 10 people per ha. This average hides the fact that most people live at a higher density than this (200 people at 20 people per ha). Population weighted density first works out the percentage of people living in the three areas, then multiplies that figure by the density in each area. Table Three sets out the example.

Table 3 Population weighted density example

(1) Area	(2) Population	(3) Population weight	(4) Density of area (people per ha)	(5) Population weighted density column 3 times by column 4
A (10ha)	50	$50/300 = 16.6 \%$	5	$0.166*5=0.83$
B (10 ha)	50	$50/300 = 16.6\%$	5	$0.166*5=0.83$
C (10ha)	200	$200/300 = 66.6\%$	20	$.666*20=13.3$
Total (30ha)	300	99.8% say 100%	10	14.96, say 15

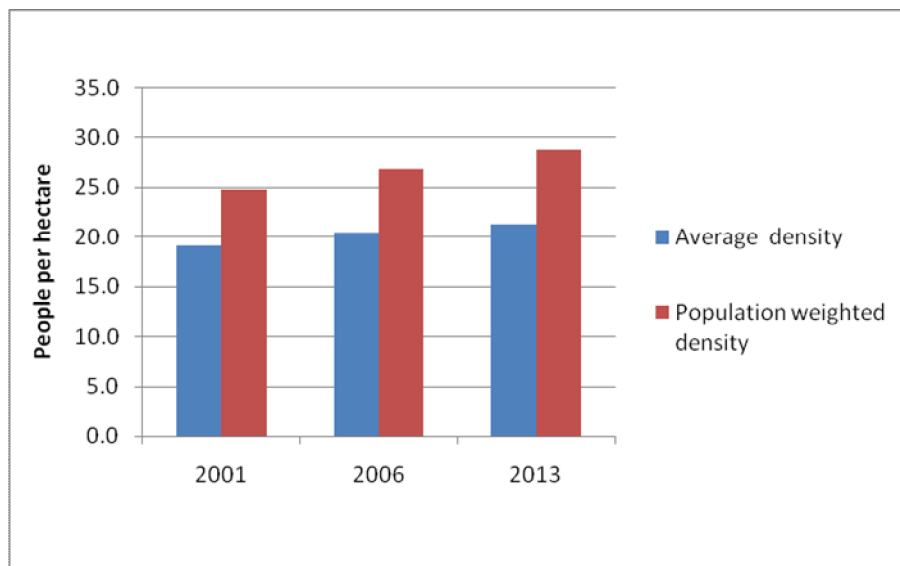
The difference between the simple, average density of a city and its population weighted density gives a clue as to how density is concentrated. In the above case, the average density of 10 people per hectare compares to a population weighted density of 15.

Auckland's Population Weighted Density

What then is Auckland's population weighted density and how does that compare with other cities?

Figure Three sets out Auckland's average and population weighted densities for 2001, 2006 and 2013, as calculated by me. It can be seen that in 2013, the city's population weighted density was just below 30 people per hectare compared to a simple, average density of just over 21 people per hectare.

Figure 3. Auckland urban area population weighted density



To calculate the numbers in Figure Three, I used census data for the usually resident population of Stats NZ Area Units in the Auckland Council area, while the area of land was based on the land area of these area units, in hectares.

The first thing to note is that the land area of the Area Units includes all land within them, whether this has housing on it, or is used for businesses or open spaces, or is used for roads. Therefore it is a gross measure of urban density. Actual net densities could be much higher.

To take account of the fact that the Auckland Council area spans large areas of rural land as well as urban land, I only counted population where the density of people was more than 3 people per ha.

This is quite a low cut off point between urban and rural, but was a point used in other studies, more of which soon.

Table Four sets out the data behind the graph.

Table 4 Calculation of Auckland's population weighted density

Element	2001	2006	2013	Change	% Change
Total population	1,159,860	1,304,580	1,415,172	255,312	22.0%
Population of Area Units > 3 people per ha	1,056,435	1,191,681	1,297,929	241,494	22.9%
Area of land (ha) of Area Units > 3 people per ha	55,269	58,329	61,219	5,950	10.8%
Average density (people per ha)	19.1	20.4	21.2	2.1	10.9%
Population weighted density (people per ha)	24.7	26.9	28.8	4.1	16.4%

Looking at Figure Three and Table Four, it is apparent that the city's population weighted density has been increasing faster than its average density. This suggests that density is becoming more uneven across the city, overtime, and some parts of the city are building up their density.

This is not unexpected. As cities grow in population size it can be anticipated that they will grow by spreading outwards as well as growing upwards. An important question for Auckland is what is the "natural rate" of expansion versus intensification. By natural, I mean unconstrained by zoning controls? Is Auckland's growth in population weighted density faster than it should be due to planning constraints like the Metropolitan Urban Limit Line, or is it slower than it should be because zones within that urban limit do not provide enough realistic capacity and redevelopment is being stifled?

Checking Out the Neighbours

Comparisons with other cities can help us to understand these issues, but will not necessarily provide a definitive answer.

Table Five sets out data on the population weighted density of the larger Australian state capitals, using the same approach as I have used for Auckland. I have inserted Auckland into the table.

I obtained the Australian data from: <http://chartingtransport.com/2013/11/05/are-australian-cities-becoming-denser/>.

Is the data reliable? I don't know for sure, but let's work with it.

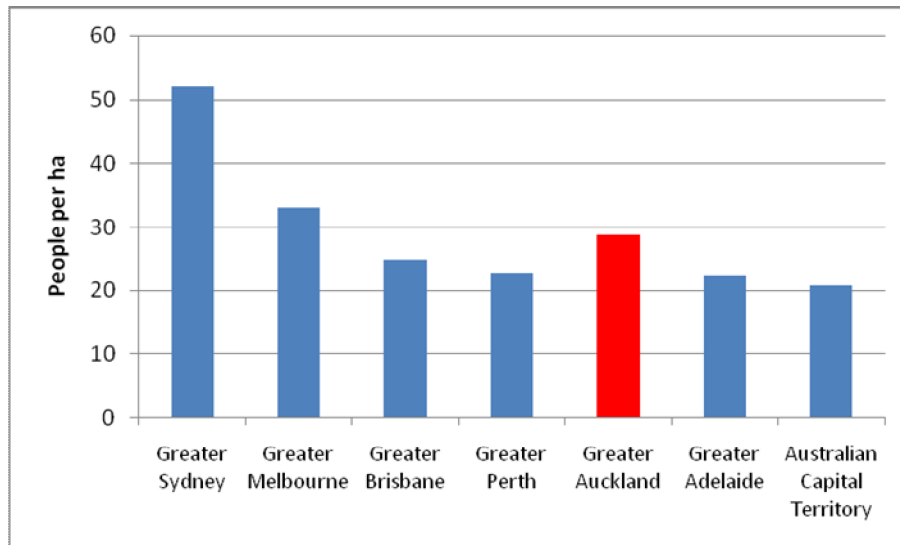
Table 5: Population weighted density of Australian cities

Greater City Statistical Area	Pop (2011)	Pop (>3/ha)	Area, square km (>3/ha)	Pop-weighted density, persons/ ha (SA1s >3/ha)	Average residential density, persons/ ha (SA1s >3/ha)
Greater Sydney	4,391,578	4,225,278	1530	52.1	27.6
Greater Melbourne	3,999,924	3,832,366	1812	33.1	21.1
Greater Brisbane	2,066,134	1,866,794	1127	24.8	16.6
Greater Perth	1,728,567	1,639,849	963	22.7	17
Greater Auckland*	1,415,172	1,297,929	612	28.7	21.2
Greater Adelaide	1,225,136	1,161,668	644	22.3	18
Australian Capital Territory	356,563	350,917	221	20.8	15.9

*Note: Auckland * = 2013 data.*

When you graph the population weighted density it is easy to see that Auckland is more densely settled than its peers, with a population weighted density higher than similar sized Perth and Adelaide, but not as much as the Demographia study suggests. See Figure Four.

Figure 4 Population weighted density, 2011/2013 , Auckland and Australian cities



On a population weighted basis, Auckland is less densely settled than Melbourne or Sydney. So maybe Auckland is not quite as whacky as it first seems.

What about the Cousins Once Removed?

Data on the average population weighted density for Canadian cities is available on the web. I found this post: <http://www.skyscrapercity.com/showthread.php?t=1474130>, which contains the information in Table 6.

The figures are from 2006. The web site does not say what area was used to calculate the figures, so they are likely to have a different "base" to the Australian figures or my Auckland figure, but the numbers look reasonable - the larger the city, the higher the population weighted density. Calgary at 1.1m has a population weighted density of 28 people per hectare, much the same as Auckland with 29.

Table 6 Population weighted density of Canadian cities

City	Population (2006)	Population weighted density (people per ha)
Toronto	5,178,733	57.35
Montreal	3,299,497	54.55
Vancouver	2,189,688	46.69
Calgary	1,101,023	27.91
Ottawa	1,022,490	29.91
Edmonton	878,827	25.32
Quebec	704,772	26.10
Hamilton	693,793	29.90
Winnipeg	673,856	29.51

A side note

As noted, the relationships in Figure Four are quite different to the relationships set out in Figure One (the data from Demographia). This may be not just because one set of figures is average density while the other is population weighted.

Part of the difference appears to be driven by how the urban area has been measured. This is back to the warning at the start about how you measure things makes a big difference. In terms of density, the factor that always seems to be different is the area of land

Table Seven lists out the population size and land area for the Australian cities and Auckland from the Charting Transport and Demographia websites. The total population of these cities are not dissimilar between the two sets of figures. What is different is the area assumed to be "urban". In the case of Sydney and Melbourne, Demographia have used a much larger area, for Auckland a smaller area. Who is right? I don't know.

Table 7: Charting Transport and Demographia comparison - population and land area

City	Charting Transport population	Demographia population	Charting Transport land area (km ²)	Demographia land area (km ²)
Greater Sydney	4,225,278	3,956,000	1,530	2,037
Greater Melbourne	3,832,366	3,761,000	1,812	2,543
Greater Brisbane	1,866,794	1,912,000	1,127	1,972
Greater Perth	1,639,849	1,657,000	963	1,566
Greater Auckland	1,297,929	1,310,000	612	544
Greater Adelaide	1,161,668	1,120,000	644	852
Australian Capital Territory	350,917	382,000	221	472
Total	14,374,801	14,098,000	6,909	9,986

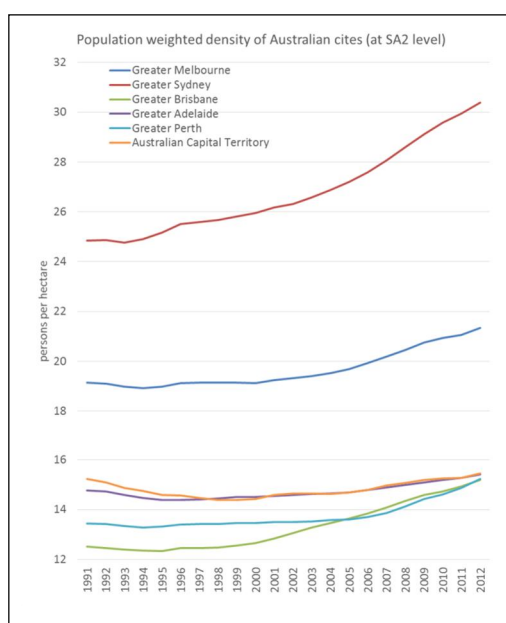
All you can say is that you need to tread carefully!

It seems impossible to find an agreed figure for the urbanised area of the Auckland Region. This is not a fatal problem as the more interesting question is how density is changing over time.

Changing Density

The Charting Transport website that lists the population weighted density of Australian cities also has a graph which shows change over time. This is reproduced below in Figure Five.

Figure 5: Changes in density of Australian cities



The first point to note from Figure Five is that it looks like it uses different geographic areas to those used to compute the figures in Table Two. This is because in Figure Five, Sydney has a population weighted density of just over 30 people in 2012, yet table two lists the 2011 figure as 55 people per ha. The website indicates that the data in Figure Five is based on a larger area. The website says:

"here is a look at population-weighted density of the six largest Australian cities, measured at SA2 level (the smallest geography for which there exists a good consistent set of time-series estimates)".

Leaving aside the actual numbers, what is interesting is the change over time in population weighted density. A couple of cities do not seem to have changed much - Canberra and Adelaide fall into this camp, but then they may not have grown much either. Greater Brisbane and Sydney have both seen an increase of a similar scale to Auckland, and both are fast growing cities like Auckland. Perth and Melbourne are in between.

By looking at the graph, Brisbane has gone from (say) 13 people per ha in 2001 to 15 people per ha in 2011. An increase of 15%. Sydney has seen a similar increase (from 26 to 30 people per ha). Over the same time, Auckland's population weighted density has grown by 16%.

What is interesting is that the Australian cities show a distinct pick up in the rate of density increase in the second decade. My data on population weighted density for Auckland only goes back to 2001, not 1991, but it is reasonable to assume that density has increased over the past decade or so.

Why the pick-up in the period since 2000? In Auckland, the 1999 Auckland Regional Growth Strategy is often seen as the start of the strangulation of Auckland's outward growth and the steady forcing of density within the existing urban area. But why has Auckland followed the same path as other cities? Now possibly Sydney and Brisbane have been following the same planning strategies as Auckland, and the step up in population weighted density is all down to restrictive urban growth controls, but frankly that seems a bit simplistic.

It's time to dig a bit deeper.

Density gradient

What the data on city-wide density doesn't tell us is how the density is changing within the city and why. To help with understanding changes within the city, it is useful to draw a density gradient. A density gradient is a simple measure of how density reduces further away from a central point. Typically urban density is like a pyramid with the greatest density at the centre trailing out to the periphery. It is the angle of the slope which is interesting - it is steep or is it shallow? A steep gradient suggests people wish to or have to locate close to the centre. If it is shallow then they are more willing or able to spread out.

Which way is Auckland's density gradient heading?

To find out I assembled census data on usually resident population numbers from 1981 to 2013, at the Area Unit level. I then coded these area units into 5km bands from the central city (i.e. within 5km, 5 to 10kms, 10 to 15kms etc). This was not a precise exercise as the Area Unit boundaries do not neatly follow the distance measures. Nevertheless a pattern emerges:

- The 5km band covers the inner Isthmus and the southern edges of the North Shore (Devonport Peninsula and Birkenhead). It roughly covers the ring of "heritage suburbs" around the city centre.

- The 10km band goes out to the edge of the Isthmus (Tamaki River, Manukau Harbour, Whau River). It also covers the middle part of North Shore
- The 15km band goes out to the edge of the urban area in the west and to the top of North Shore. Parts of Manukau are included - Pakuranga and Mangere, for example.
- The 20, 25 and 30km bands extend to the north and south and east, but with the weight of population increasingly to the south. The 30km band encompasses Orewa to the North and Papakura to the south.

The consideration of density based on distance from the CBD is only one way of looking at the city and is very simplistic, but it is still a useful way of considering density. As we will get into later, urban economists are fond of explaining urban form as a trade off that households make between transport costs and house prices - further from the centre and you have further to commute and as a result less money to spend on a house. Closer in, transport costs are less, but you need to live closer together. In other words it is useful for later analysis to consider density on the basis of distance from the CBD. However there are other measures that could be used, not least of which would be proximity to amenities like coastal areas. We would all like to live near the beach!

Compiling the data was not straight forward as area unit names change over time, and as areas develop, they get split into smaller areas. In some cases it was not easy lining up the changes in names over time.

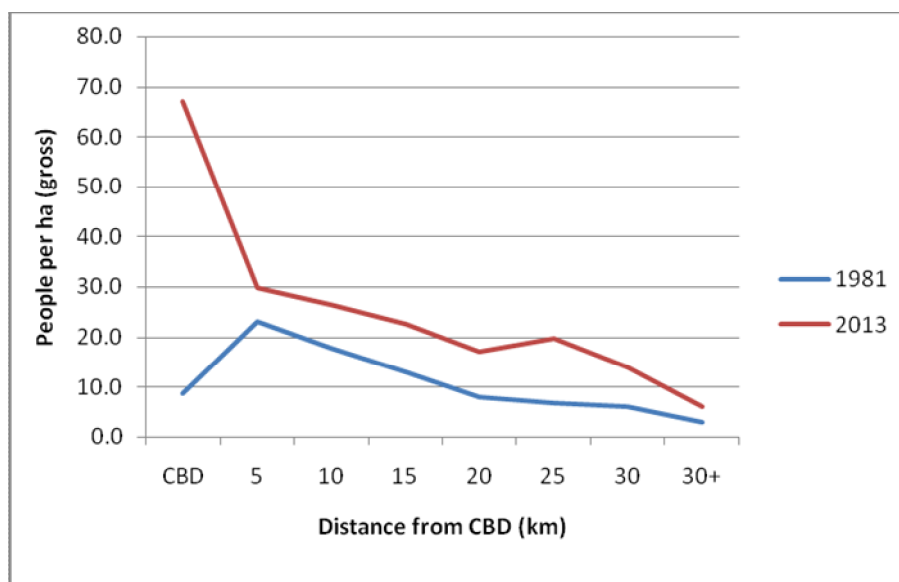
I grouped the area units into the 5km bands as it was easier and quicker to do that than measure the distance from the centre of each area unit to the CBD. I just measured a simple "as the crow flies" distance for the bands, not road distance or some other fancy measure of transport accessibility.

As for the above analysis of the population weighted density, any area unit with a population of less than 3 people per ha in 2013 was classed as rural/not urban. This did mean that a few area units within the current urban area were not counted as they had only a few people living in them.

Down at this sub city level, the density figures per distance band, per 5 years are not population weighted. This is because it is not easy to compute a population weight over time, given the data available. The fact that smaller geographic areas are used means that average density and population weighted density are much closer together than at the city wide scale.

Figure 6 sets out the result of my analysis.

Figure 6: Auckland's density gradient 1981-2013.



What is immediately apparent is the change in the density of the CBD, from hardly anything in 1981 to over 65 people per hectare in 2013.

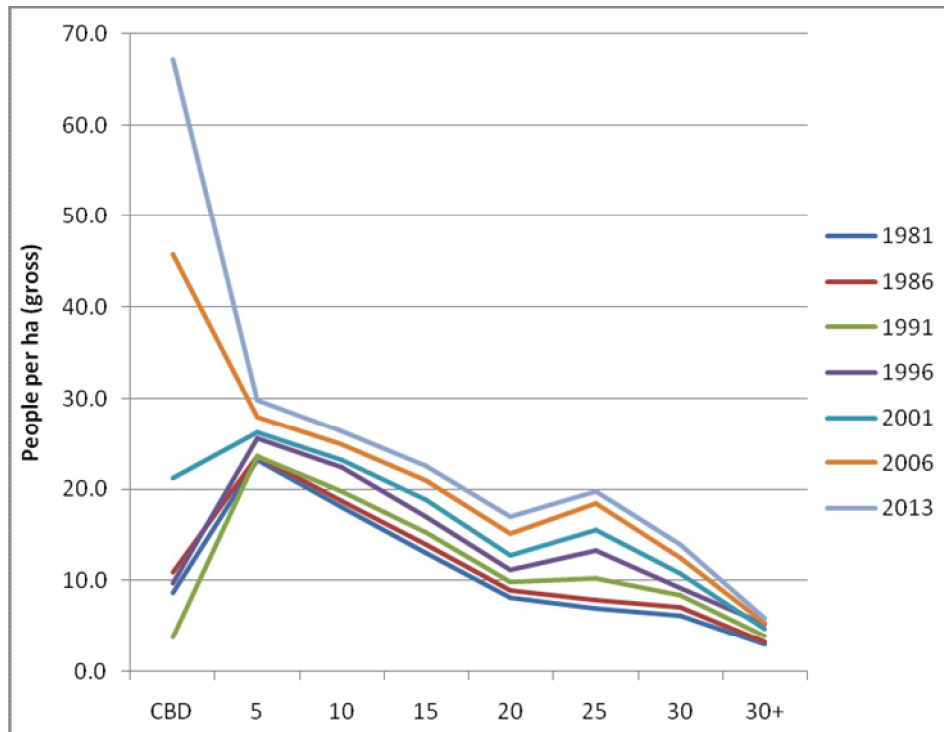
But it is not just the CBD that has increased in density. The city has intensified across all of the distance bands. It is not concentrated in one area or another.

Table Eight sets out the data on people per ha, while Figure Seven provides a graph of the five year changes.

Table 8 Average people per ha

Distance band (km)	1981	1986	1991	1996	2001	2006	2013
CBD	8.7	11.0	3.8	9.7	21.2	45.8	67.2
5	23.2	23.6	23.6	25.5	26.2	28.0	29.8
10	18.0	18.7	19.7	22.4	23.2	25.0	26.3
15	13.1	14.0	15.2	17.1	18.8	21.0	22.6
20	8.1	9.0	9.8	11.1	12.8	15.2	17.0
25	7.0	7.8	10.3	13.4	15.5	18.4	19.7
30	6.2	7.1	8.4	9.2	10.8	12.5	13.9
30+	3.0	3.3	3.9	5.2	4.8	5.3	5.9

Figure 7 Auckland's density gradient over time - 1981 to 2103



In terms of the density bands that have accommodated the most population growth between 1981 and 2013, the heavy lifting has been in the 10 to 20km bands. It is true to say that this area has seen a mix of greenfields type growth, as well as infill.

Figure 8: Population change 1981-2013, by distance band from CBD

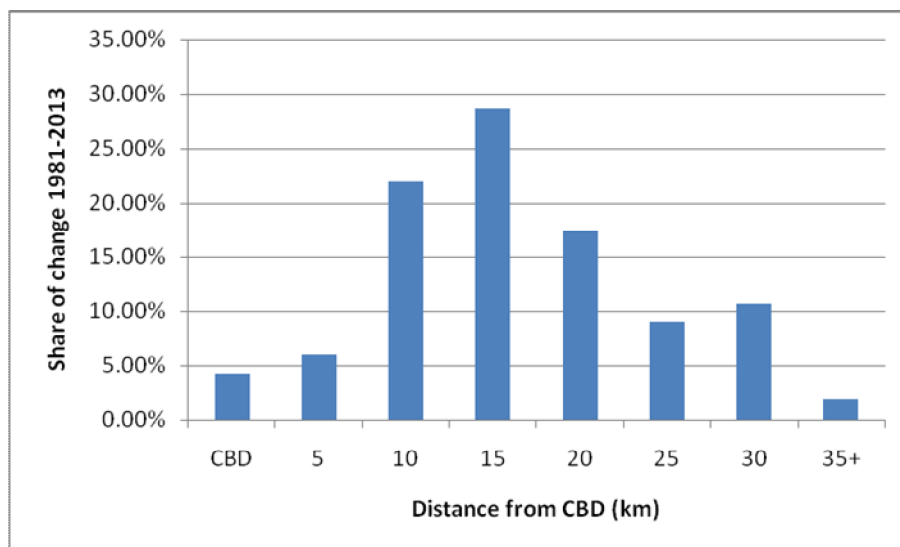


Table Nine presents the data.

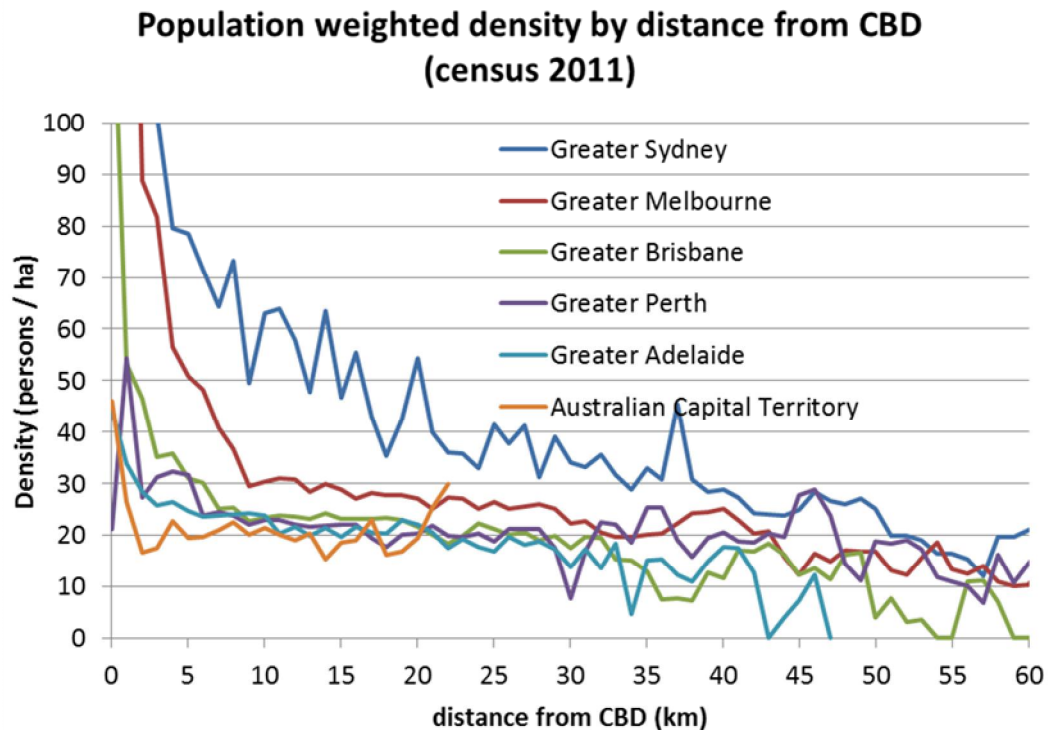
Table 9: Population change 1981-2013, by distance band from CBD

Area	Population 1981	Population 2013	Change	Share of change
CBD	3,417	26,307	22,890	4.24%
5	114,426	147,045	32,619	6.04%
10	258,250	377,085	118,835	22.00%
15	212,358	367,470	155,112	28.72%
20	86,484	180,963	94,479	17.49%
25	26,463	75,093	48,630	9.00%
30	46,069	103,542	57,473	10.64%
35+	10,343	20,424	10,081	1.87%
total	757,810	1,297,929	540,119	100%

Back to the Neighbours

My simple profile of Auckland's density gradient can be compared to those Australian cities listed in the Charting Transport website. Figure Nine sets out data from that website.

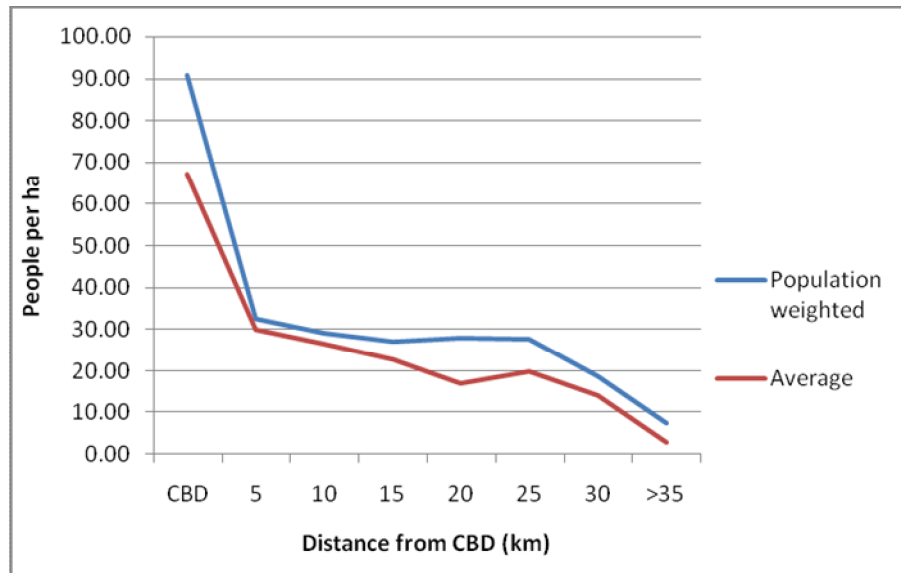
Figure 9: Density gradient of Australian cities



To get a comparable set of figures for Auckland, I need to convert my average densities by distance band into population weighted density by distance band. I can only do this for 2013.

Figure Ten presents this data, alongside the average density I computed for Figures Five and Six above.

Figure 10: Auckland's population weighted density by distance from CBD



The interesting pattern here is how the population weighted population density is more even across the bulk of the urban area, with the population weighted density across the 10 to 25 km distance bands being very similar.

So is Auckland's density profile more like Melbourne's and Brisbane's, with a steep drop off from the city centre, then an even spread across the urban area. Sydney's profile has more a pyramid look to it.

The population weighted density profile for Auckland outside the CBD suggests that households are, to an extent, indifferent to distance from the CBD. There is no obvious trade off between distance and density. But is the profile being artificially constrained by zoning? Closer to the centre, is redevelopment being contained by zoning controls that largely reflect the current built environment, when that area should be able to redevelop upwards, while out towards the edge, is the natural inclination to spread out a bit being constrained by the MUL?

Where to for Auckland's density?

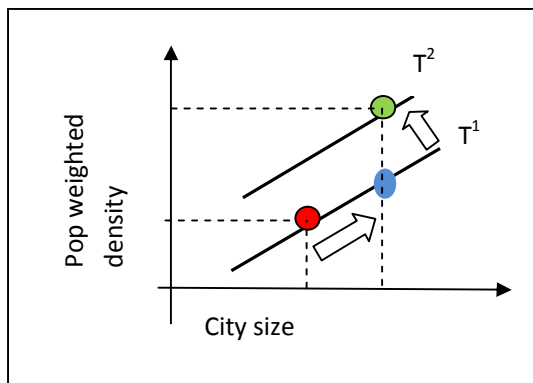
The question is how Auckland's density may change in the future if we assumed a more relaxed approach to zoning? In a further paper I will look more closely at urban economic models of city densities and what they may foresee in terms of Auckland's density. Here I will finish off the above discussion with two observations about Auckland's density - related to its size and to its density profile.

First some more numbers. What might be the overall density of Auckland when it reaches an urban population of 2 million? Getting to an urban population of 2 million will take time, around 2041 at least, if not longer. By 2031, under a medium growth scenario, Statistics NZ suggest that the Auckland Region as a whole may be just under 2 million people. But some of these people will be living in rural areas, around 10%, so the actual urban part may be more like 1.8m, or an increase of 500,000 or so on the current urban population of 1.3m. Add another decade to get to an urban population of 2 million and a regional population of 2.2million.

Let's start by noting that the above data suggests that cities are getting more densely settled. That is after a long period of decreasing density during the post war period (driven by falling transport costs), urban density is increasing. As cities get bigger, then that rate of intensification seems to be getting faster.

So as Auckland grows, then it will shift up along the density line, from the red dot to the blue dot in the graph below. At the same time, that density line seems to shifting itself "up the page". So the end point may actually be the green dot.

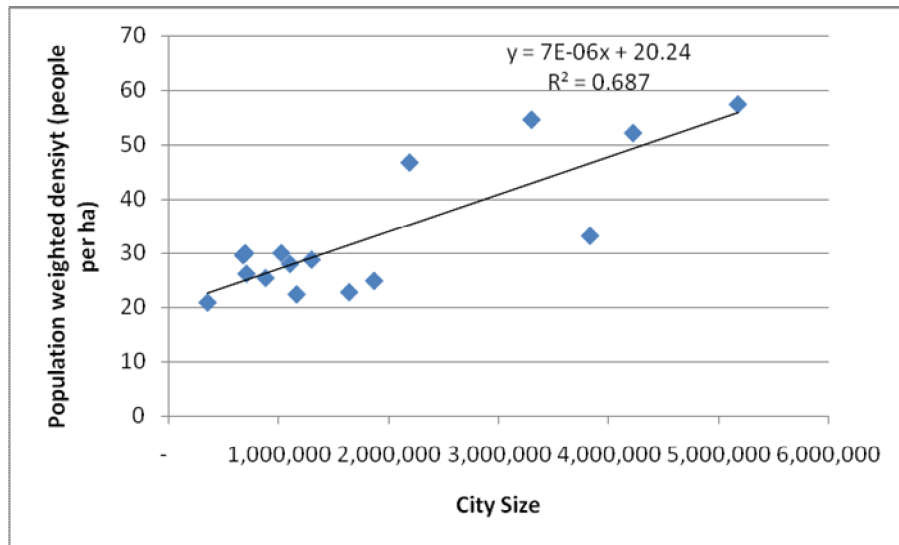
Figure 11: Shifts in city density



What might Auckland's density be at an urban population of 2 million?

To start with, let's look at the relationship between city size and population weighted density. If we take the figures for Australian and Canadian cities and plot city size and population weighted density, then we get the relationship in Figure 12.

Figure 12: City size and population weighted density



Based on the above sample, Auckland at 1.3million should have a population weighted density of 29 people per hectare. Auckland is currently right on this trend line.

As the urban part of the city heads towards 2 million then the above (albeit limited sample) suggests that the city needs to plan for a population weighted density of something around 20% higher than at present. That is, from 29 people per ha to 34.5 people per ha, if Auckland remains on the trend line.

What that figure doesn't tell us is how far the city might spread out and what would be the density profile within that footprint (and what might it mean in terms of the built environment, you can add, but that is for another day) .

As for how far out the city might spread, this is going to be determined by a host of factors including transport and infrastructure costs, environmental constraints and planning-led judgements about overall expansion. Is there any way of estimating what the land area might be, setting aside the planning-led part of the equation?

One place to start would be to look at the trends over the past 10 years. Table 10 reproduces the data for Auckland's growth, as I have estimated.

Table 10. Trends in Auckland's growth

Factor	2001	2006	2013	Annual rate of change
Total population	1,159,860	1,304,580	1,415,172	1.5%
Urban population	1,056,435	1,191,681	1,297,929	1.6%
Urban land area (ha)	55,269	58,329	61,219	0.8%
Average population density (people per ha)	19.11	20.43	21.20	0.8%
Pop weighted density (people per ha)	24.72	26.85	28.77	1.2%

Based on these figures, you could hazard a guess that to accommodate an urban population of 2 million, the urban area would need to expand to around 772 square kilometres, or an increase of 160 square kilometres. Table 11 sets out the figures behind that guess.

Table 11: Possible urbanised land area

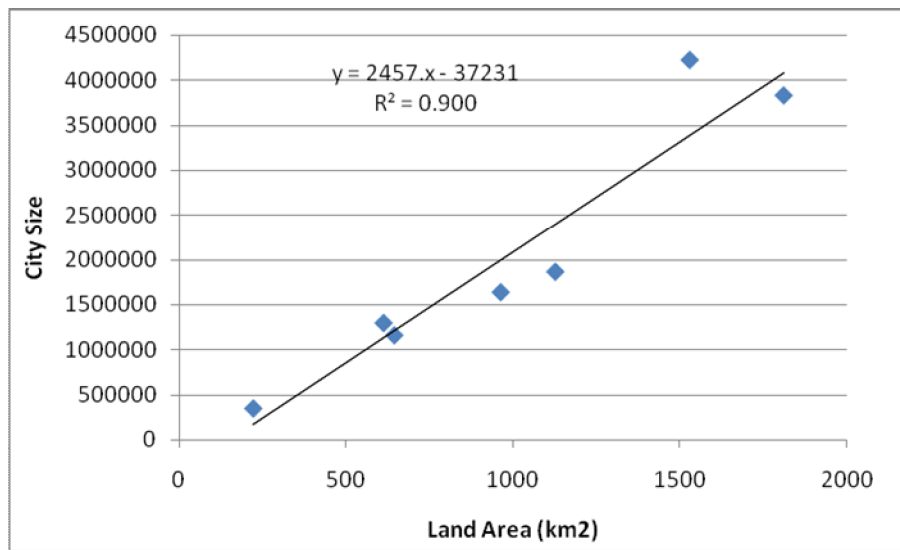
	Rate of Change	2013	2041
Total population	1.6%	1,415,172	2,200,000
Urban population	1.6%	1,297,929	2,046,000
Average density (people per ha)	0.8%	21.2	26.5
Land area (ha)	0.8%	61,219	77,208

However, it could be said that the rate of growth of the urban footprint over the past 10 years has been controlled by the MUL and is not a 'natural' rate of expansion.

Looking at our cousins across the ditch provides some clues. If you plot our limited sample of cities and their land areas, then you get the relationship set out in Figure 13. At 2 million people you might expect an urban area of about 830km², based on the relationship and associated equation

calculated by Excel. This is an increase of 220km² over my estimated 2013 figure of 610km² (which is larger than Demographia's).

Figure 13: City footprint and city size.



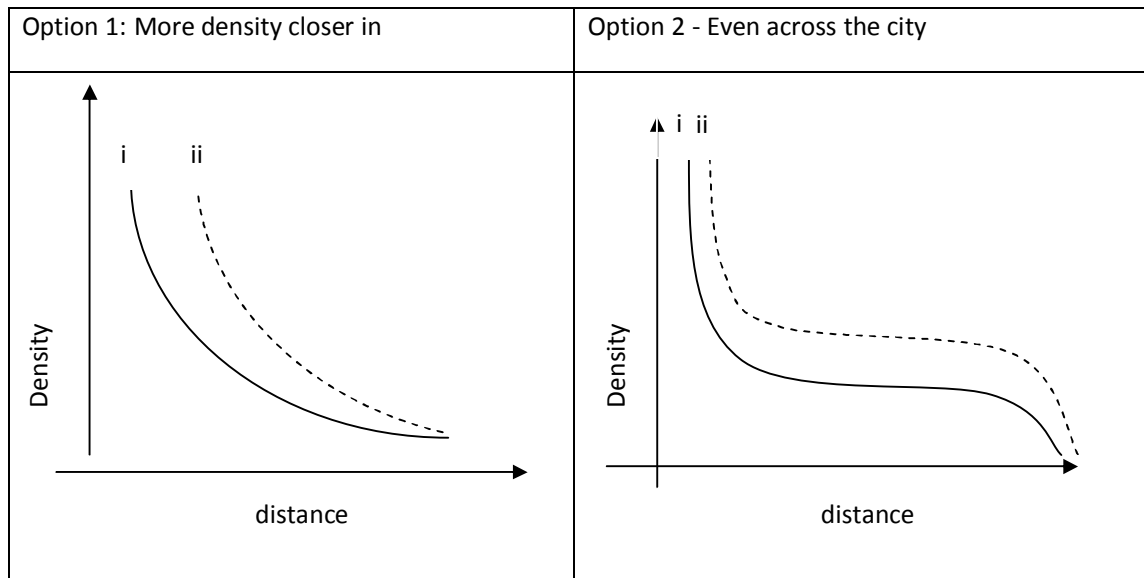
At an urban area of 830km², the average density would be 2,400 people per km², or 24 people per hectare.

If the city did expand by around 220km², then at an average of 1,500 people per square kilometre 330,000 people might be accommodated in the greenfields areas. This of a total increase of 700,000 people. The other 370,000 or so will need to fit into the current urban area.

What might happen to the density profile in the city be in that case?

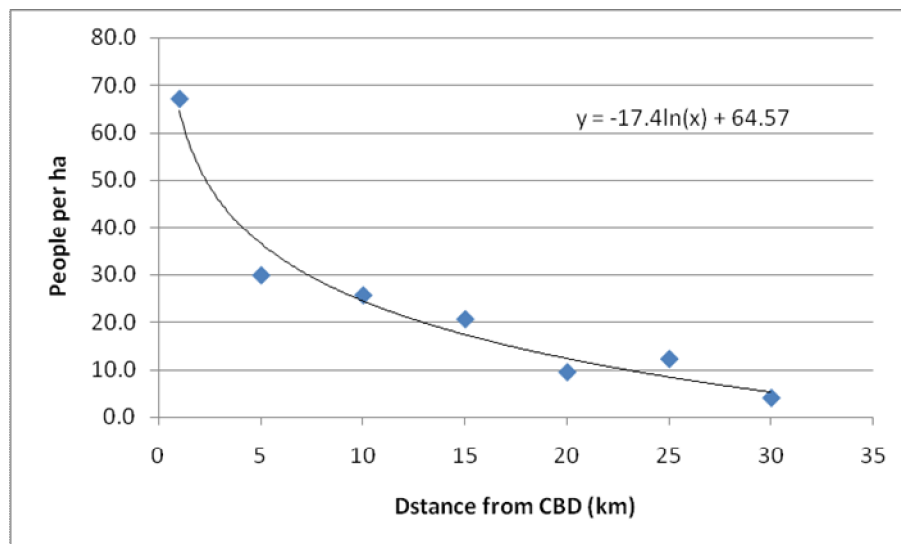
Figure 14 shows two possible options. The first option is a more Sydney-like density profile, the second a more Melbourne-like.

Figure 14: Density gradient options



The first option can be represented by the following graph (Figure 15) and equation, using the 2013 average density gradient profile of Auckland, as a base.

Figure 15: Average density and distance from CBD

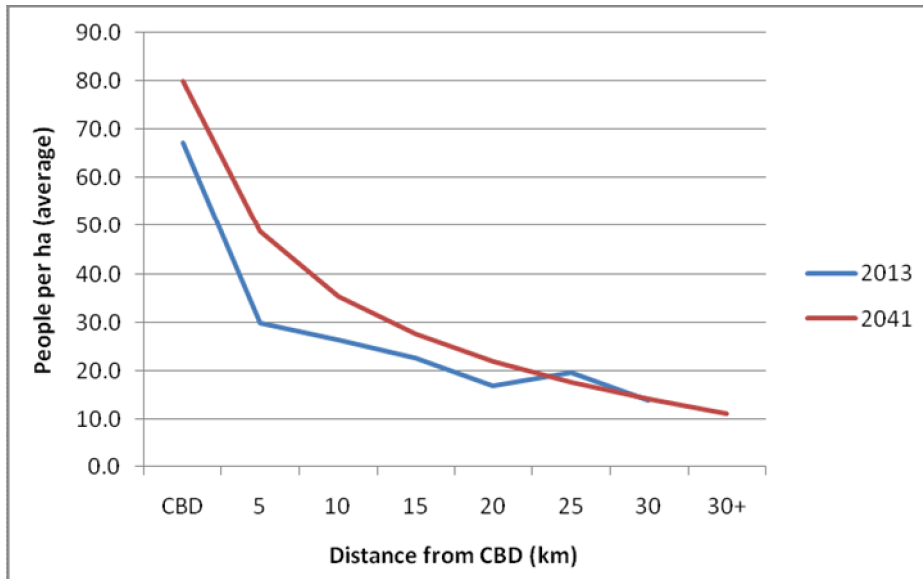


This relationship presents a pleasing curve, with density increasing towards the centre.

We can use this curve as a base and steepen up the curve.

To fit in 375,000 more people we end up with a profile something like the following:

Figure 16: Density gradient, 2013 and 2041, option 1



While that may not look like too much change, when you generate the numbers then the following numbers results (see Table 12).

Table 12: Population of distance bands, 2013 and 2041, under option 1

Area	2013	2041	Change	% Change
CBD	26,307	31,327	5,020	19.1%
5	147,045	240,854	93,809	63.8%
10	377,085	507,809	130,724	34.7%
15	367,470	449,019	81,549	22.2%
20	180,963	234,195	53,232	29.4%
25	75,093	67,395	7,698	-10.3%
30	103,542	105,335	1,793	1.7%
35+	20,424	38,575	18,151	88.9%
Total	1297929	1674510	376,581	29.0%

The inner rings see the largest increase.

You can see that at the 25km band, the new curve is lower than the existing. The simple equation used smooths out the bumps in the graph.

Despite this, the picture represents a possible scenario.

The other approach is to use the population weighted profile, and to shift this north, as in Figure 16.

Figure 17: Density gradient, 2013 and 2014, option 2

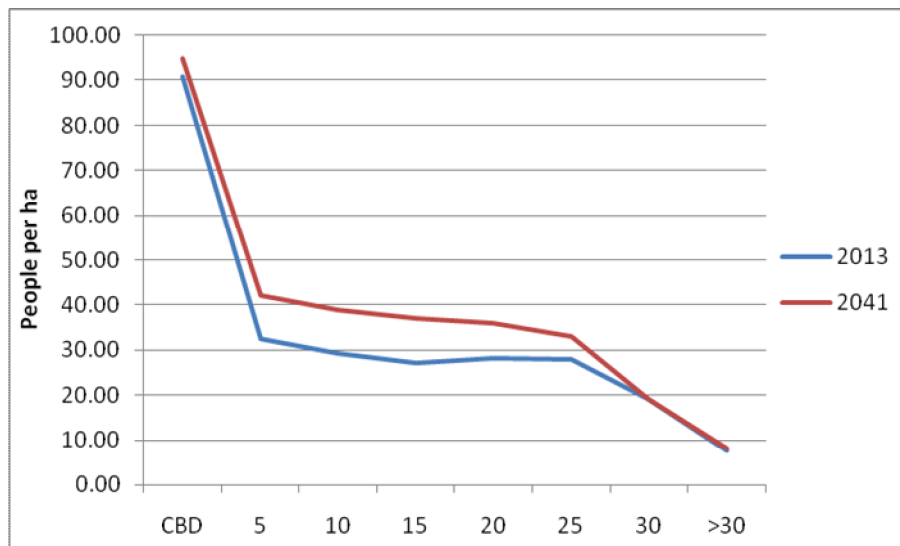


Table 13 sets out the outcome of this approach. Future growth is more evenly spread across the city.

Table 13: Population of distance bands, 2013 and 2041, option 2.

Area	2013	2041	Change	% Change
CBD	26,307	27,540	1,233	4.7%
5	147,045	190,383	43,338	29.5%
10	377,085	505,763	128,678	34.1%
15	367,470	502,124	134,654	36.6%
20	180,963	232,235	51,272	28.3%
25	75,093	891,77	14,084	18.8%
30	103,542	104,294	752	0.7%
>30	20,424	21,834	1,410	6.9%
Total	1,297,929	1,673,351	375,422	

In both options, the population weighted density is close to our target of 35 people per hectare.

Neither of these options is a 'fixed and final' picture of the city. They merely provide a helpful exploration of what increased density may mean in the future.

To really get to grips with what may happen, we need to explore the dynamics of city density in more detail and that is what I intend to do in my next paper.

So What Have I Learned?

Population weighted density is a far more useful way of looking at city wide density than a simple average density measurement (total population divided by total area)

Population weighted density makes comparisons between cities more realistic

Auckland's population weighted density is greater than same sized cities in Australia but the difference is much less than average density figures suggest

Auckland's population weighted density has been increasing over time, as with other cities

The density gradient of Auckland has changed over the past 30 years, most noticeably with the increase of density in the central city, but the increase is not confined to this area. There is a general steepening of the average density gradient towards the centre

On a population weighted basis, there is less of a difference between inner and outer suburbs in terms of density - Auckland appears to have a fairly "even" density profile. This contrasts with some other cities where there is more of a pyramid shape, even on a population weighted basis.