DENSITY AND SUSTAINABLE TRANSPORT IN US, CANADIAN AND AUSTRALIAN CITIES: ANOTHER LOOK AT THE DATA

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INTRODUCTION: THE COMPACT CITY

Growing international concerns about climate change and insecure oil supplies have highlighted the problem of automobile dependence in cities. There is widespread agreement that cities must become more sustainable, by reducing trip lengths and shifting travel to walking, cycling and public transport (UN, 1993).

The most popular recipe for sustainable urban travel is the suite of policies that have come to be known as the compact city. Low population densities are regarded as the main cause of automobile dependence, with Los Angeles held up as the pre-eminent example of the connection between 'sprawl' and excessive automobile use. By contrast, Portland Oregon is hailed as a model of 'smart growth', with increased urban densities due to Transit-Oriented Development.

The link between density and automobile use is accepted by many critics of the compact city, as well as by advocates of the idea. Critics argue that the density increases required to substantially change transport patterns are unachievable or undesirable, with the result that there is no practical alternative to continued automobile dominance. This view seems even to have influenced the International Panel on Climate Change, whose fourth Climate Change Assessment Report, released in 2007, has little to say about transport. This in turn reflects the pessimistic tone of the report from the IPCC's Transport Working Group, which says: 'Providing public transport systems… and promoting non-motorised transport can contribute to GHG mitigation. However, local conditions determine how much transport can be shifted to less energy intensive modes.' The potential for mode shift is 'strongly influenced by the density and spatial structure of the built environment', but 'densities are decreasing everywhere' (Kahn-Ribeiro et al, 2007, pp. 326, 367). The working group's recommendations focus on technological responses to emissions from transport, perhaps unsurprisingly since its coordinating authors were a Brazilian engineer specialising in biofuels and a Japanese researcher working at the Toyota R & D laboratory on 'clean energy vehicles'.

However, the IPCC working group makes a valid point. Increasing the urban density of a large metropolis is likely to be expensive, disruptive and time-consuming, and may be impossible to achieve within the timeframe necessary to combat urgent problems like climate change and oil insecurity. This is particularly so if some commentators are correct about the magnitude of the density increases that are required for sustainable urbanism.

In the United Kingdom, it is widely argued that a density of 100 residents per hectare is required to allow bus services to be provided, with even higher figures cited as necessary for rail services. In the words of a leading UK planning guidebook:

> We may lament the decline in public transport and the effects of deregulation and reducing subsidy. However it must be recognised that the dispersal of development and the reduction of housing densities has also played its part. The Local Government Management Board estimates that densities of 100 persons per hectare are required to support a viable bus service and 240 persons per hectare for a tram service, whereas the average density of new housing development is just 22 units to the hectare [or] around 50 people (Rudlin & Falk, 1999, p. 158).

So British urban densities need to double just to allow bus services to be provided, and increase five-fold before trams can be considered; the increases for North American or Australian cities would presumably be even greater. Quite simply, changes of this magnitude are never going to happen. There is not sufficient time, nor is it likely that there will be political support. The majority of the houses Britons will inhabit in 2050 already exist, and the same is true in other developed nations.

Density-based responses to the environmental problems of transport tend to downplay the importance of transport policy itself, as the comments cited above illustrate, with their dismissal of regulation and subsidy issues. But transport policy can be changed much more rapidly than urban form, and the financial and political costs may also be lower. Before accepting that sustainable transport requires changes in urban form that may be impossible to achieve, policy-makers should carefully scrutinise the evidence supporting these arguments. This has not generally been the case.

Let's look at that again

The British density figures cited above come from a report written for the UK Local Government Board by a team of researchers from the University of the West of England in Bristol. It does specify 100 persons per hectare as the minimum density for buses (Barton et al, 1985, p. 80), but contains no mention of a threshold for trams. However, the report did not estimate the 100 per hectare figure: it simply cited the first edition of Peter White's book *Public Transport* as the source. But White never claimed that 100 per hectare was the minimum density for bus service. His only mention of the figure comes in a discussion of the then-new mode of 'dial-a-bus', which cites un-named American consultants who believe it requires 'about twenty to forty persons per acre [50 to 100 per hectare]' (White, 1976, p. 112). Later editions of White's book omit this discussion, noting that dial-a-ride turned out to be a high-cost mode, and that most services have been withdrawn.

So the supposed density requirement for buses turns out not to have been estimated or calculated at all, while the higher figure for trams seems to have emerged from thin air. This has not prevented the supposed minimums being widely used, and not just in the UK. The new regional public transport authority for greater Toronto cited similar figures in a 2008 paper, which argued that 'Transit modes and services that are appropriate to a given corridor can be determined almost exclusively by land-use density and trip density in that corridor' (Metrolinx, 2008, pp. 17-18).

There has been one study that estimated a density threshold for bus services of around 100 persons per hectare. This was the Chicago Area Transportation Study 1956, the study that pioneered modern transport modelling and planning techniques. The study began with an 'inventory', or survey, of land use and transport in the greater Chicago region. The analysis of urban form found that population densities declined with increasing distance from the city centre. The analysis of travel revealed that a quarter of regional trips were by public transport and three-quarters by car (the study did not count walking or cycling), with public transport's share of the market also declining with distance from the CBD.

'This evidence', the study team concluded, 'partially destroys the idea that people choose their mode of travel' (CATS, Vol. 1, p. 74). Public transport mode share could be predicted using an equation in which the variables were density and car ownership (p. 119). Having established the equations relating traffic to land use for 1956, the study used them to predict travel patterns for the design year of 1980. The starting point was a prediction of future land use patterns. CATS assumed that the historical trend towards a more spacious city would continue, leading to a continued decline in density. The consequence, according to the CATS equations, would be a further reduction in public transport's share of the market, from 24 per cent of trips in 1956 to 14 per cent in 1980.

Given these trends, CATS recommended that 92 per cent of investment should go to highways and the remaining 8 per cent to public transport (half of this was for car parking at stations). Anticipating criticism that planning for public transport decline would be a self-fulfilling prophecy, the study team responded: 'The conditions of land use and density… are the major determinants of the travel market. If demand is constrained by these factors, it is unlikely that changes in supply will have any great effect on the number of users' (vol. 2, p. 53).

In fact, CATS claimed, regular public transport could not operate at all at the densities found in Chicago's suburbs in the 1950s, densities that were predicted to become the norm in future decades. The inventory had established that most bus trips occurred within the boundaries of the City of Chicago or adjacent inner suburbs. 'The explanation', according to the study team, 'lies in the density of land use, and car ownership. Bus service can be provided only where there are enough passengers to pay operating costs… There are enough passengers only in districts which have a certain minimum density [which] appears to be about 25,000 persons per net residential square mile.' Below this figure, which is equivalent to 96.5 per hectare, 'buses apparently cannot operate economically' (vol. 1, pp. 43-4).

This finding was picked up by other writers and so widely disseminated that it has become a truism. The British economist Colin Clark took the CATS figure, halved it to allow for non-residential uses, and concluded that 'a population density of 12,500 per gross sq. mile (48 persons/hectare) in a predominantly residential area is likely to be the limit below which 'bus services will be unremunerative without a subsidy.' This suggested public transport did not have a long-term future, since '[r]esidential densities in modern cities... are tending to stabilize well below this limit' (Clark, 1967, p. 366). Clark's assumption that half of developed land was residential was incorrect: CATS actually found that only a third was, so Clark's density threshold should have been 32 per hectare, not 48.

The Australian transport planners Peter Newman and Jeff Kenworthy took Clark's figure, reduced it again on the basis that most public transport systems now receive some subsidy, and arrived at a minimum density of 30 persons per hectare below which public transport cannot be provided (Newman & Kenworthy, 1989, p. 131). The supposed minimum density of 30 per hectare – which would have been 20 if the starting-point of 32 had been used instead of 48 – has been widely accepted by urban planners in Australia and North America.

Nobody seems to have taken the trouble to examine the original CATS figures to see if they really prove that bus services could not have been provided in Chicago's suburbs. In fact, the lack of suburban bus service in Chicago was the result of politics, not density (Mees, 2010, chapter 2; Yago, 1984, chapter 6). Public transport was provided for many decades by private franchisees, operating on a similar system to that employed for British Rail services in the UK, and trains and trams in Melbourne. Despite strong support for public ownership, demonstrated in a series of plebiscites beginning in 1902, Chicago's private transit franchisees held onto their properties until they went bankrupt during the Depression. More than a decade of indecision and decline followed before the banks, acting as receivers, sold operations to the Chicago Transit Authority, a body created by state legislation in 1947.

The CTA was financially hamstrung by the need to rehabilitate the dilapidated systems it inherited, and cut costs by replacing ageing trams with buses. There were no funds available for significant service extensions or improvements. An attempt in 1956 – the very year CATS officially commenced – to use state fuel tax funds to finance modernization and extension of CTA services was defeated by vigorous lobbying by a coalition of highway interests.

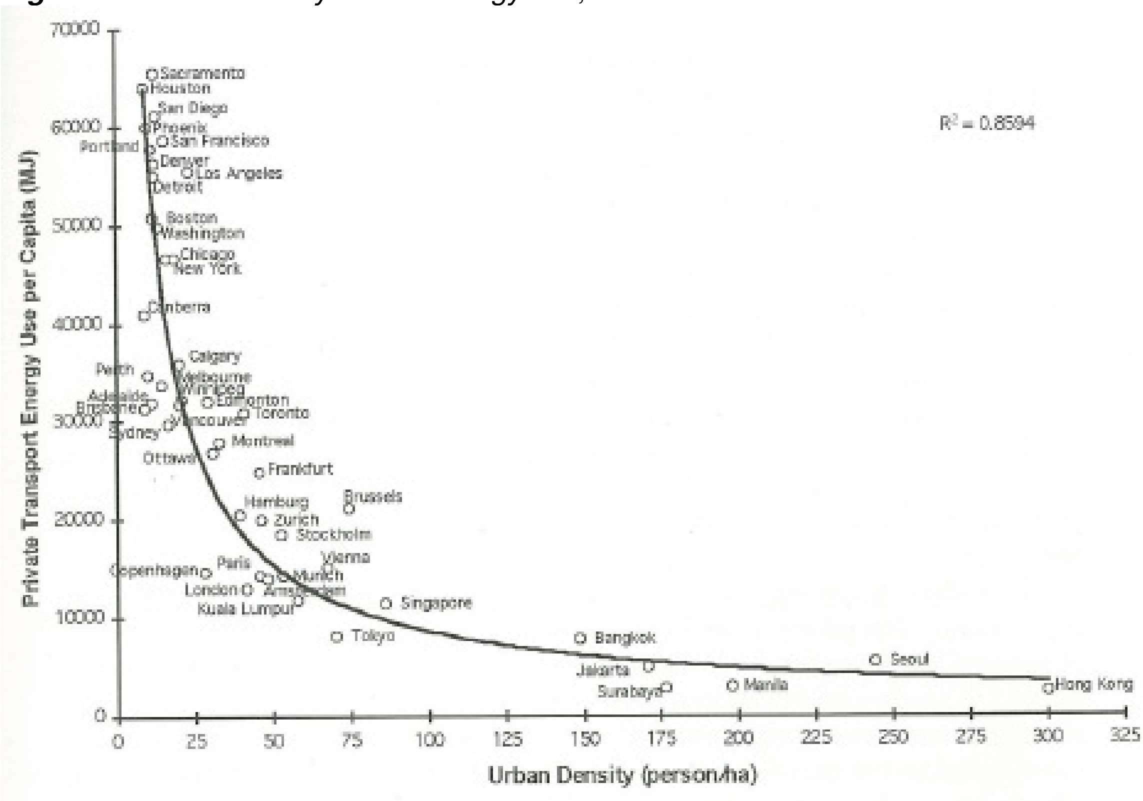
Suburban municipalities could choose whether to join the CTA, and given its parlous state most did not: they were served by private commuter railroads and may not have seen a great need for buses. These municipalities had no bus services, and therefore no bus passengers. A few closer-in suburbs did join the CTA, and were provided with bus service. These were the suburbs CATS observed as having bus passengers. Density had nothing to do with it, as the density map in the CATS report shows they were all well below the supposed minimum (p. 21).

So the Chicago density threshold was a pseudo-scientific rationalization for a state of affairs that had arisen through public policy failures. Even Carroll's assistant Roger Creighton later acknowledged that the treatment of public transport had been the weakest part of CATS: 'the answer was never considered satisfactory… In retrospect, one looks at these arguments with mixed emotions… But this was the fault of the times' (Creighton, 1970, pp. 303-4). Nobody apparently noticed, however, and the Chicago density threshold has been used ever since.

Newman and Kenworthy

Most contemporary commentary on the density-transport connection takes as its starting point the multi-city comparisons of Newman and Kenworthy (1989, 1999). Compared with the British planners discussed above, Newman and Kenworthy are moderates, suggesting that the threshold for sustainable transport is around 30 per hectare rather than 100 or more. As discussed above, they derived this figure from the work of Clark, who in turn took it from CATS, but they corroborated it with a famous graph in which transport energy use (an indication of automobile dependence) and density are mapped across a range of international cities: see Figure 1. The graph shows a strong correlation between the two variables, and a threshold of 'about 20 to 30 persons per hectare' below which automobile use appears to increase exponentially (Newman and Kenworthy, 1999, p. 100).

Figure 1 *– Urban density versus energy use, 1990*



Source: Newman and Kenworthy, 1999, p. 101.

Critics of Newman and Kenworthy's work point out that correlation is not the same as causation, and that other factors also influence automobile use. A recent report by the US Transportation Research Board argues:

> Aggregate analyses such as Newman and Kenworthy's mask real differences in densities within metropolitan areas, as well as in the travel behaviour of subpopulations, that vary on the basis of socioeconomic characteristics. For example, central cities may house disproportionate shares of lower-income residents, who are less able to afford owning and operating an automobile, and younger people and older households without children whose travel is below average. On the other hand, suburban areas tend to include a disproportionate share of families, who are often in higher-income groups with higher levels of automobile ownership and travel demands for jobs, education and extracurricular events (TRB, 2009, pp. 33-34).

Although the general criticism that correlation is not the same as causation is undoubtedly correct, the TRB's specific examples reveal a US bias. In Australian cities, as well as much of Canada and Europe, inner cities house the wealthiest sections of the community, with lower-income groups increasingly forced to middle and outer suburban locations. But the patterns of lower automobile use in the inner city and higher rates in outer areas can still be found, especially in Australia, where the dependence of low-income outer-suburban residents on cars is a subject of increasing concern (Dodson & Sipe, 2008).

A more cogent criticism is that closer scrutiny of the Newman and Kenworthy data suggests that the pattern may be less simple than has been suggested. Mindali et al (2004) analysed the original data set from the 1980s (Newman and Kenworthy 1989), paying particular attention to a cluster comprised of US and Australian cities, which have many similarities in urban form. Among this cluster, there was no relationship between density and automobile usage: Australian cities had similar densities to their US counterparts, but dramatically lower car travel. A similar pattern can also be found in the 1990 data shown in Figure 1. The Australian cities are all to the left of the trend line, with lower automobile use than their densities would suggest; US cities are on the line or to the right. In fact, the Australian cities' automobile usage rates are slightly closer to the denser European cities than to the US cities, which have identical average densities to their Australian cousins (Canberra is an exception). Canadian cities also appear to the right of the trend line in Figure 1, with similar automobile usage rates to Australian cities, but much higher densities.

The two biggest anomalies in Figure 1 are Toronto and Los Angeles, both of which are well to the right of the trend line, because they have much higher densities than their peers, but similar levels of automobile use. In the case of Toronto, the main reason for the anomaly appears to be the use of the Municipality of Metropolitan Toronto – which became the City of Toronto in 1998 – as a proxy for the metropolitan area. As Newman and Kenworthy note, the City houses barely half the population of the wider area, which has a significantly lower density: 26 per hectare compared with 41 for the City (Newman & Kenworthy, 1999, p. 96).

These anomalies suggest a need to examine the data for Australian, Canadian and US cities more closely. Fortunately, the census data collected by the three countries' statistical agencies enables this task to be attempted.

DEFINING AND COMPARING DENSITY

The problem of Toronto discussed above illustrates the importance of ensuring that density comparisons are made on a consistent and rigorous basis. Failure to do so will produce results that are at best meaningless, and at worst downright misleading.

The problem is not new. More than six decades ago, Ernest Fooks published a little book titled *X-Ray the City!* Fooks arrived in Melbourne as a refugee from Nazism in 1939. He was the first person in Australia – and possibly the English-speaking world – to hold a doctorate in town planning, which he had obtained in Vienna with an investigation of linear cities. Fooks was the first lecturer in town planning at the Melbourne Technical College, now RMIT, although he ultimately ended up working as an architect (Townsend, 1998). Fooks wanted to place Australian town planning on an intellectually rigorous footing, and wrote the book to show how this might be done.

The central argument of *X-Ray the City!* is one that still needs to be made in the 21st century. Most reported measurements of urban density are calculated by dividing the population of a municipality or other administrative region by its gross area. 'It is of the utmost importance,' Fooks says, 'to stress the major defect of such figures: THE ARBITRARY NATURE OF URBAN BOUNDARIES' (Fooks, 1946, p. 43; capitalisation in original). Municipal and administrative boundaries rarely correspond to actual urbanised areas. Some cities (e.g. Brisbane) contain large areas of vacant land within their boundaries, while others (e.g. the City of Toronto) occupy only the inner part of the urbanised area. Therefore, more accurate density measures are needed: Fooks proposed a series of them, linked to form a 'density diagram' that could be used to 'X-Ray the city'.

Fooks' efforts to introduce rigour and consistency into Australasian discussions of density were unsuccessful. Nearly half a century after Fooks' book, Brian McLoughlin (1991) lamented the shallowness of local analysis, arguing that British town planners had established rigorous definitions of density that could be used for comparative purposes, but were being ignored.

The key point Fooks and McLoughlin make is that useful measures of density should be based on the area of urbanised land, not on arbitrary administrative boundaries. The whole urban area should be counted, not just that portion lying with the boundaries of a central municipality: urbanised New York extends far beyond the five boroughs of New York City, into Long Island and even the neighbouring states of Connecticut and New Jersey. Conversely, only urbanised land should be counted when measuring density, so measurements must exclude non-urban land that happens to lie within city boundaries.

Density can be examined in more detail by distinguishing between residential and non-residential land. Using McLoughlin's nomenclature, Net residential density is calculated by considering only the residential blocks on which houses are built. Gross residential density includes non-residential uses found within residential neighbourhoods, such as local schools and parks. Overall urban density includes all other urban uses, such as industrial areas, transport terminals and regional open space.

Different definitions of density will naturally produce different figures. So when comparing the densities of different cities, or parts of cities, it is important to use consistent definitions, count only urbanised land and count all the urbanised land. Most discussions of density by urban planners have failed this test. Countless discussions of metropolitan areas have compared 'densities' of inner and outer municipalities based on the whole area within municipal borders. Since outer municipalities often incorporate large areas of non-urban land, the result always appears to be a steep decline in density with distance from the centre. But this decline is likely to be exaggerated or even completely illusory: Max Neutze's careful analysis of Adelaide three decades ago found that the apparent decline in density was a statistical artefact, with residential densities actually highest on the urban fringe, and overall urban densities roughly constant throughout the metropolis (Neutze, 1981, p. 67).

Newman and Kenworthy expressly attempted to avoid problems of this kind in their multi-city comparison, by using a definition that corresponds to overall urban density in the above discussion. They were successful in most cases, but not all. In some cities, especially in Europe, land use data for complete urbanised areas proved difficult to obtain, and only the central municipality was studied. Because the central municipality is the most densely-populated part of the region, this means the density figures are overstated for all such cities. In the case of the 1999 study, this means Amsterdam, Brussels, Frankfurt, Hamburg, Munich, Stockholm and Vienna – the majority of the European cities shown on the graph in Figure 1 (Kenworthy et al, 1999, pp. 27-32).

A similar problem affected Newman and Kenworthy's density data for Toronto, which as we have seen was confined to the City of Toronto. The resulting overstatement of density was magnified by the fact that the gross residential area was inadvertently used as the basis for calculating density, instead of the overall urban area. This can be seen clearly from the map of urbanised Toronto in Kenworthy et al (1999, p. 375), which shows Toronto and York Universities, two large cemeteries, the main racecourse and numerous parks as non-urban.

Density, travel mode and census data

Newman and Kenworthy had little difficulty specifying the densities of cities in the United States, because that country's Census Bureau has been calculating overall urban density figures for some time (see US Census Bureau, 2007, p. A-22). An 'urbanized area' is defined for each metropolitan region, made up by combining adjacent 'census blocks' (the smallest units for which data is collected) with more than 1000 residents per square mile, or 386 per square kilometre, regardless of how many municipal or even state boundaries are crossed. Less-dense census blocks that are surrounded by 'urban' blocks are also included. This generally contains most of the population of the equivalent 'metropolitan statistical area', which covers non-urban as well as urban land. The main exception is free-standing settlements within the boundaries of the census area, which are counted as separate urbanized areas if sufficiently distant from the main area: for example, San Bernadino is counted separately from Los Angeles.

Newman and Kenworthy used the urbanized area density figures for US cities, but did not use their equivalents for Australian and Canadian cities, possibly because these were hard to locate until recently. Statistics Canada defines 'urban areas' on an almost identical basis to the United States, using a density threshhold of 400 per square kilometre (Puderer, 2009, pp. 5-6). The Australian Bureau of Statistics does the same for 'urban centres', although with a threshhold of 200 per square kilometre (ABS, 2006, chapter 6), which means that Australian urban densities will be slightly understated relative to the other two countries.

Each country's statistical agency also asks a question in the census about the method of travel to work, in a manner that enables the answers to be compared. While work trips only account for a minority of urban travel, they are the only kind for which this kind of consistent information is available across such a range of cities. Surveys of overall travel are usually conducted locally, in different years, and often with inconsistent methodologies.

Despite the limitations of this census data, it enables a more rigorous comparison of urban densities and transport patterns across the three countries than has been made previously – partly because not all the information was available at the time Newman and Kenworthy collected their data. The Canadian census has only included a question on the method of travel to work since 1996, while the land areas of Canadian urban areas were not published until the 2006 census (the Australian urban centre areas were released for earlier censuses up to 1991, but not released again until the 2006 census).

One difference with Newman and Kenworthy's methodology is made necessary by time and resource constraints. Newman and Kenworthy included all urban areas within the boundaries of the broader statistical regions in their density figures, for example including San Bernadino in Los Angeles. Because there are so many smaller urbanised areas, the following data is based on the central urban area only, which usually accounts for the great majority of the urban population. This difference makes the density figures for the US and Australia slightly higher than those of Newman and Kenworthy, but is unlikely to significantly affect the rankings of different urban areas.

The results are set out in Table 1, using figures from the most recent census in each country: 2006 in Australia and Canada, 2000 in the United States. Because there are so many metropolitan areas in the USA relative to Canada and Australia, only the largest have been included. The urban areas have been arranged in order of overall urban density, from highest to lowest.

Table 1 *– Overall urban density versus transport mode for the journey to work, 2000/2006*

City	Country	Population	Density (per hectare)	Car %	Public Transport %	Walking %	Cycling %	Other %
Los Angeles	US	16,373,645	27.3	91.1	4.7	2.7	0.6	1.1
Toronto	CA	5,113,149	27.2	71.1	22.2	4.8	1.0	0.9
San Francisco	US	4,123,740	27.0	84.2	9.7	3.4	1.1	1.4
San Jose	US	1,682,585	22.8	Included in San Francisco data: see notes.				
New York	US	21,199,865	20.5	67.6	24.8	5.7	0.3	1.6
Sydney	AU	4,119,189	20.4	71.2	21.2	4.9	0.7	2.0
Montreal	CA	3,635,571	19.8	70.4	21.4	5.7	1.6	0.9
New Orleans	US	1,337,726	19.7	89.3	5.4	2.7	0.6	1.4
Las Vegas	US	1,563,282	17.7	91.2	4.1	2.4	0.5	1.4
Ottawa	CA	846,802	17.2	68.1	21.2	7.6	2.2	0.9
Vancouver	CA	2,116,581	17.2	74.4	16.5	6.3	1.7	1.1
Miami	US	3,876,380	17.0	92.7	3.9	1.8	0.5	1.1
Melbourne	AU	3,592,592	15.7	79.3	13.9	3.6	1.3	1.9
Denver	US	2,581,506	15.4	91.4	4.4	2.5	0.7	0.8
Chicago	US	9,157,540	15.1	83.9	11.5	3.2	0.3	1.0
Sacramento	US	1,796,857	14.6	92.3	2.7	2.3	1.4	1.0
Winnipeg	CA	694,668	14.3	78.7	13.0	5.8	1.6	0.9
Calgary	CA	1,079,310	14.0	76.6	15.6	5.4	1.3	1.0
Phoenix	US	3,251,876	14.0	93.4	1.9	2.1	0.9	1.4
Adelaide	AU	1,105,839	13.8	83.1	9.9	3.2	1.5	2.3
San Diego	US	2,813,833	13.2	91.2	3.4	3.5	0.6	1.4
Washington DC	US	4,923,153	13.1	86.5	9.4	3.0	0.3	1.0
Portland	US	2,265,223	12.9	89.4	6.0	3.1	0.8	0.7
San Antonio	US	1,592,383	12.6	93.6	2.8	2.4	0.1	1.2
Perth	AU	1,445,073	12.1	83.3	10.4	2.7	1.2	2.4
Detroit	US	5,456,428	11.9	95.3	1.7	1.8	0.2	0.5
Baltimore	US	2,552,994	11.7	Included in Washington DC data: see notes.				
Houston	US	4,669,571	11.4	93.9	3.3	1.6	0.3	1.1
Dallas	US	5,221,801	11.3	95.5	1.7	1.5	0.1	1.0
Victoria	CA	330,088	11.1	71.7	10.2	10.4	5.7	2.0
Philadelphia	US	6,188,463	11.0	86.1	8.8	4.0	0.3	0.8
Columbus	US	1,540,157	11.0	94.3	2.2	2.5	0.2	0.5
Seattle	US	3,554,760	10.9	87.7	7.0	3.3	0.6	1.4
Canberra	AU	368,129	10.8	82.0	7.9	4.9	2.5	2.7
Cleveland	US	2,495,831	10.7	93.7	3.4	2.1	0.2	0.6
Milwaukee	US	1,689,572	10.4	92.7	4.0	2.8	0.2	0.6
Hobart	AU	200,524	10.3	82.6	6.4	7.6	1.1	2.3
Minneapolis	US	2,968,806	10.3	91.8	4.5	2.5	0.4	0.6
Virginia Beach	US	1,569,541	10.2	93.7	1.8	2.7	0.3	1.6
Edmonton	CA	1,034,945	10.1	82.8	9.7	5.1	1.1	1.2
Orlando	US	1,644,561	9.9	95.4	1.6	1.3	0.4	1.1
Tampa	US	2,395,997	9.9	94.9	1.3	1.7	0.6	1.1
St. Louis	US	2,603,607	9.7	95.2	2.3	1.6	0.1	0.7
Brisbane	AU	1,763,129	9.2	78.6	13.8	3.7	1.1	2.8
Providence	US	1,188,613	9.0	93.1	2.4	3.3	0.2	0.7
Boston	US	5,819,100	8.9	85.1	9.0	4.2	0.4	0.9
Kansas City	US	1,776,062	8.9	96.0	1.2	1.4	0.1	0.8
Cincinnati	US	1,979,202	8.6	94.1	2.6	2.3	0.1	0.7
Indianapolis	US	1,607,486	8.5	96.0	1.2	1.7	0.2	0.8
Pittsburgh	US	2,358,695	7.9	88.8	6.2	3.7	0.1	0.6
Atlanta	US	4,112,198	6.9	94.2	3.6	1.3	0.1	1.1
Charlotte	US	1,499,293	6.7	96.6	1.3	1.2	0.1	0.8

Sources: Australian and Canadian Census 2006, US Census 2000

Notes:
• Population and mode share figures are for the entire census area, density is for urban area only, except for the following US regions: San Francisco Consolidated Metropolitan Statistical Area includes San Jose urban area, and Washington CMSA includes Baltimore, so Metropolitan Statistical Areas figures have been used for population (unfortunately, mode share figures were only available for the larger CMSAs).
• 'Car' includes car passenger and truck; 'other' includes motorcycle and taxi (counted as public transport in some US studies).

The density and transport table

The results are very different from what might have been expected. Far from being the archetype of sprawl, Los Angeles has the highest density of any urban area in the table, just edging out Toronto and San Francisco, and significantly higher than other Canadian and US cities. LA is considerably denser than all Australian cities, even allowing for the understatement of the Australian figures created by the differing definition of urban areas. By contrast, Portland, Oregon has less than half the density of the City of the Angels, with a lower figure than most Australian cities. And there are other surprises: Boston's density is much lower than Las Vegas or Phoenix, as is Brisbane's.

The US and Australian results are consistent with those reported by Newman and Kenworthy: all editions of their data-set show Los Angeles having a higher density than any other city in the US or Australia. The big difference comes with the Canadian figures – which, it should be recalled, are compiled on a virtually identical basis to those for US cities. The problem here seems to have been that Newman and Kenworthy's Canadian city densities were calculated on a 'net residential', rather than 'overall urban' basis, as we saw above in the case of Toronto. This made the Canadian densities seem much higher than those in Australia and the United States, when in reality they are much the same.

One thing the results make clear is that high-rise city cores are not good predictors of overall urban densities. New York City does have a high urban density, but its 8 million residents are surrounded by 13 million suburbanites, many of whom live in very spacious surrounds. The City of Los Angeles is less dense than New York City, but its suburbs are considerably more dense than those of the Big Apple. In each case, the suburbs, which house the majority of the population, have the biggest impact on the overall result. Robert Bruegmann (2005, pp. 67-8) points out that the high suburban densities of West Coast US cities are partly due to their dependence on piped water, which prevents the very scattered, 'ex-urban' development found along much of the East Coast.

Australian cities are more like Los Angeles than New York. Their central regions have lower densities than those of older North American cities, but their suburbs generally have higher densities, thanks to stronger regional land-use planning, which has restricted scattered fringe development. Brisbane, with a weaker tradition of regional planning, has a significantly lower density than any other large Australian urban area.

The densities of Australia, Canadian and US cities are more similar than has generally been believed, and bear little relationship with the amount of high-rise development in their centres. They also show little relationship with public transport use. Los Angeles is three times as dense as Brisbane, but public transport's share of work trips is only a third as high; New York's density is nearly a third lower than San Francisco's, but the mode share for public transport is more than twice as high. Portland, Oregon has a higher public transport mode share than Los Angeles despite its much lower density, but with only 6 per cent of workers using public transport, Portland is less successful than any Australian or Canadian city.

The US cities, apart from New York, have the lowest rates of public transport use and the Canadians the highest, with Australia in-between. The same national patterns are apparent for walking rates, which are generally highest where public transport use is highest. Smaller cities tend to have more walking than larger ones; they also tend to have lower densities. Cycling is of negligible importance across all three countries, but a similar pattern applies to that with walking: the Canadian figures are highest, despite the country's inclement weather.

Car usage rates are, naturally, the reverse of the other modes, lowest in Canadian cities and New York; highest in the United States. Again, density is a poor predictor of car usage rates: New York and Ottawa are the only cities where the figure is below 70 per cent, but do not have particularly high densities. Victoria British Columbia, a small relatively low-density city, is noteworthy for its high walking and cycling rates, which together with respectable public transport usage produce a comparatively low rate of automobile use.

Analysing the data

The data in Table 1 can be analysed more closely using regression analysis, the same methodology employed by Newman and Kenworthy to create the graph in Figure 1 and its predecessors. Figures 2, 3, 4 and 5 below set out the results, with density plotted against the share of work trips made by public transport (Figure 2), walking and cycling (Figure 3), all 'sustainable modes' – i.e. walking plus cycling plus public transport (Figure 4) and private cars (Figure 5).

***Figure 2** – Public Transport versus Urban Density*

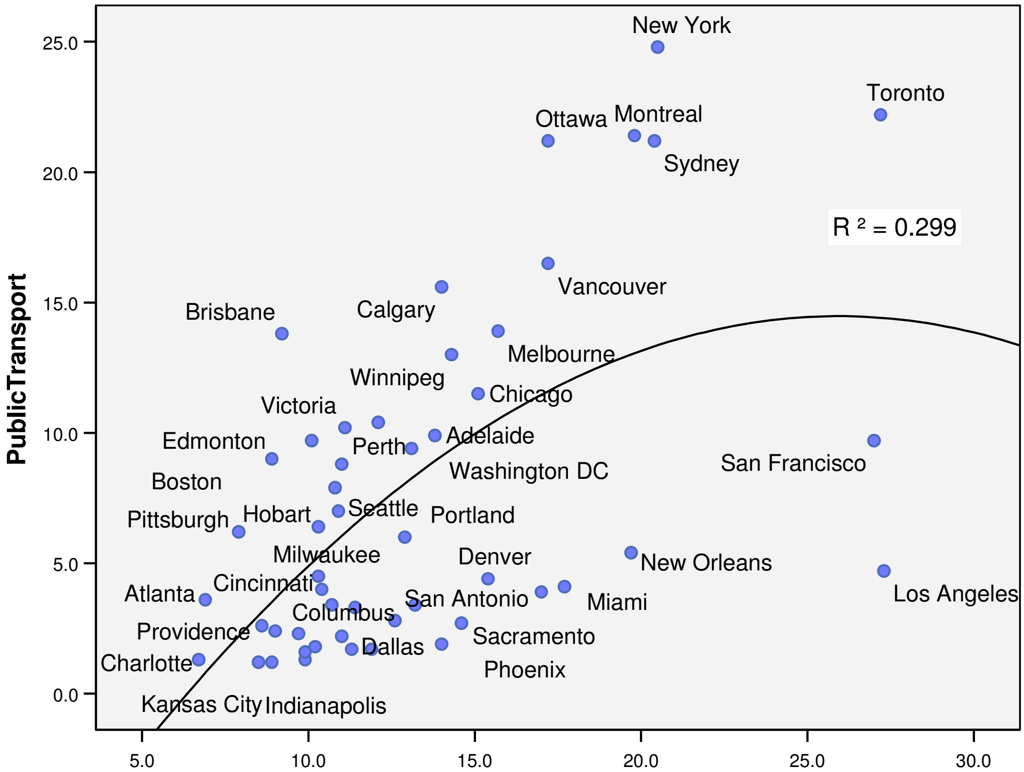


***Figure 3** – Walking and Cycling versus Urban Density*

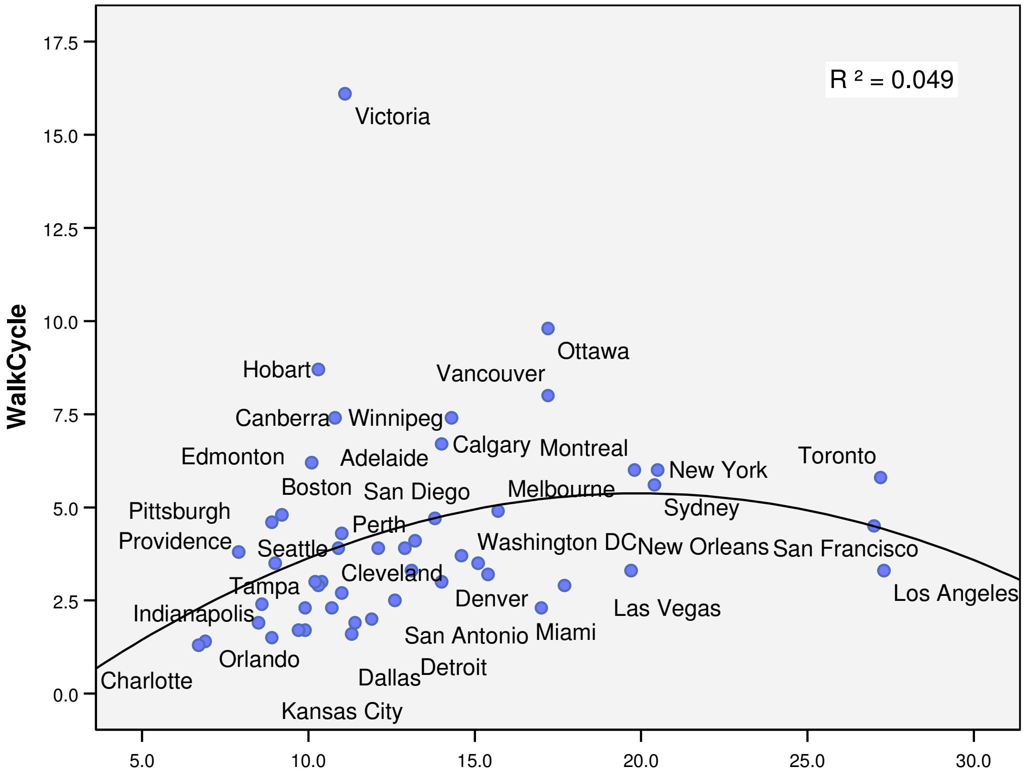


Figure 4 *– Sustainable Transport versus Urban Density*

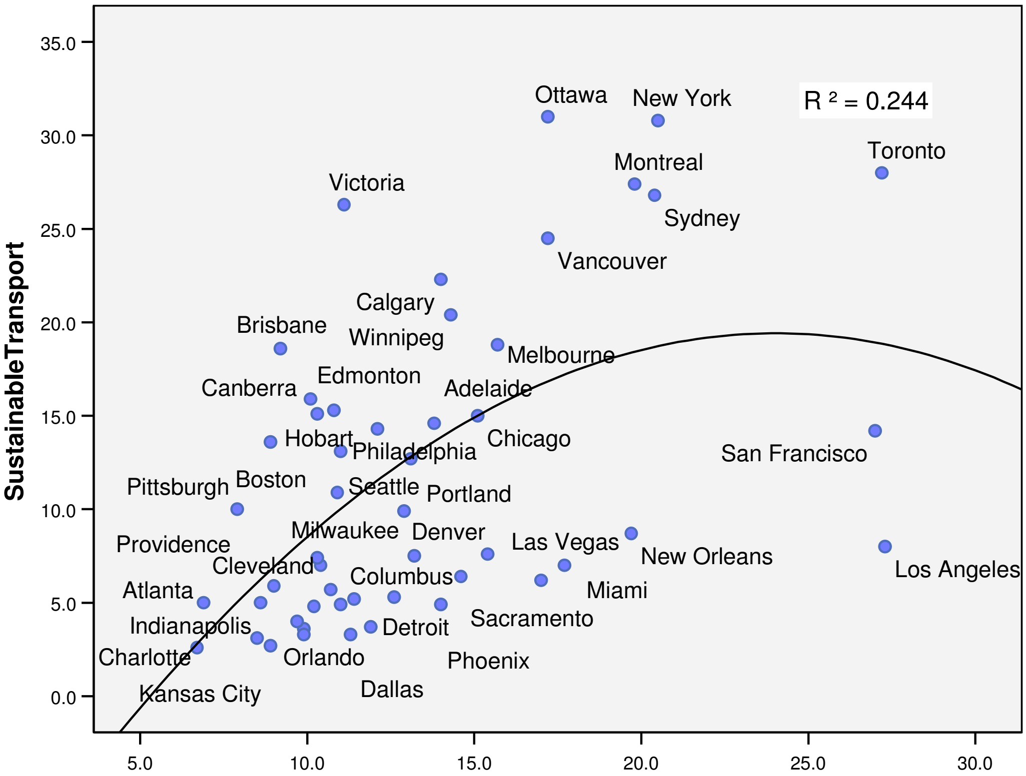
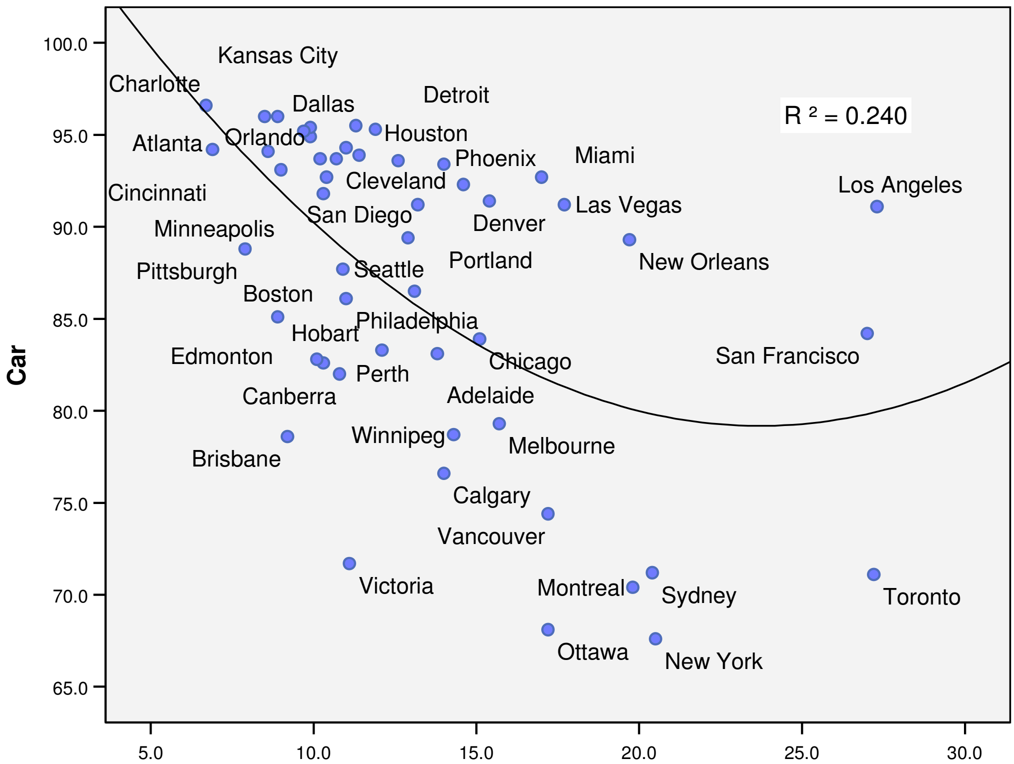


Figure 5 *– Private Car Use versus Urban Density*



The results are very different from those obtained by Newman and Kenworthy. There is little correlation between density and the use of public transport, sustainable modes or the car, with R-squared numbers around 0.3, compared with the 0.8 to 0.9 found by Newman and Kenworthy. And there is no correlation at all for walking and cycling, with an R-squared below 0.1.

With such low figures, the shapes of the curves are largely irrelevant, but it should be noted that there is no evidence of a threshhold at which automobile use takes off or sustainable modes collapse. In fact, the pattern is the reverse of this, with sustainability declining above 20 to 25 persons per hectare due to the influence of relatively dense US cities like Los Angeles and New Orleans. It is also noteworthy that all bar one of the cities below the curves for sustainable modes (Figures 2, 3 and 4) and above the curve for automobile use (Figure 5) are US cities: the Australian and Canadian cities lie on the other side of the curve, with the Canadian cities further from it.

So the regression analysis confirms that density is not responsible for the differing transport performance among the three countries' cities. Instead, it confirms that US cities apart from New York perform poorly from a sustainability perspective, Australian cities are somewhat better and Canadian cities perform best – regardless of density.

DISCUSSION OF RESULTS

Urban form or structure?

So what is responsible for the differences in transport performance if not density? Mindali et al (2004) found that the share of employment in the Central Business District (CBD) was strongly (negatively) correlated with automobile usage, suggesting that urban structure is more important than urban form (cf. Thomson, 1977). It has not been possible to assess this connection using the data and methodology employed here, because while the Australian, Canadian and US census agencies have agreed on comparable definitions of urbanised areas, they have not done so for the CBD; in addition, only the Australian Bureau of Statistics publishes census data giving CBD employment levels.

Australian and Canadian cities are more strongly centralised than US cities, except for New York, which in this respect is more like an Australian or Canadian urban area. It is easy to understand why strongly centralised urban regions might see greater usage of public transport, although the connection with walking and cycling is less obvious. But Australian cities are more centralised than their Canadian counterparts (see Mees, 2000, ch. 7 for a detailed discussion of Melbourne and Toronto), while Vancouver, which is not the Provincial capital and has an awkwardly-sited CBD, is a 'weak-centred city' like many US counterparts.

There is some evidence that the superior performance of Canadian cities relative to their Australian counterparts is due to higher use of sustainable modes, particularly public transport, by workers employed in non-central locations, rather than the share of workers employed in the CBD or their travel behaviour. In all metropolitan areas across the three countries, the great majority of workers are employed outside CBDs, and an even greater majority of non-work travel is to non-central locations. So the travel choices of suburban workers have more influence on the overall result than do those of CBD workers.

A Statistics Canada report on the 2001 Canadian census gives detailed data on mode choice for CBD and suburban workers. The share of CBD workers using public transport was 59 per cent in Toronto and 55 per cent in Montreal (Statistics Canada, 2005, p. 51), similar to the 56 per cent figure for Melbourne CBD workers at the 2006 census (ABS, 2008: data for 'Melbourne-Inner' plus 'Melbourne–Docklands/Southbank'). But the share of workers in suburban employment clusters using public transport was much higher in the Canadian cities, ranging from 9 to 36 per cent in Toronto and 11 to 28 per cent in Montreal, compared with a range of 3 to 8 per cent for Melbourne. As a result, while CBD workers accounted for 43 and 38 per cent of public transport commuters in Toronto and Montreal, they accounted for 51 per cent in Melbourne.

The reasons for public transport's greater effectiveness in serving the suburban market in Canada, and the links to higher rates of walking and cycling, are beyond the scope of this paper, but are discussed in Mees (2010).

Space does not permit a detailed analysis of UK and European density figures, which are discussed in Mees (2010, chapter 4). However, the broad pattern is that British urban densities are higher than those in Europe, thanks to the stronger control over suburban sprawl provided by the UK planning system. British cities are more like Los Angeles, with relatively even densities; many European cities are more like New York, with high central densities surrounded by low-density, scattered suburban development (EEA, 2006).

The UK Office for National Statistics defines a series of 'major urban areas', but uses a different methodology to that employed by in Australia and North America, resulting in higher density figures. Instead of aggregating small census areas, the ONS directly measures the extent of urbanisation, using satellite imagery and maps (ONS, 2005, chapter 3). Interestingly, the Swiss Federal Statistical Agency appears to use a similar methodology to the ONS in delineating land areas, so British and Swiss density figures can be compared, at least broadly. The densities of English major urban areas range from a low of 32 persons per hectare in Teeside to a high of 51 per hectare in London. By comparison, the density of the urbanised portion of the Canton (State) of Zurich – which covers Zurich city, suburbs and ex-urns – is approximately 38 per hectare (calculated from SFSO 2009), towards the lower end of the UK figures, and below Merseyside (44 per ha) and Greater Manchester (40). But the shae of work trips made by public transport in Canton Zurich is more than double the average for UK cities, except for London.

Conclusions

The data used in this paper has multiple limitations, arising from the following factors:

• the US figures date from 2000, while those for Australia and Canada date from 2006

• the three countries do not employ exactly the same definitions of urban areas, which means the Australian figures are under-stated relative to the other countries

• densities have been calculated for the principal urbanised area within each statistical region, whereas ideally 'satellite' areas should also be included; and

• mode share figures are for the journey to work only, rather than for all travel.

Nevertheless, despite the limitations, the data in Table 1 suggests the need for a serious re-examination of the 'compact city' solution to mode shift. This will require additional work to address the limitations mentioned above, and will become easier once data from the 2010 US census and 2011 Australian and Canadian censuses becomes available.

There is no doubt that very large differences in density can influence transport patterns. Hong Kong's very high density is a major reason why automobile use is so low: if the city somehow became as spacious as Boston or Brisbane, car usage rates would increase. But the question for policy-makers is whether changes in density of the kind that might be possible in real urban environments will significantly influence mode share.

On this question, the answer appears to be in the negative. The compact city is not the solution to the problem of automobile dependence. Many decades of compact city policies might make Ottawa as dense as Los Angeles is now, or Brisbane as dense as Las Vegas, but changes like this are unlikely to produce significant shifts to metropolitan-wide travel patterns. This analysis supports the suggestion made 15 years ago by the UK Royal Commission on Environmental Pollution: 'there is no single pattern of land uses that will reduce the need for travel, and so reduce the effects of transport on the environment' (RCEP, 1994, p. 151). Similarly, the notion that effective public transport cannot be provided in areas with densities below 100 or even 30 persons per hectare appears to be incorrect.

These findings should be good news for policy-makers and others concerned about problems like global warming and oil security. They suggest that transport policy, which can be changed more rapidly and with less expense and controversy than urban density, is a more important influence on outcomes (see Mees, 2010). It might even be possible to make the necessary changes in time to save the planet.

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