DENSITY AND TRANSPORT MODE CHOICE IN AUSTRALIAN, CANADIAN AND US CITIES

Keywords: Transport planning; urban density; mode choice; journey-to-work

Author: Dr. Paul Mees
Senior lecturer in transport planning
School of Global Studies, Social Science and Planning
Royal Melbourne Institute of Technology
GPO Box 2476V
Melbourne, 3001.

paul.mees@rmit.edu.au
03 9925 5243

Bio: Paul Mees is a senior lecturer in transport planning at RMIT, Melbourne. He is the author of *A Very Public Solution: Transport in the Dispersed City* (Melbourne University Press, 2000) and *Transport for Suburbia: Beyond the Automobile Age* (Earthscan, London, 2009: to be release in early December).

ABSTRACT

This paper re-examines the relationship between population density and transport mode choice, taking another look at the ideas that have come to be known as the 'compact city'. It begins by reviewing the origins of the view that density determines mode choice, and that viable public transport cannot be provided below a density threshold variously estimated at 30 to 100 persons per hectare. The claim has been widely made, but an examination of the alleged basis reveals multiple layers of citation ultimately deriving from a single source, the Chicago Area Transportation Study 1956. The CATS analysis erroneously attributed poor suburban public transport to low densities, when the real causes were failures of planning and policy. The paper then reviews the more recent data provided by Newman and Kenworthy, who found a similar relationship to that reported in CATS. Use of the most recent census data from Australia, Canada and the United States suggests that the Newman-Kenworthy data contained errors in the estimation of urban densities. When these are corrected, the results reveal only a very weak correlation between density and public transport use, and no correlation at all with walking and cycling. The paper concludes that the 'compact city' notion is not substantiated by evidence.

INTRODUCTION

The relationship between population density and the share of travel by different modes has been a mainstay of the transport and urban planning literature, with mode split generally regarded as an outcome of density. As a result, the most popular recipe for mode shift away from the automobile is the 'compact city', or 'smart growth' as it is called in the United States. This paper questions the assumptions behind the compact city recipe for mode shift, by re-examining the historic and contemporary evidentiary basis for it. Interestingly, increasing city densities was originally advocated as a way to facilitate, rather than reduce, the dominance of the car.

DENSITY AS DESTINY

When automobiles began to appear in large numbers in the 1920s, urban planners were unsure how to respond. The most radical proposal came from the French architect Le Corbusier. In his 1924 book *The City of To-morrow and Its Planning*, Le Corbusier argued:

> In Paris… the combined superficial area of the vehicles using the roads is actually greater than that of the roads themselves… And where do all these motors go? To the centre. But there is no proper superficial area available for traffic in the centre. It will have to be created. The existing centres must come down (Le Corbusier, 1971, pp. 116-7).

'We must decongest the centres of our cities', Le Corbusier said, 'by increasing their densities.' Skyscrapers would be built on stilts so the ground could be covered with car parking, served by elevated freeways. 'Running north and south, and east and west… there would be great arterial roads for fast one-way traffic built on immense reinforced concrete bridges 120 to 180 yards in width and approached every half-mile or so by subsidiary roads from ground level.' Underneath the roads and parking, railways would run in tunnels, but trams would be abolished. 'The tramway has no right to exist in the heart of the modern city' (pp. 164-5).

By the end of the Twentieth Century, the argument had been reversed. The low-rise city came to be seen as intimately linked with the car, and public transport – especially light rail – with high densities. By the 21st century, the Le Corbusian skyscrapers invented to make room for cars were routinely presented as the antidote to automobile dependence.

An important step in this process came with the Chicago Area Transportation Study 1956 (CATS), the first major computerised transport and land-use study. CATS was directed by Dr. J. Douglas Carroll Jr, a sociologist from of the University of Michigan, and ran from 1955 to 1962. The study began with an 'inventory', or survey, of land use and transport in the greater Chicago region in 1956. 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 (Yago, 1984, chapter 6; Flink, 1988, pp. 362-4). 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 (vol. 1, 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.

THE COMPACT CITY

Cars and suburbs seemed to have developed together in the United States, while public transport held its own mainly in European cities, which remained much denser. The contributions made by different urban transport histories and policies, including the European tradition of public ownership of public transport, have been largely forgotten. Even critics of automobile dominance accepted the overwhelming importance of urban form, with the result that the 'compact city' has emerged as the most popular prescription for planning 'sustainable cities'.

The idea is not new. The Chicago Area Transportation Study canvassed it half a century ago, citing unnamed writers who 'argue that the suburban dweller should be prevented from stretching out into quarter acre lots because a high density, compact city would be more efficient'. So 'why not control land use and density so as to

control the level of mass transportation usage?' The study team's answer was that people prefer dispersed living and would be unlikely to accept measures to restrain densities. 'A more reasonable position is that people, acting in their own interests in a relatively free society, are gradually evolving their desired environment' (vol. 2, pp. 73, 53-4).

As concern about the environmental and others problems of automobile dependence grew, the reasonableness of this position was increasingly questioned. Contemporary advocates of the compact city have the opposite view of car dominance to the Chicago transport planners of the 1950s, but their recipe for change accepts the same logic, namely that unless densities are substantially increased, alternatives to the car are impossible. Environmentalists who argue in this manner can unintentionally provide support for the continuation of unsustainable transport policies.

This problem can be seen in the United Kingdom today. Outside London, urban public transport is extremely unattractive and offers no serious competition to the car, for reasons discussed in Mees (2009). But many British advocates of sustainable transport seem more interested in higher-density housing than in fixing public transport. The dominant view is presented in *Building the 21st Century Home*, a widely-used guidebook published in 1999:

> 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 transport policies are not the main barrirs to improved public transport; density is the problem. Apparently, development densities need to double just to make bus services possible, and to increase five-fold before Britons can think about trams. Quite simply, this is never going to happen. This an argument for giving up on alternatives to the car.

So where do the density figures come from? The report cited as the source, published by the Local Government Board but written by academics from the University of the West of England in Bristol, does specify 100 residents per hectare as the minimum density for buses, but I could find no reference in it to a minimum for trams (Barton et al, 1985, p. 80). The report did not 'estimate' the bus figure, however; it simply cited White (1976) as the source. White's only mention of a specific density threshold comes in a sceptical discussion of the then-new concept of 'dial-a-bus', which refers to un-named American consultants who believe it requires 'about twenty to forty persons per acre' (50 to 100 per hectare). White omitted the figure from later editions of the book, noting that dial-a-ride was a high-cost mode and most services have been withdrawn (White, 1976, p. 112; cf. White, 2002, p. 97). So the supposed density requirement for buses is not the result of estimation or calculation at all, while the higher figure for trams seems to have emerged from thin air.

In the process of migrating to the UK, the CATS/Clark figure mysteriously doubled for buses and increased five-fold for trams. It also became gospel, and is now cited in almost any discussion of sustainable cities in the UK. For example, the Commission for Architecture and the Built Environment endorsed the 100 for bus and 240 for tram figures in 2005 Better Neighbourhoods, even arguing that 275 people per hectare is a 'sustainable urban density' – bad news for the City of Paris, with only 250 (CABE, 2005, p. 7).

Britain is not the only place where low densities are said to create insuperable problems for public transport. The American architectural historian Robert Bruegmann writes in his 2005 book *Sprawl*: 'It appears that 10,000 people per square mile [39 per hectare] is a threshold for the extensive use of public transportation systems'. Although Bruegmann never mentions CATS in his book, he derives his threshold from the gross density of the City of Chicago, on the basis that it and New York are the only US cities where public transport is used extensively (Bruegmann, 2005, p. 55). Alan Moran, from the Australian free-market think-tank the Institute of Public Affairs, offers the highest figures of all. 'A rule of thumb is that rail-based systems require 40,000 people per square kilometre [400 per hectare] to be viable. … Express bus systems need 26,000 per square kilometre [260/ha]' (Moran, 2006, p. 15). No source is cited for these figures.

Arguments that densities many times current levels are needed before transport trends can change are really arguments for continuing with automobile dependence. Bruegmann and Moran intend us to draw this conclusion, and while other commentators seek to encourage higher-density development, the main effect of their arguments is to provide support for the advocates of autopia.

THE DENSITY DEBATE IN AUSTRALIA

The leading academic advocates of the compact city as a response to automobile dependence are Professors Peter Newman and Jeff Kenworthy, based for many years at Murdoch University, but now at Curtin University. Their pioneering study of cities and transport began after the oil shock of the 1970s and culminated in 1989 with publication of *Cities and Automobile Dependence* and supporting papers in planning journals. *Cities* and its 1999 update *Sustainability and Cities* set the terms for the debate over density in the last two decades, coining the term 'automobile dependence', reviving the idea of the compact city as the response, and establishing the multi-city comparison of transport and urban form as the methodology for investigating the issue (Newman & Kenworthy, 1989; 1999; Kenworthy et al, 1999; 2001).

Compared with Moran and the British density enthusiasts, Newman and Kenworthy are moderates, suggesting the critical threshold is around 30 per hectare, rather than 100 or more. This figure was, as we have seen, derived from the Chicago Area Transportation Study via Colin Clark, but Newman and Kenworthy corroborated it with their comparison of densities and automobile use across a range of cities and countries. The comparison was expressed as a much-reproduced graph showing a hyperbolic relationship in which car use increases exponentially once densities drop below about 30 per hectare. Hong Kong had the highest density and lowest energy

use; Houston the lowest density and highest energy use. Interestingly, an almost identically-shaped graph, comparing car trip-making and density in different parts of Chicago, appears in the first volume of the CATS report (p. 61).

The compact city thesis has been debated for more than two decades, and the debate may have produced more heat than light. David Banister (2005, p. 98 & chapter 6) offers a comprehensive review of the literature, observing that much of the analysis has been 'very simplistic in its approach', and concluding that 'the situation is very much more complex than is often argued.'

Some compact city critics have questioned the quality of Newman and Kenworthy's data, generally without offering anything better to replace it – the principal exception here is the American transport and planning critic Wendell Cox (see his website www.demographia.com). With each successive edition of the database, now in its third iteration, Newman and Kenworthy have corrected errors and omissions as well as expanding the range of cities reported. Interestingly, over time their figures have converged with those of Cox.

Not all critics of the compact city are advocates of the automobile. Professor Ian Lowe is President of the Australian Conservation Foundation, and author of *Living in the Hothouse* (2005), a plea for serious action to combat climate change. But Lowe also understands the attractiveness of leafy suburbs, and the equity issues involved:

> This comparatively uncrowded urban form is one of the aspects of Australian urban lifestyle which appeals to those of us who have lived in the northern hemisphere. I live in a Brisbane suburb, ten minutes bicycle ride from Griffith University and near an express bus route which takes twelve minutes to the city centre, but in a quiet street backing onto bush. I am more likely to be awakened by rainbow lorikeets than traffic. Few of the world's cities offer such a lifestyle to any but the very rich (Lowe, 1994, p. 30).

Lowe acknowledges that the current transport pattern in Australia 'fails on all three criteria of sustainability.' Change is needed, but Lowe would like it to happen without depriving ordinary Australians of quiet streets backing onto bush. He seems unsure about how this might be accomplished.

Other Australian urbanists share Lowe's concerns. Pat Troy of the Australian National University penned *The Perils of Urban Consolidation*, a swingeing rebuttal which indicts the compact city on efficiency, equity, environmental and democratic grounds. The economic historian Hugh Stretton shares these concerns and adds a political argument. 'Australians would rather lose their cars than lose their cars and their houses. However hard it may be to get them to trade their big cars for little ones... or to give them up altogether, it would be harder still to get them to do it by first giving up their houses and gardens and neighbourhood parks and playing fields' (Stretton, 1993, p. 136).

Stretton advocates a modern version of Ebenezer Howard's 'garden city' – 'poly-centred conurbations in which land is used generously for housing but more densely for many public and commercial uses' (Stretton, 1975, pp. 5-6), with efficient public transport connecting the centres. This alternative version of the sustainable city is

championed as an antidote to global warming by Gleeson (2008), but it appears to be a minority taste among 21st-century urban planners.

Troy's most telling criticism of compact city advocacy is that correlation is not the same as causation. Walking and public transport use tend to be higher the closer one comes to the city centre, for a variety of reasons: the share of trips made to the centre (the best-served destination by public transport and the hardest to reach by car) increases; municipally-provided public transport is usually better in the central municipality (as in 1950s Chicago); and radial public transport routes converge, reducing walking distances to stops and stations. Car use rises with distance from the centre even in cities with uniform densities, such as Canberra. Since density also declines with distance from the centre in most cities, then there will appear to be a relationship between density and car use. But this correlation does not prove causation: the number of fire engines sent to a fire correlates strongly with the amount of damage done by the fire, but sending fewer crews will not reduce the damage bill.

There is no doubt that very large differences in density do affect transport patterns. It would be impossible for the car to dominate travel in Hong Kong or Manhattan, no matter how much effort was devoted to the task. Conversely, in spacious cities like Houston and Canberra, it is possible to plan on the basis that cars will dominate. So the general relationship shown in Newman and Kenworthy's famous graph is undoubtedly correct. But Houston is never going to become Hong Kong or anything like it: that would require demolition and rebuilding on a Corbusian scale. The question is whether achievable changes in density are likely to make a significant difference, and here the evidence is less compelling.

ANOTHER LOOK AT THE DATA

In 2004, a team of Israeli researchers re-examined the Australian and US cities in the original *Cities and Automobile Dependence* data-set. Their analysis, replete with a reproduction of the famous hyperbola, found no correlation between density and energy consumption: the US cities had similar densities to the Australian cities, but much higher car and energy use (Mindali et al, 2004). The Newman and Kenworthy graph actually shows that Australian cities' car use rates are closer to those of the European cities than to the US cities, despite the large differences in density.

More recently, Rickwood and Glazebrook (2009) analysed the relationship between density and public transport's share of work trips in Australian cities at the census collection district (CD) scale (CDs are the smallest units for which the Australian Bureau of Statistics reports census data). They concluded that 'moderate increases in local area densities, without changes to transport infrastructure, will result in no change in transit use' (p. 185), but that larger changes in the long term may have an impact. One interesting aspect of the Rickaby and Glazebrook study was the development of a different methodology for estimating urbanised areas, and therefore densities, from that used by Newman and Kenworthy. Kenworthy estimated the urban areas of Australian cities from maps and satellite images, but Rickaby and Glazebrook aggregated all CDs with a density of 5 or more persons per hectare.

The Australian Bureau of Statistics has employed a similar methodology to delineate urbanised areas since the 1960s, based on Linge (1965). The main differences are that the ABS methodology uses a lower threshold of 2 persons per hectare, and also includes non-residential CDs that are surrounded by, or contain land uses that relate closely to, residential CDs (ABS, 2005). Rickaby and Glazebrook did not use the ABS methodology, as it necessarily involves the inclusion of some non-residential land (p. 174), but it has the advantage of enabling international comparisons. The reason for this is that Statistics Canada and the US Census Bureau employ a similar methodology to that of the ABS for delineating urbanised areas (Puderer, 2009; US Census Bureau, 2007), although with a higher density threshold of 4 persons per hectare (in the US, 1000 per square mile, or 3.86 per hectare).

Newman and Kenworthy actually used the 'urbanized area' data from the US Census Bureau to estimate the densities of US cities for their database, but did not use the equivalent Canadian or Australian figures, as the land areas of these units were not published until the 2006 censuses. It is now possible to compare the densities of urban areas across the US, Canada and Australia on a consistent basis – subject to the qualifications that the US figures are from the 2000 census, while the others are from 2006, and that the lower threshold for Australian cities under-states densities somewhat relative to the North Americans. As each country's census also includes a question about the mode of travel for the journey to work, it is also possible to compare mode shares across the three countries. Although each country's census reports the mode share data slightly differently (for example, the US figures include taxis in 'public transport'), more detailed data is available which allows these differences to be corrected for, producing figures that can be compared. While work trips only account for a minority of travel, they provide a consistent basis on which a wide range of cities can be compared: by contrast, surveys of overall travel are conducted in different years, often using different methodologies.

The results are set out in table 1, with urban areas arranged in order from most to least densely-populated. Because there are so many cities in the United States, only the largest have been included.

Table 1. *Density and method of travel to work in US, Canadian and Australian cities (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 truck; 'other' includes motorcycle and taxi (counted as public transport in some US studies).

The results cast serious doubt on the idea that density determines transport patterns, because the urban area with the highest density of all – even allowing for the understatement of the Australian figures – is Los Angeles, the archetype of automobile dependence. Brisbane, with barely a third Los Angeles' density, has three times as much public transport use, and more walking and cycling. The lowest rate of car use is in New York, which has a relatively high density, but one considerably below Los Angeles, San Francisco and San Jose. However, if taxis (counted in 'other' and used extensively in New York) are included with cars, then Ottawa has the lowest car use. But Ottawa's density is not particularly high, being lower than Sydney's, and probably about the same as Melbourne's when allowance is made for the different Australian density threshold.

Another surprising city is Portland, Oregon, hailed among urban planners as a model of 'smart growth' and 'transit-oriented development'. Its density is barely half that of Los Angeles, and lower than Adelaide's, although its public transport mode share, at 6 per cent, is higher than the City of the Angels. Although Portland showed the largest increase in public transport mode share of any US city between the 1990 and 2000 censuses (a full percentage point), its 2000 performance shown in Table 1 is lower than any Canadian or Australian city, even Canberra and Hobart. It is not clear why Portland should be regarded as a mode of either smart growth or successful public transport in Canada or Australia.

The US density figures in Table 1 are similar to those reported by Kenworthy et al (1999; 2001), which is unsurprising, since they come from the same source. The Australian figures in Table 1 are significantly higher than Kenworthy's, because the census methodology counts less non-residential land as 'urban'. The biggest difference comes with the Canadian cities, where the census densities are much lower than those reported by Kenworthy et al. The reason for this appears to be that Kenworthy's Canadian figures were 'net' or 'residential' figures that excluded non-residential land mixed in with residential land. This can be seen clearly from their map of Toronto (Kenworthy et al, 1999, p. 375), which shows parks, cemeteries and Toronto and York Universities as 'non-urban' land.

The census data confirms Newman and Kenworthy's finding that US cities are the most automobile-oriented, followed by the Australians, with Canadian cities least auto-oriented. The Canadian cities have the highest rates of walking and cycling, as well as public transport use, the US cities the lowest. But the census data does not show a similar pattern with densities: the three countries' cities are surprisingly similar, with the largest differences being between cities in the same country. And importantly, the differences in density do not correlate closely with differences in mode share: there is a very weak relationship between density and public transport mode share, and no relationship at all between density and walking/cycling.

Brisbane and Boston have relatively high rates of public transport use despite very low densities; Victoria, the capital of British Columbia, has surprisingly low automobile use despite its low density, thanks to a combination of respectable public transport use with high rates of walking and cycling.

It has not been possible to include European cities in this comparison, because that country's statistical agencies do not publish comparable data on urban densities.

However, it can be observed that most of the European figures covered in the Newman-Kenworthy databases appear to be for central cities only, rather than entire urban areas, because of the difficulty of obtaining data for the true urban area (Kenworthy et al, 1999, pp. 27-32). Since central cities are usually denser than their suburbs, this means the apparent large difference between European urban densities and those in Australia, Canada and the USA is at least partly an illusion. Kenworthy and his colleagues were able to obtain density estimates covering the entire urban region for some European cities, but these figures – 28.5 per hectare for Copenhagen and 24.0 for Oslo – are not that different from cities like Los Angeles, Toronto and San Francisco, and probably Sydney as well (allowing for the under-statement of the Australian figures).

CONCLUSIONS

The idea that urban density is the main determinant of the share of travel made by different modes, and that public transport cannot be operated effectively below a minimum density somewhere between 30 and 100 persons per hectare, rests on a very weak evidentiary base. It appears to have originated from the discussion of suburban bus services in the Chicago Area Transportation Study, but that discussion erroneously attributed to density a problem that was really the result of planning and policy failures. The more recent trans-national comparison by Newman, Kenworthy and colleagues appears to have under-estimated the densities of Australian and US cities relative to those in Canada and Europe. More recent Australian, Canadian and US census data suggests that, when measured accurately, population density is only very weakly related to public transport's share of work trips, while there is no link at all for walking and cycling.

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

• the US figures date from 2000, while those for Ausralia 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 date from the 2010 US census and 2011 Australian and Canadian censuses becomes available. The additional work is important, because transport policies are much easier to change than the urban densities of large cities, which alter only slowly and with great disruption and controversy. If transport policy is more significant than density in effecting change (Mees, 2000; 2009), then the environmental problems of urban transport may be easier to solve than has been widely believed. Alternatively,

the more ‘backyard-friendly’ path to urban sustainability advocated by Stretton and Gleeson may prove more effective than the compact city.

REFERENCES

ABS (Australian Bureau of Statistics) (2006). *Statistical Geography: Volume 1*. (Cat. 1216.0). Canberra.

Banister, D. (2005). *Unsustainable Transport: City transport in the new century*. London: Routledge.

Barton, H., Davis, G. & Guise, R. (1995). *Sustainable Settlements: A Guide for Planners, Designers and Developers*. Luton, Bedfordshire: Univ. of the West of England/ Local Government Management Board.

Bruegmann, R. (2005). *Sprawl: a compact history*. Chicago: University of Chicago Press.

CABE (Commission on Architecture and the Built Environment) (2005). *Better Neighbourhoods: Making higher densities work*. London: CABE.

CATS (Chicago Area Transportation Study) (1959, 1960, 1962). *Chicago Area Transportation Study: Final Report*, 3 vols. Chicago.

Clark, C. (1967). *Population Growth and Land Use*. London: Macmillan.

Creighton, R. L. (1970). *Urban Transportation Planning*. Urbana: University of Illinois Press.

Flink, J. (1988). *The Automobile Age*. Cambridge, Mass: MIT Press.

Gleeson, B. (2008). ‘Waking from the dream’, *Griffith Review* 20, 13-49.

Kenworthy, J. and Laube, F. (1999). *An International Sourcebook of Automobile Dependence in Cities, 1960 – 1990*. Boulder, CO: University Press of Colorado.

Kenworthy, J. & Laube, F. (2001). *The Millennium Cities Database for Sustainable Transport*. CD, Brussels: UITP.

Le Corbusier (1971). *Urbanisme*, 3rd ed, (1st ed 1924; English translation, 1929 as *The City of To-morrow and Its Planning*) London: The Architectural Press.

Linge, G. (1965). ‘The delimitation of urban boundaries for statistical purposes with special reference to Australia’, report to Commonwealth Statistician. Canberra: unpublished.

Lowe, I. (1994). ‘Transport and sustainable cities’, in K. Ogden & E. Russell (eds) *Australian Transport Policy ’94*, pp. 30-37. Melbourne: Montech Publishing.

Mees, P. (2000). *A Very Public Solution: Transport in the Dispersed City*. Melbourne: Melbourne University Press.

Mees, P. (2009). *Transport for Suburbia: Beyond the automobile age*. London: Earthscan.

Moran, A. (2006). *The Tragedy of Planning.* Melbourne: Institute of Public Affairs.

Newman, P. & Kenworthy, J. (1989). *Cities and Automobile Dependence: An International Sourcebook.* Aldershot, UK: Gower.

Newman, P. & Kenworthy, J. (1999). *Sustainability and Cities: Overcoming Automobile Dependence*. Washington DC: Island Press.

Puderer, H. (2009). *Urban Perspectives and Measurement*. (Cat. 92-F0138-M). Ottawa: Statistics Canada.

Rickwood, P. & Glazebrook. G. (2009). 'Urban Structure and Commuting in Australian Cities', *Urban Policy and Research* 27(2), 171-188.

Rudlin, D. & Falk, N. (1999). *Building the 21st Century Home*. Oxford: Architectural Press.

Stretton, H. (1975). *Ideas for Australian Cities* (2nd ed). Melbourne: Georgian House.

Stretton, H. (1993). 'Transport and the structure of Australian cities', *Australian Planner* 31(3), 131-136.

US Census Bureau (2007). Census 2000 Summary File 1: Technical Documentation. Washington DC.

White, P. (1976). *Planning for public transport*. London: Hutchinson.

White, P. (2002). *Public Transport: Its planning, management and operation*, 4th ed. London: Spon.

Yago, G. (1984). *The Decline of Transit: Urban transportation in German and U.S. cities, 1900 – 1970*. Cambridge: Cambridge University Press.