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Urban Design to Reduce Automobile Dependence

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Abstract

A major goal of urban design, especially in centers, is to reduce automobile dependence in order to address issues of viability and sustainability. Long-term data from cities around the world appear to show that there is a fundamental threshold of urban intensity (residents and jobs) of around 35 per hectare¹ where automobile dependence is significantly reduced. This article seeks to determine a theoretical base for what the data show. It suggests that below the threshold intensity of urban activity, the physical constraints of distance and time enforce car use as the norm. The basis of these physical constraints is outlined and the link between density and access to services that provide amenity is established, including the service levels of public transport. A design technique for viability of centers is suggested as well as how a city can restructure itself to overcome automobile dependence.

Keywords: Automobile Dependence, New Urbanism

Introduction

The era of designing cities as if car access alone was sufficient appears to have ended. Virtually every city plan today attempts to create options that reduce traffic and the need for cars. Yet, the urban design parameters and concepts for doing this still are not very clear.

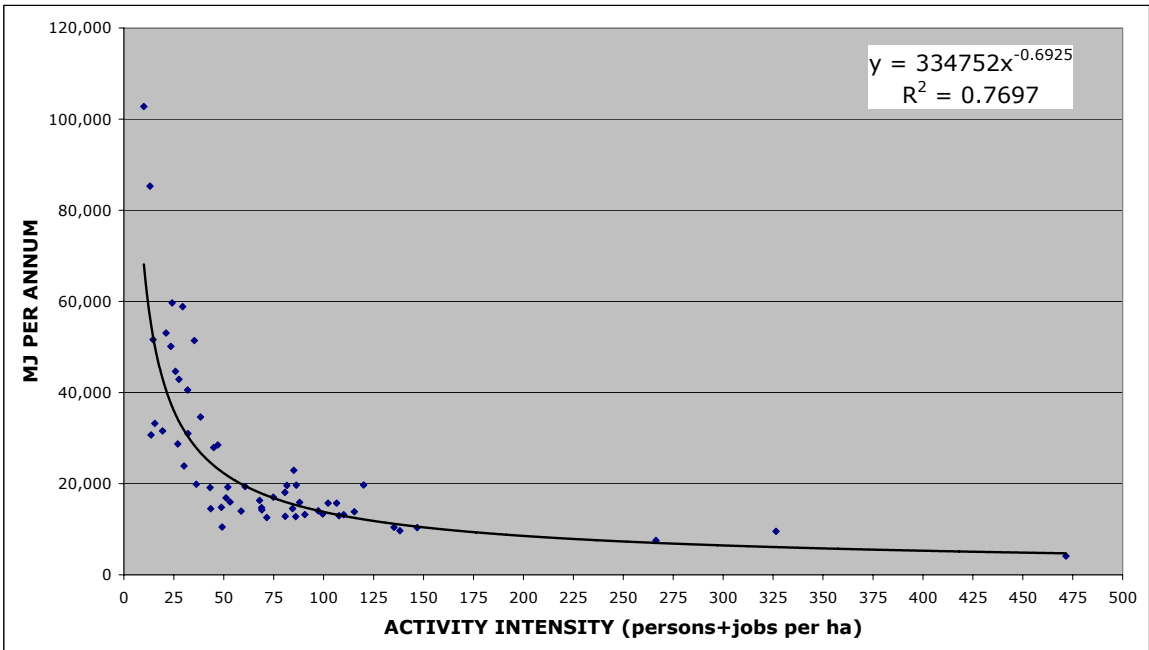
New Urbanism, and much new urban development in the United States and Australia, is being rationalized through the use of urban design to reduce automobile dependence. These design techniques assert the importance of the pedestrian catchment, or Ped Shed, to define a

neighborhood center. Such approaches then aim for sufficient density to create a largely self-sufficient local center with an emphasis on legible and permeable streets (e.g., Calthorpe 1993). However, it is never clear how much activity should be included in this area to make it walkable and more serviceable by public transport.

There has been growing public awareness of the damaging impacts of cars on cities in the past few decades. Car dependence and large ecological footprints as well as the loss of many urban qualities including walkability, viable public transport, jobs

¹ One hectare equals 2.47 acres. There are 259 hectares in a square mile.

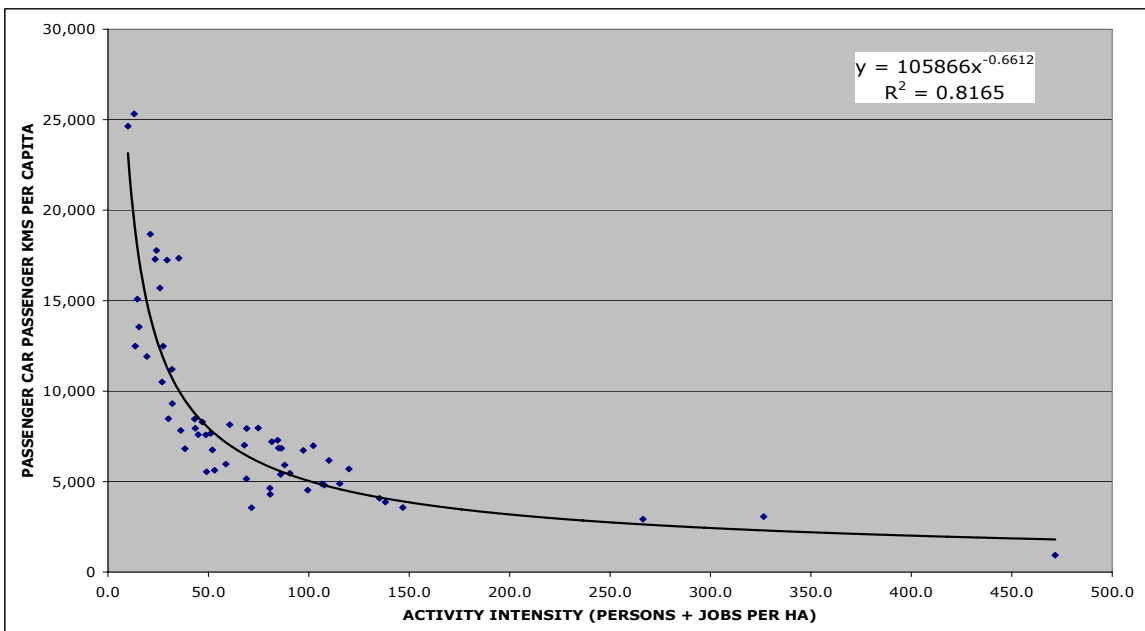
Figure 1. Activity Intensity versus Private Passenger Transport Energy Use in 58 Higher-Income Cities, 1995



access, and other urban amenities have been tied together. Now, obesity levels, stress levels and children’s mental health development have been linked to automobile dependence (Gee and Takeuchi 2004; Hillman 1997). Urban sprawl is a political reality addressed by developers

and governments. Surveys reveal a desire for governments to find alternatives (summarized in Newman 2003). The need to address car dependence through better infrastructure options is clear, but the urban design implications are not.

Figure 2. Activity Intensity versus Passenger Car Use in 58 Higher-Income Cities, 1995



Urban design thinking on automobile dependence is focusing on making centers work. Viable centers cannot be car dependent. The domination of car parks and traffic defeats walkability and precludes the higher-order functions that centers need. “Viable” thus is taken to mean a center that is not dominated by cars, but is sustainable in long-term economic, social, and environmental amenities (Government of Western Australia 2003; Department of Infrastructure, Planning, and Natural Resources 2004).

Many developments, however, despite promising a reduction of car dependence, are not delivering. New Urbanist developments, focused on town centers and permeable street systems, too often do not work. There is a large gap between New Urbanist rhetoric and reality. This article tries to describe the minimum level of urban intensity and why it appears to be understandable in terms of human movement and activity. Finally, it will outline how to design for reduced automobile dependence in viable centers and how a car-dependent city can be restructured.

Data on automobile dependence

Since the term “automobile dependence” was defined in 1989 (Newman and Kenworthy 1989), researchers have been attempting to gather data on urban car use to gain perspective on the issue. Data have now been collected on over 100 urban systems from around the world over the period from 1960 to 2000 (Newman and Kenworthy 1999; Kenworthy et al. 1999; Kenworthy and Laube 2001). The link

between urban intensity and automobile dependence has been confirmed repeatedly, as demonstrated by Figures 1 and 2. The vertical axis can be car use or it can be transport energy use (which can include public transport energy use as well) and the horizontal axis can be population per urban hectare or jobs per urban hectare or both together – called activity intensity. The same-shaped graph emerges.

Figure 1 shows the relationship between per-capita, private-transport energy use and activity intensity in 58 higher-income metropolitan areas around the world (Kenworthy and Laube 2001). Figure 2 uses the same data, but graphs car use instead of energy use against activity intensity. It reveals an even stronger statistical relationship because it eliminates scatter introduced by factors related to energy use per se (e.g., variable fuel efficiency of car fleets in different cities).

When activity intensity is used on the horizontal axis, the point on the graph where rapid acceleration in car usage appears to occur seems to be around 35 people and jobs per hectare; the error band is around 30 to 40 per hectare.²

The same relationship can be found within cities. Detailed data are presented below on local government areas³ (LGAs) in Sydney and Melbourne showing the sharp reduction in car use and thus transport energy, as density reaches certain cut-off levels (Figures 3 and 4). Interestingly, the two data sets used were collected just over 20 years apart, yet show an identical relationship between transport and land use intensity, even when the central business district

² Note that the density figures referred to here are genuine “urban density” in that they use total urbanized land as the denominator (residential, commercial, industrial land, local parks and open spaces, plus roads and any other urban land uses). The denominator excludes large areas of undeveloped land such as urban zoned yet-to-be-developed land, regional scale open spaces, agriculture and forestry land, etc. The relationships shown in this article will not work with other measures of density such as residential density because they are irrelevant to transport issues.

³ Local government areas are collections of government-defined neighborhoods that can range widely in population size.

Figure 3. Per Capita Passenger Transport Energy Use versus Activity Intensity in Melbourne Local Government Areas, 1980



areas are removed to allow the suburban areas to stand out more clearly. As Figures 5 and 6 show, the same clear patterns emerge despite the fact that in this 20-year period the inner, denser local areas have become significantly wealthier than the outer areas. Wealth seems to be much less of an issue in determining transport activity

than urban design.

The interesting cut-off point at around 35 people and jobs per hectare is not something that has escaped the notice of others who have collected urban data. Calthorpe (1993) came to a similar figure based on his impressions of what makes

Figure 4. Per Capita Passenger Transport Energy Use versus Activity Intensity in Sydney Local Government Areas, 1981

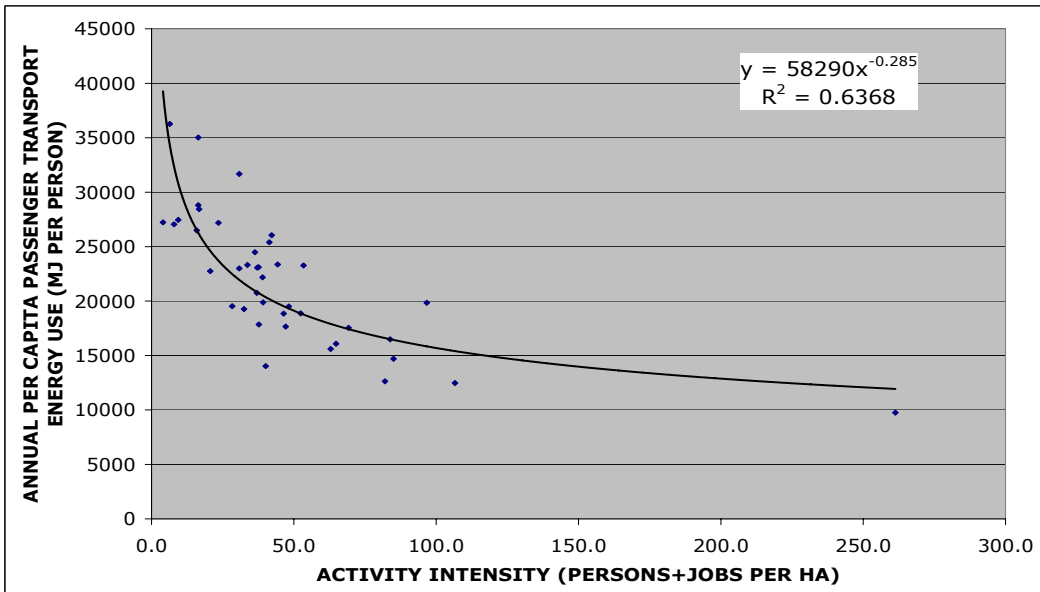


Figure 5. Per Capita Passenger Transport Energy Use versus Activity Intensity in Melbourne Local Government Areas, 2002



a viable center. Holtzclaw et al. (2002) compiled detailed data on San Francisco, Los Angeles, and Chicago with the same pattern of sharp increases in car use below this kind of density. Data have been examined for cities as different as Paris (INRETS 1995), New York (Newman and

Kenworthy 1989), and San Francisco (Holtzclaw 1990). Data for the latter two are shown in Tables 1 and 2. Naess (1993 a, 1993b) developed similar data for Scandinavian cities. Jeffrey Zupan, quoted in Owen (2004), states the following about the idea of a critical threshold density:

Figure 6. Per Capita Passenger Transport Energy Use versus Activity Intensity in Sydney Local Government Areas, 2002

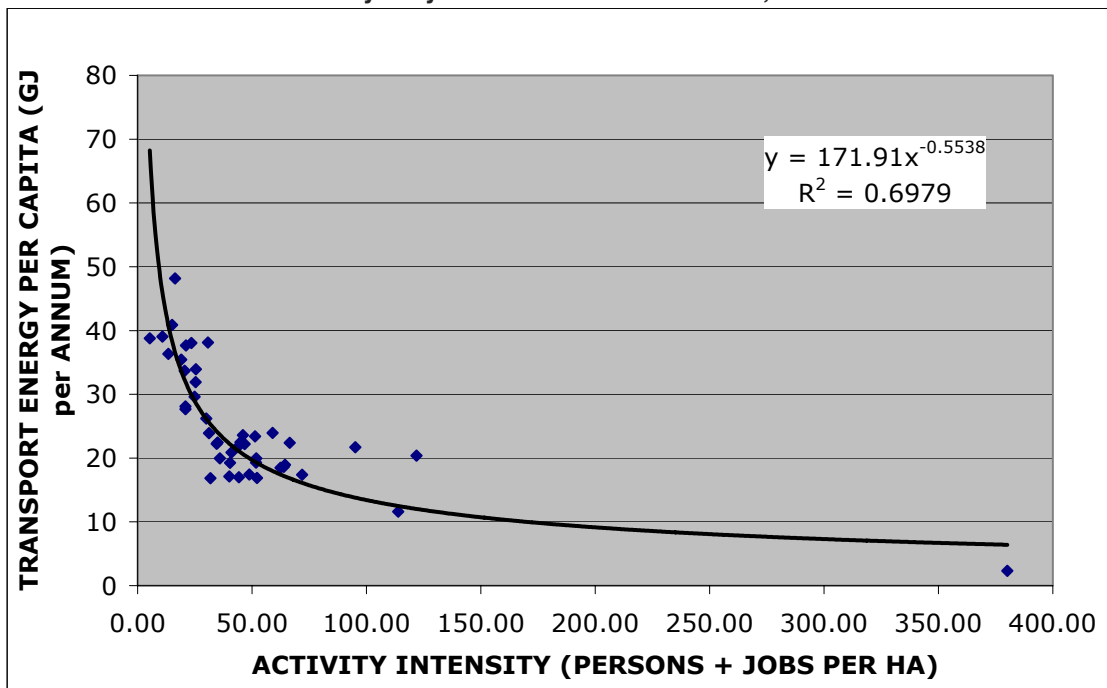


Table 1. Urban Density versus Gasoline Use for the San Francisco Region

Urban Center	Gasoline Use (MJ per capita)	Urban Density (persons per ha)
Central San Francisco	17,449	128
Inner city (City of San Francisco)	33,337	57
Middle Suburb with strong sub-center (Rockridge/Berkeley)	45,548	25
Middle Suburb with no sub-center (Walnut Creek)	49,641	10
Outer Suburb (Danville-San Ramon)	67,090	5

Table 2. Urban Density versus Gasoline Use for the New York Region

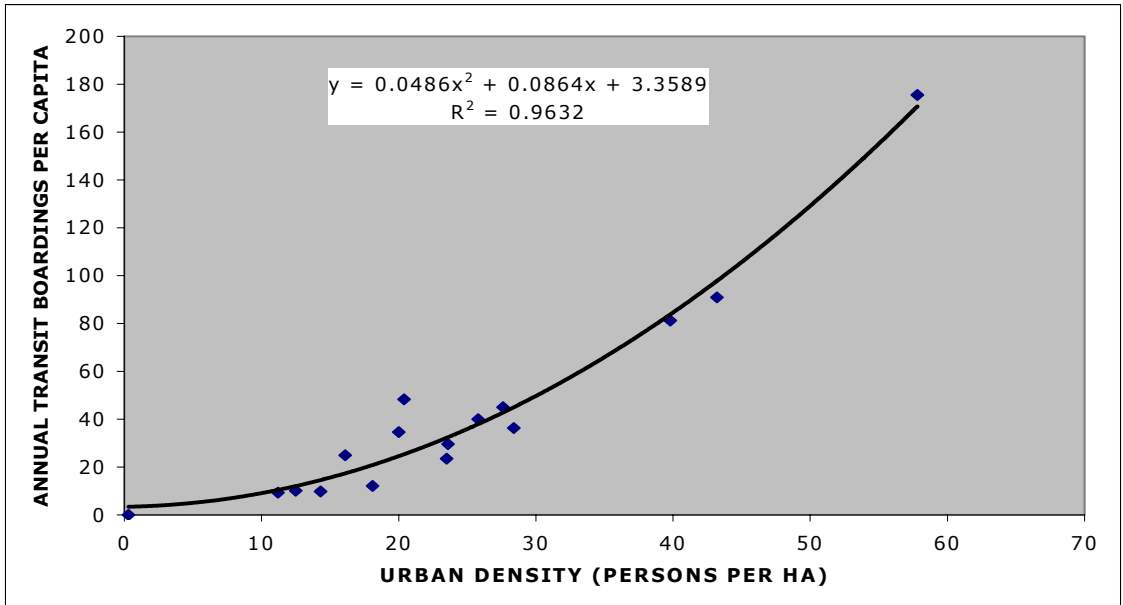
Urban Center	Gasoline Use (MJ per capita)	Urban Density (persons per ha)
Central City (New York County, including Manhattan)	11,860	251
Inner city (City of New York)	20,120	107
Whole city (Tri-State Metropolitan Region)	44,033	20
Outer Suburbs	59,590	13

Table 3. Differences in Wealth and Travel Patterns from the Urban Core to the Fringe in Melbourne

	Core	Inner	Middle	Fringe
Percentage of Households earning >A\$70,000 per year	12	11	10	6
Car Use (trips/day/capita)	2.12	2.52	2.86	3.92
Public Transport (trips/day/capita)	0.66	0.46	0.29	0.21
Walk/bike (trips/day/capita)	2.62	1.61	1.08	0.81

Source: Newman and Kenworthy 2002.

Note: Core areas are the central business district and immediately adjacent areas. Inner areas are the next ring of suburbs developed before 1939 (pre-automobile suburbs developed on the basis of transit). Middle suburbs are the post-World War II suburbs surrounding the inner area and beyond, apart from the fringe suburbs, which are those far-flung outer areas of the metropolitan region developed at very low densities.

Figure 7. Urban Density versus Transit Use in the Los Angeles Region, 1990

The basic point is that you need density to support public transit. In all cities, not just in New York, once you get above a certain density two things happen. First, you get less travel by mechanical means, which is another way of saying you get more people walking and biking; and second, you get a decrease in trips by auto and an increase in trips by transit. That threshold tends to be around seven dwellings per acre. Once you cross that line, a bus company can put buses out there, because they know they're going to have enough passengers to support a reasonable frequency of service.

Seven dwellings per acre at a reasonable dwelling occupancy is equivalent to around 35 to 40 persons per hectare.

All these studies reveal similarly shaped

relationships to those seen in the figures on Sydney and Melbourne between travel patterns (as reflected by per capita passenger-transport energy use) and intensity of urban activity.

Finally, when transit use patterns within cities are analyzed, such as in data obtained by the authors for planning zones across the Los Angeles region, urban density can be used to explain 96 percent of the variance in per capita transit use (Figure 7).

The question becomes: "What is behind this?"⁴ Questions of wealth do not appear to drive this phenomenon as there is an inverse relationship between urban intensity and household income in Australian cities and a variety of wealth patterns across all the cities cited above. As the data on Melbourne in Table 3 indicate, poorer

⁴ Brindle (1994) suggested that attempts to link transport and density were flawed by a statistical problem involving per capita relationships on both axes. Evill (1995) explained how the graphical relationship was quite correct. If the per capita factor is removed from both, then you just relate transport for the whole city to the area of the city. This is no difference when it comes to policy on how to reduce transport energy (reduce the area for the city, i.e., increase its density), but it is harder to follow. The emphasis on ecological footprint of cities today perhaps makes it easier to see by just presenting transport energy and area of the city, but in terms of planning for people and jobs it is easier to see as a simple direct relationship.

households drive more, while using public transport and walking less. There obviously are other factors than the intensity of activity that affect transport. Such factors include the network of services provided, income, prices, and cultural factors. But all of these can be linked back to the intensity of activity. Thus, although many discussions have tried to explain transport in non-land use terms (e.g., Brindle 1996; Mindali, Raveh, and Saloman 2004), the data suggest that the physical layout of a city does have a fundamental impact on movement patterns. The role of this article is to go the next step and explain how the relationship between transport and activity intensity works.

Our analyses show that factors such as culture, climate, politics, income, prices, and education do not provide consistent insights to explain car dependence (Newman and Kenworthy 1989, 1999). Urban design, reflected chiefly in population and job densities, emerged as the most significant determinant of the travel patterns in cities around the world. This research seeks to pursue a more fundamental explanation in terms of the physical design of cities and in particular for this article, the design and intensity of activity in centers.

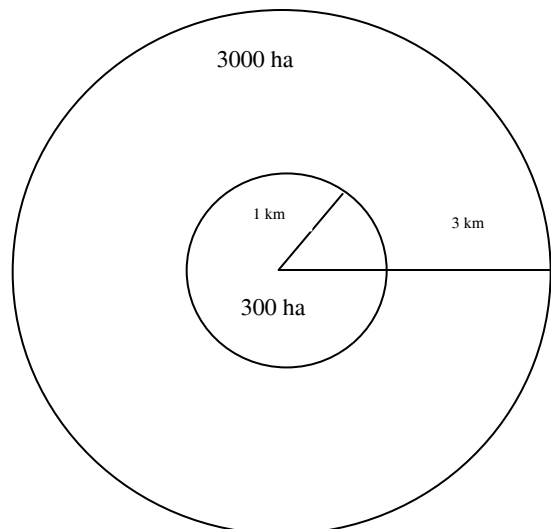
Explaining car dependence in terms of access to amenities in centers

If there is a universal pattern linking density and movement, it is likely to be understood in terms of a universal principle that shapes urban activity. This principle can be found in the Marchetti Constant. The Marchetti Constant explains how cities throughout history have functioned on the basis of an average one hour per day travel-time budget (Marchetti 1994). This principle shows a remarkable consistency in the United Kingdom over six centuries of urban life (SACTRA 1994). It can be used to

explain why walking cities in history were just 5 to 8 kilometers in diameter, transit cities could spread to 20 to 30 kilometers, and automobile cities could spread to 50 to 60 kilometers. Due to the different speeds of walking, transit, and cars, these cities, regardless of physical size, were all “one hour wide” in diameter. Large urban areas today are combinations of these city types – with most journeys being within that “one-hour-wide” locus.

In the 33 international cities with available journey-to-work trip time data (Newman and Kenworthy 1999; Kenworthy et al. 1999), the Marchetti Constant largely holds in terms of averages of half an hour or less. In those cities where travel time has begun to exceed that figure, transport issues are big on the political agenda. The biological or psychological basis of the Marchetti Constant seems to be a need for a more reflective or restorative period between home and work, but it cannot go too long before people become very frustrated due to the need to be more occupied rather than just moving between activities. The link between obesity and car dependence is that if the whole travel time budget is taken up by driving, little time for walking will be

Figure 8. Ped Sheds for Different Scale Centers



found. Building cities where walking is part of the travel-time budget is a major reason for creating less car-dependent cities.

Time constraints mean that people will arrange their location and their mode of travel accordingly. Overcoming automobile dependence thus becomes a question of whether people can access the amenities of a city without a car. In particular for an urban center, it becomes whether the time available for car travel is less than the time it would take to access the urban center using a bike, walking, or riding public transit.

This element can be assessed using the Ped Shed model to create circles of activity for 10 minutes of walking or 30 minutes of walking. Ten minutes is the accepted time people will take to get to public transport or to a local amenity before that trip exceeds the whole travel-time budget. Thirty minutes covers the whole travel-time budget for those walking to urban services, and particularly jobs, within the Ped Shed. Other nodes can be used in that 30-minute Ped Shed, but this is the fundamental area within which urban amenities need to be provided without requiring personal, motorized transport.

Thus two types of centers can be examined using this technique. The Local Center is essentially a Transit-Oriented Development with sufficient intensity of activity to make it an effective and viable transit center, supported by local services that bring people there as part of its multiple urban functions. The Town Center (Regional Center or Sub Center) is a place providing viable services for a region within a city. The Local Center is defined by its 10-minute Ped Shed and the Regional Center by its 30-minute radius (Figure 8). The latter is an area that can be reached by walking for most urban services.

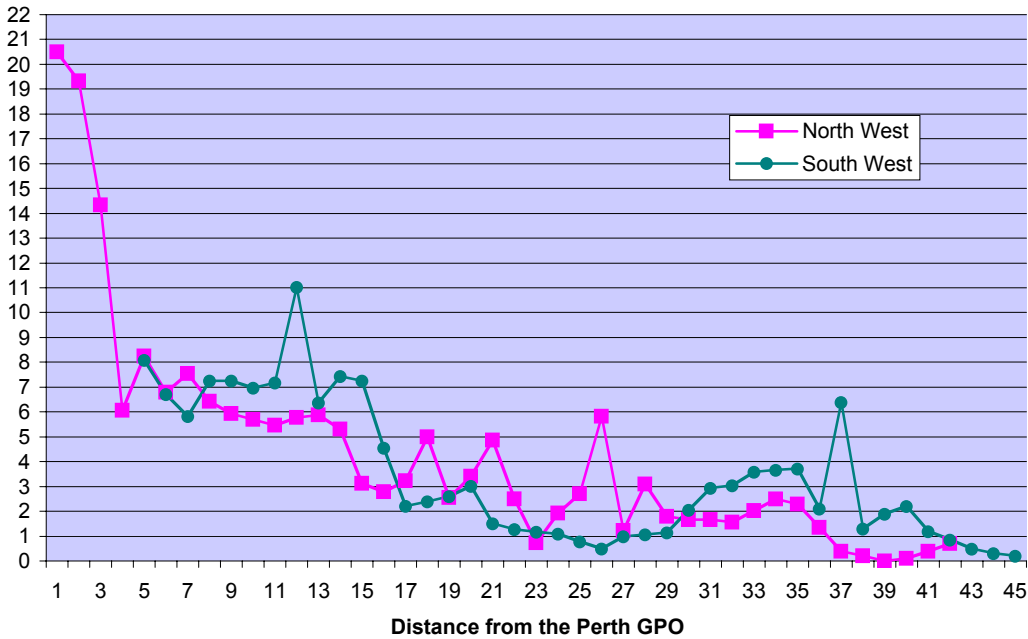
The key notion in this article is that car dependence can be overcome through critical design elements that create diversity of urban amenities within the 10- to 30-minute Ped Shed. The most fundamental factor will be the intensity of urban development. The question therefore becomes: What are the factors that underlie the minimum threshold of intensity of 35 jobs plus people per hectare?

Urban center viability and size of population/ jobs in ped sheds

A 10-minute Ped Shed creates an area of approximately 220 to 550 hectares based on 5 to 8 kilometers per hour walking speed. Thus, around 300 hectares at 35 people and jobs per hectare means there is a threshold of approximately 10,000 residents plus jobs within this 10-minute walking area. The range would be from about 8,000 to 19,000, with jobs and residents being interchangeable for transport demand. Some centers will have a lot more jobs than others, but the key is having a combined minimum activity intensity. This suggests the approximate minimum base of people that appears to be necessary for a reasonable Local Center – and a public transport service to support it (Pushkarev and Zupan 1997; Ewing 1996; Frank and Pivo 1994; Seskin et al. 1996; Cervero et al. 2004). Either way, the number suggests a cut-off point below which services become non-competitive without predominant car access that extends the catchment area of the center.

Many new car-dependent suburbs have densities more like 12 jobs/people per hectare and hence have only one-third of the population and jobs required for a viable center. When a center is built for such suburbs it tends to have low job densities. Hence, the Ped Shed never reaches the kind of intensity that will enable walkable environments. Many New Urbanist devel-

Figure 9. Amenity and Distance to the Central Business District of Suburbs in Perth’s Western Corridor



opments are emphasizing legibility and permeability of street networks, not density of activity. Hence we should not be surprised when the centers they design are not able to attract viable commercial arrangements and have weak public transport. However, centers can be built in stages with much lower numbers to begin with as long as the goal is seen to be to reach these kind of densities ultimately through infill at higher intensities.

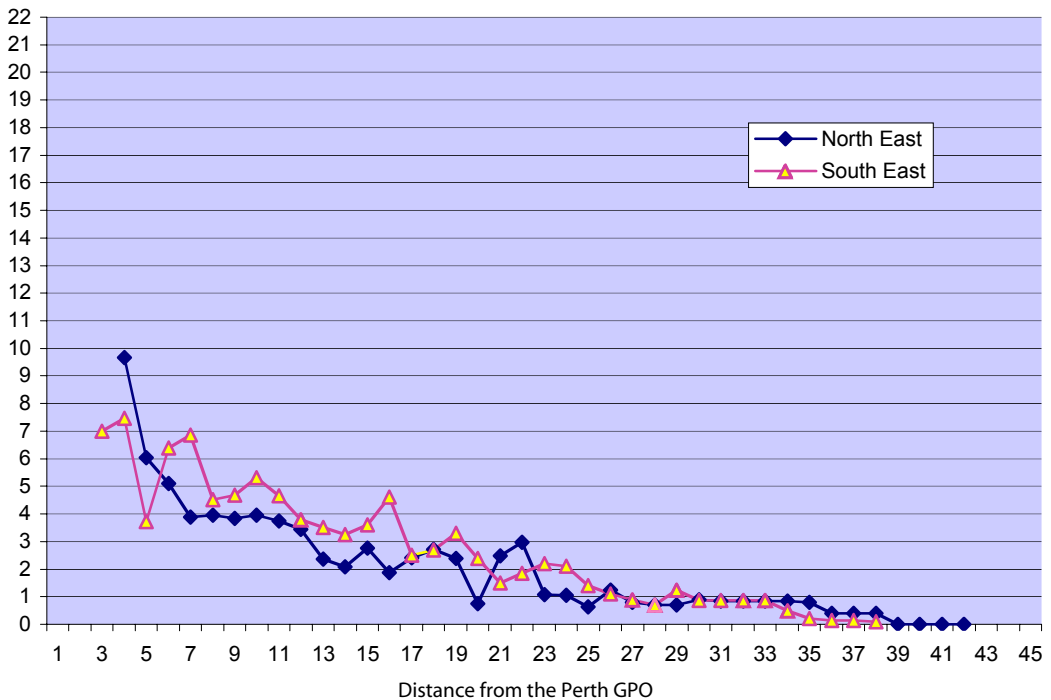
If a 30-minute Ped Shed for a Town Center is used, the area of the catchment extends to between 2,000 and 5,000 hectares. Thus, 35 people and jobs per hectare over 3,000 hectares provide approximately 100,000 residents and jobs within this 30-minute walking area. The range again is from around 70,000 to 175,000 people and jobs. This number could be the basis of a viable Town Center based on standard servicing levels. Any less than this means services in such a center become impractical. Of course, many driving trips within a walking Ped Shed still occur. But only shorter car trips are needed, making the center

less car-dependent. “Footloose jobs,” particularly those related to the global economy, theoretically can go anywhere in a city and can determine the success of a center. However, there is considerable evidence that such jobs are locating in dense centers of activity due to the need for networking and quick face-to-face meetings of professionals. Such employment can be encouraged to locate in centers by the kind of high-diversity, walking-scale environments supported by the analysis in this article.

Supporting data on amenity/density

There is an obvious link between the ability to provide urban intensification (i.e., greater density) and urban amenity, both economic and psychological. Markets in the development of land are primarily determined by access to amenity, and if amenity is high then density can be easily created. If amenity is low, density generally is hard to provide. However, there is a chicken and egg issue, as amenity often is not provided without a minimum of density to support it.

Figure 10. Amenity and Distance to the Central Business District of Suburbs in Perth's Eastern Corridor



The link between transport, access to urban amenities, and intensity of urban activity in Ped Sheds can be seen in a study of Perth (Newman et al. 2003). In this study, transport patterns and amenity were determined by suburb. Amenity was determined by the scale of local services for jobs, education, health, public transport, open space, etc.⁵ Amenity was found to be closely linked to density with the highest value found in the higher density inner areas that are close to the 35 per hectare urban activity intensity. The extra information provided by this study is the cross-city data, which is found to decrease with distance from the Central Business District (also closely linked to density) and is quite distinct within the two main corridors of Perth – the Western Corridor and the

Eastern Corridor (Figures 9 and 10). In particular, the only viable area in terms of amenities (apart from the areas that focus on Perth city) is the Fremantle Regional Center, where sufficient intensity of urban activity is associated with high amenity and low transport energy use. Some differences can be seen around Joondalup and Rockingham Regional Centers (also on the Western Corridor), but no difference over the background is observable in the Eastern Corridor, where several Regional Centers are supposed to exist but appear to lack the necessary density of activity.

The data on amenity in centers confirms the link to density. In Perth, only the inner suburbs such as Subiaco and the sub-center of Fremantle are above the 35

⁵ Scaling was done from 1 to 5 for each of 12 parameters based on data from each suburb. These were added with and without weighting, though this made little difference. The majority of 5 scales for each amenity parameter were found in the western suburbs of Perth. The 12 areas are schools, tertiary education, shops, lack of crime, health facilities, public open space, sports facilities, entertainment/cultural facilities, community facilities, employment, public transport, and rising property values. If a place had top scores on a range from 1 to 5 on all parameters, it would rate at around 60. The highest values are around 25 as not every place can have all amenities and some are in conflict.

people and jobs per hectare level. Thus, the commercial reality of running a public transport service or locating in a center depends on this kind of activity intensity. Further evidence could be collected on the viability cut-offs that are found across various cultures and economies, although these differences are likely to be lessened by the physical practicalities that lie behind all urban activity.

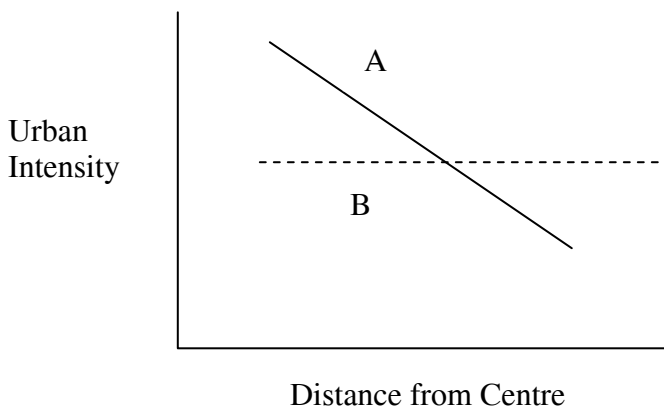
Thus, by providing at least 10,000 people and jobs in a 10-minute walk radius – or 100,000 in a 30-minute walk radius – the amenities of a city can be provided. Thus, public transport, walking, and cycling become viable, and car dependence is sharply diminished. If such numbers are not reached, almost total car dependence appears to be required for the viable provision of urban amenities. When this occurs, the centers that result are less able to attract the amenities and density that together make a center viable. Of course, these goals can be approached over a period of time.

Urban design and minimum activity intensity

Urban design can build in threshold levels to reduce car dependence by creating Ped Sheds of 300 hectares (i.e., a radius of 1 kilometer) based around every Local Center/public transport node or 3,000 hectares (i.e., a radius of about 3 kilometers) based around every Town Center. Each Ped Shed should target redevelopment to reach thresholds of around 10,000 people plus jobs in each Local Center or public transport node, and around 100,000 people plus jobs in each Town Center. Without reaching or exceeding these thresholds, the generation of considerable car traffic will be impossible to prevent.

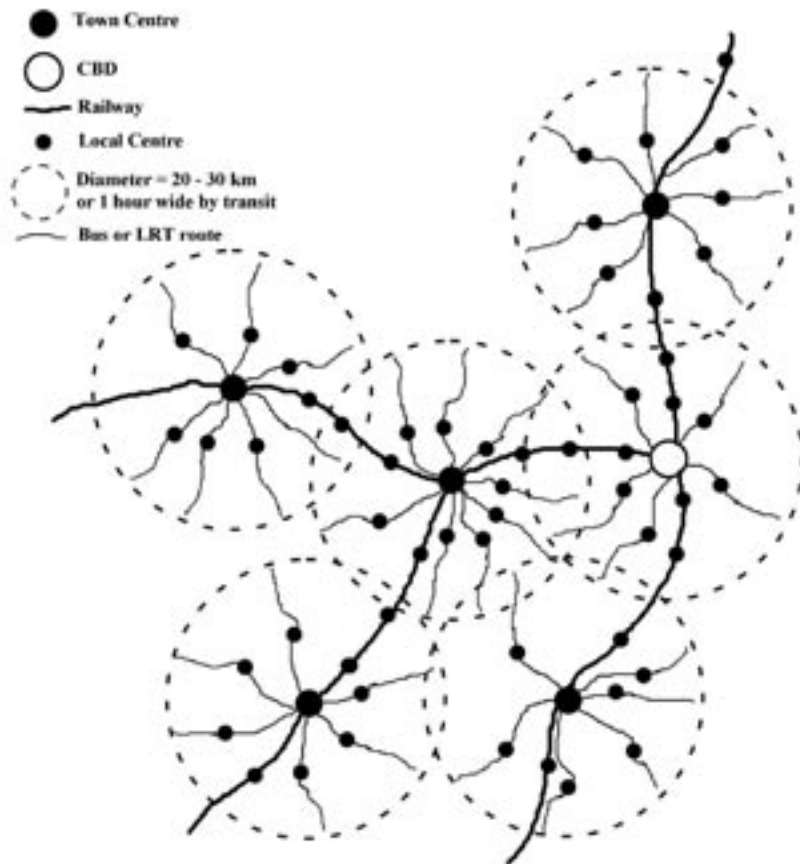
The design of a Ped Shed of urban development can be at different gradients of intensity and still be able to reach the minimum scale of intensity for reducing car-dependence. Two extremes are outlined in Figure 11.

Figure 11. Options for Achieving Minimum Activity Densities in Centers



Notes: Option A has a high-intensity urban core with lower-intensity development further out. Option B has medium-intensity development across most of the area scaling slightly with distance. Option A is likely to be associated with a center that has an urban rail node and Option B a bus or light rail node.

Figure 12. A Conceptual Plan for Reconstructing an Automobile City



Note: Based on Sydney, showing how a series of transit cities can be formed around Town Centers and Local Centers with a bus or light rail node.

The link between urban center intensity and public transport

As outlined above, urban amenity is enhanced if there is sufficient intensity of urban activity. However there is a "Catch 22." If some urban amenities are provided first, they can attract increased urban development. Density creates amenities, but also amenities attract density. This is particularly obvious when the amenities are associated with a public transport node.

An urban rail node can provide faster access and quieter urban environments than a bus node. Rail nodes attract large pedestrian flows. The attractions for people and jobs are thus vastly increased around urban rail centers (see Newman 2001;

Dittmar and Ohland 2004). For automobile dependence to be overcome, Ped Sheds with an urban rail node will have the potential for much higher densities. If only a bus node is provided, medium densities need to be designed across the Ped Shed area.

Higher urban intensities not only are possible but are likely to be needed around an urban rail node. It is not only more feasible to provide higher urban intensities (due to the amenities), it will require more people to ensure viability (Transportation Research Board 2004).

Reconstructing an Automobile City

Cities across North America and Australia, which developed around car dependence over the past 50 years, now are trying to transform into places where more transport options are available for the future. This usually involves a new or refurbished transit system, usually rail, and a set of centers to focus urban activity. One new rail line and a few centers are unlikely to change a city much because they lack breadth and penetration. However, based on the Marchetti idea, it is possible to restructure the expanses of an automobile city into a series of linked transit cities. Transit cities are 20 to 30 kilometers in diameter. It is best to try to create a series of these with a rail and bus service that feeds into a Town Center. Along the lines feeding in to the Town Center would be a number of Local Centers. The whole city would be made up of transit cities joined together and linked by a fast rail service. Most people in the city could then live within the framework of local services in the Local Center. Main services, including work, would be located in the Town Center. Some higher-level services would remain in other Town Centers, especially the historic central business district, and these would be accessible by rail. However, the key to sustainability is to generate these Local Centers and Town Centers as genuinely viable places in each of the transit city sections of the city-region.

This theory recently has been applied to the development of the Metropolitan Plan for the Sydney Region (www.dinpr.nsw.gov.au), which envisions six distinct transit cities, each around 20 to 30 kilometers in diameter and each having a major Town Center and a series of Local Centers. This approach is shown conceptually in Figure 12. By focusing the plan on these six areas and knowing the kind of intensity of activity that could make them viable, it becomes feasible to determine where to direct

growth and where new transit infrastructure will assist the development of a more sustainable city.

Conclusions

Considerable variations in urban design and development are found around the world. But there is a widespread desire to find ways of minimizing car use in urban centers to make them more viable. This article tries to show that achieving less automobile dependence will require a certain minimum of urban intensity (residents and jobs). The value of the 35-per-hectare minimum has been found to have some basis in the literature and the authors' own data. It has been explained in theory through the travel-time budget and the levels of amenities required to ensure that people do not have to rely on a car.

The redevelopment or new development of urban areas can facilitate the reduction of automobile dependence if Ped Sheds of 300 hectares (1 kilometer radius) are used around Local Centers/public transit nodes, and 3,000 hectares (3 kilometer radius) around Town Centers. These should have minimum development goals of 10,000 and 100,000 people plus jobs, respectively.

An automobile-dependent city can be restructured around a series of transit cities of 20 to 30 kilometers in diameter, with a Town Center as its focus and Local Centers linked along the transit services feeding the Town Center. Although linked across the city for many functions, these transit cities with their centers can provide a level of self-sufficiency that can form the basis for a far less car-oriented city.

Author

Peter Newman is the Professor of City Policy and Director of the Institute for Sustainability and Technology Policy, at Murdoch University. He is Chair of the Western Australian Sustainability Roundtable advising the Premier on how to implement their Sustainability Strategy. Peter's book with Jeff Kenworthy *Sustainability and Cities: Overcoming Automobile Dependence*, was launched in the White House in 1999 and his 2001 co-authored book is called *Back on Track: Rethinking Australian and New Zealand Transport*. In 2004 he was made a Sustainability Commissioner in New South Wales.

Dr Jeff Kenworthy is Professor in Sustainable Cities in the Institute for Sustainability and Technology Policy at Murdoch University in Perth. Professor Kenworthy teaches courses and supervises postgraduate research students in the area of urban sustainability. He has 27 years experience in urban transport and land use policy with over 200 publications in the field. He is particularly noted for his international comparisons of cities around the theme of reducing automobile dependence.

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