TEN KEY DIMENSIONS FOR ECO CITY DEVELOPMENT IN THEORY AND PRACTICE

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» *Sustainable urban form and transport are central to any attempts at greater sustainability or eco-city development in both prosperous and less prosperous cities, especially because of the powerful city-shaping ability of transport systems.* «

Dubai today presents many factors such as huge freeway systems that work against the quest for eco-cities. By contrast, its expanding metro and light rail system serving high density corridor development provides a more positive approach and highlights the often conflicting forces facing cities in their quest for greater sustainability

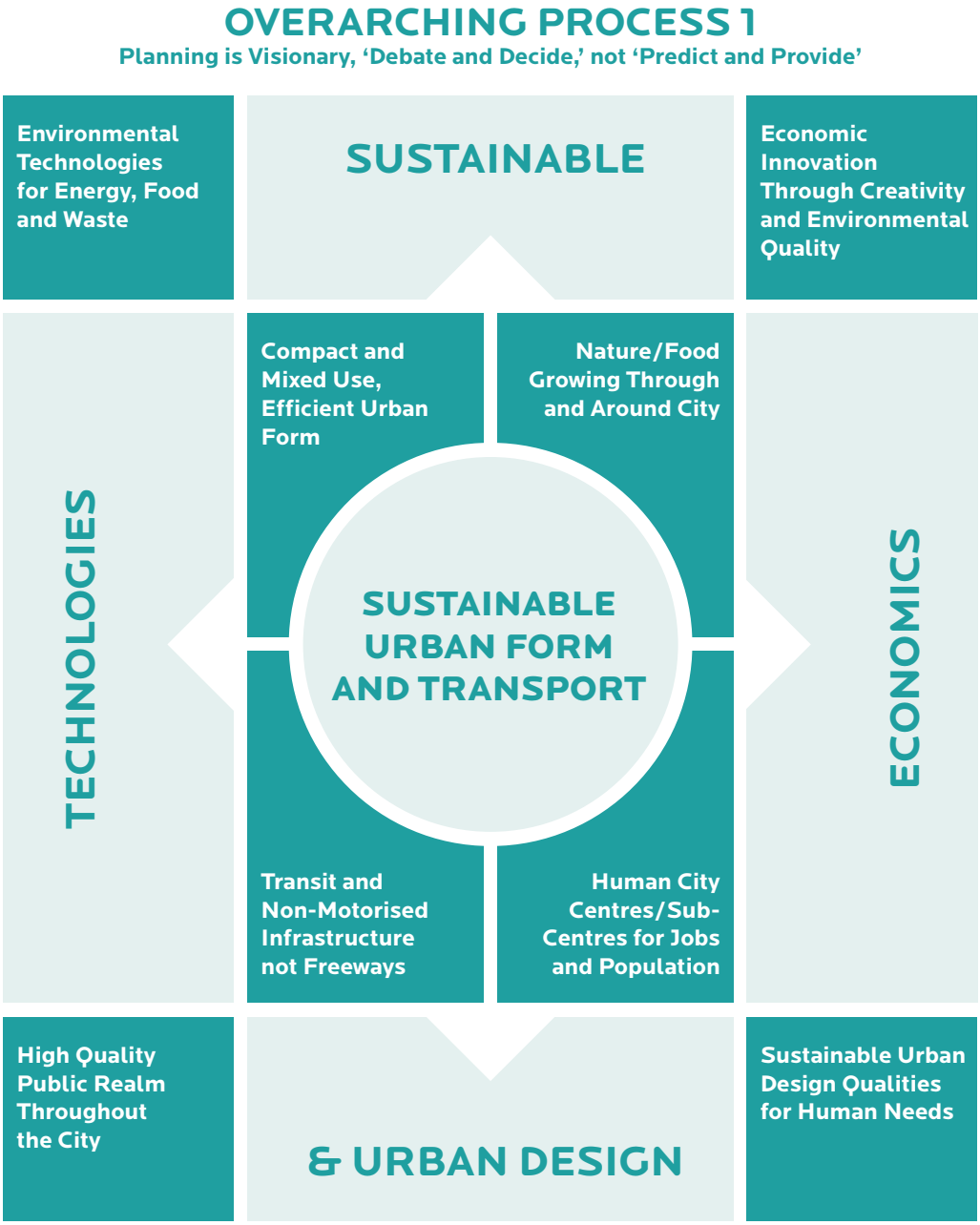


Figure 1: A conceptual model for eco-cities based on urban planning, urban transport, urban design and some governance or process considerations. Source: Kenworthy (2006)

Changing urban development from its present unsustainable forms and patterns in both wealthy and poorer cities is a very challenging process. Not only do urban form, transportation systems and water, waste and energy technologies have to change, but the value systems and underlying processes of urban governance and planning need to be reformed to better reflect a commitment to sustainability.

This paper first summarises ten critical responses which would change the nature of urban development to a more ecological, sustainable model. These dimensions revolve around urban transport systems and their links to urban form and are therefore mostly, though not exclusively, focussed on the problems of reducing automobile dependence in cities, building more sustainable urban form and creating more livable places.

These ten dimensions are not exclusive of other critical factors in the quest for urban sustainability and some caveats, limitations and omissions, as well as a detailed description of each dimension, have been provided in Kenworthy (2006). However, these ten dimensions are central to any attempts at greater sustainability in both prosperous and less prosperous cities, especially because of the powerful city-shaping ability of transport systems.

TEN KEY ECO-CITY DIMENSIONS: THEORY AND BACKGROUND

Figure 1 shows the ten critical eco-city dimensions examined in this paper as a simple conceptual model. Each dimension is described briefly below.

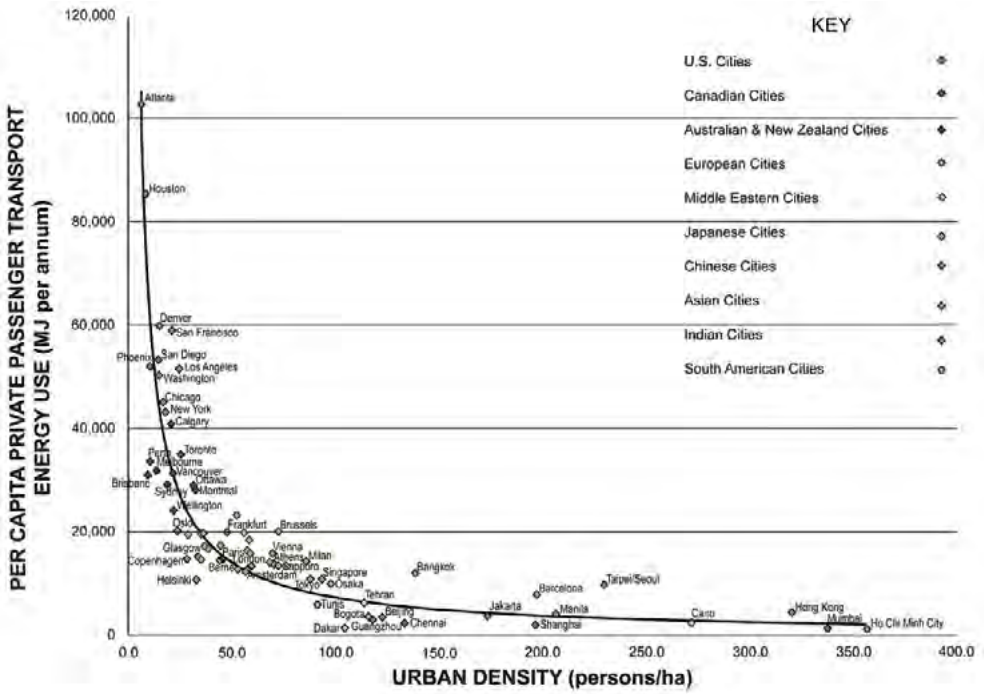
1 · Compact, mixed-use urban form that uses land efficiently and protects the natural environment, biodiversity and food producing areas

There is extensive literature showing the positive effects of compact, higher density, mixed use urban form in reducing dependence on cars, decreasing energy use and increasing the convenience and quality of public transport (transit) and mixed land use (Holtzclaw, 1994; Kenworthy and Laube, 1999; Newman and Kenworthy, 1989, 1999, 2015; Kenworthy and Laube 2001; Naess, 1993a,b). In essence, higher density, mixed uses provide shorter travel distances that make walking and cycling more feasible and make traveling by transit more competitive with the car. They also provide the concentrations of people that are necessary to create the high loads needed by transit systems to offer high frequency, convenient services. Unlike road systems, which deteriorate with increasing use, transit systems typically improve as demand increases (apart from comfort issues which can be challenging in peak periods if insufficient capacity is provided).

Figure 2 shows how density is critical in reducing a metropolitan area's use of energy in private motorised passenger transport.

2 · Natural environments permeate the city's spaces and embrace the city, while the city and its hinterland provide a major proportion of its food needs

With the peaking of world oil production and the high embodied energy costs in food, it is becoming increasingly important to source food supplies more from local bioregions (Campbell and Laherrere, 1995). In the USA, "100- mile restaurants", which source all food products within a 160 km radius, are becoming popular (Beatley, 2005). Additionally, if higher densi-



Automobile Cities
ca 25 persons per ha or less

Transit Cities
ca 30 to 100 persons per ha

Walking Cities
ca 100 persons per ha or more

Figure 2: Urban density versus private passenger transport energy use per capita in global cities, 1995. Source: modified from Newman and Kenworthy (2015)

Photo 1: High density, mixed use urban village (TOD) built on a former park-and-ride lot at Fruitvale BART station in San Francisco

Photo 2: An urban village (TOD) built on a LRT line in Helsinki incorporating land for food growing and nature

ties become a reality in more cities, then there needs to be more shared green space available to inhabitants so that people can maintain contact with nature and have places to recreate and refresh themselves. Somewhat paradoxically, more compact urban development provides greater opportunities for "green cities", both in the sense of food growing in and around the city and more parks and natural vegetation. Not all land needs to be consumed by sprawl, roads and car parks (Beatley, 2000). Additionally, biophilic architecture (green walls, green roofs etc) is becoming increasingly prominent, Singapore being a particularly notable example of its practice throughout that city (Beatley, 2010; Newman and Kenworthy, 2015).

3 · Freeway and road infrastructure are de-emphasised in favour of transit, walking and cycling infrastructure, with a special emphasis on rail. Car and motorcycle use are minimised

The need to reduce motorisation in cities and the many negative effects of excessive automobile dependence are clear (Newman and Kenworthy, 1999). Evidence about the deleterious effects of freeways in terms of increasing car use, energy consumption and automotive emissions has been available for many years (Watt and Ayres, 1974). Furthermore, the futility of attempting to tackle traffic congestion and reducing fuel use and emissions through more road construction and smoother, freer-flowing traffic is well documented (Newman and Kenworthy, 1984, 1988; Goodwin, 1997). Conversely, it has been shown how urban rail systems are central to building better transit systems and also to increasing the levels of walking and cycling, reducing parking requirements, lowering transport deaths and so on (Kenworthy, 2008).

There is also a growing body of evidence that traffic behaves more like a gas than a liquid and actually compresses (disappears) or expands (induced traffic) in response to reduced or increased road infrastructure (Kenworthy, 2012). Seoul is discussed later as an example of this trend (Cairns et al, 1998; Schiller et al, 2010; Napolitan and Zegras, 2008).

Finally, this dimension is critically important in the current transportation policy focus on electric and autonomous vehicles. In many ways the policy debate over urban transport has been hijacked by a somewhat reductionist view that all problems of the automobile and congestion can be solved by electric vehicles and autonomous vehicles, the latter of which are purported to facilitate a great capacity expansion in the existing road systems without costly new widenings or new roads. Such proposals ignore any real questioning of whether an expansion in car use is a desirable path in the first place (Riggs and Boswell, 2016). A more throughtful and measured approach is put forward by Kilcoyne (2015). He warns against the hyperbole surrounding autonomous vehicles and advocates the need to consider their impacts in a more holistic fashion to include the deeper underlying issues such as urban sprawl versus compact communities, transit and non-motorised modes versus the automobile and other factors.

Electric vehicles offer many advantages but we have to ask what role electric vehicles should have in the future. Are they a way to allow an expansion of auto use because they create potentially less pollution and can use renewable energy? Or are they a way to civilise the car so that the remaining vehicle-kilometres of travel after the end of automobile dependence in cities (Newman and Kenworthy, 2015), can be undertaken in a far less destructive way than with current internal combustion engine vehicles? (Kenworthy, 2011).

4 · There is extensive use of environmental technologies for water, energy and waste management – the city's life support systems become closed loop systems

It is very clear that the current patterns of urban resource use and waste production are unsustainable, resulting in huge urban ecological footprints (Rees, Wackernagel and Testemale, 1998). They tend to give urban systems a "parasitic" character. Cities therefore need to progressively adopt urban infrastructure systems that use renewable energy, which harvest and re-use water in a sustainable way and which feed wastes back into resource use cycles, where most life-support systems in cities become closed-

Photo 3: Sustainable water management in Rieselfeld, Freiburg

Photo 4: High quality pedestrian environment and access to the Metro in La Rambla, Barcelona

loop systems. The overall aim of environmental technologies is therefore to maximise the possibility that cities can meet their needs from the natural capital of their own bioregions in a renewable way (Newman and Jennings, 2008).

5 · The central city and sub-centres within the city are human centres that emphasise non-auto access and circulation and absorb a high proportion of employment and residential growth

Amongst the most important parts of any city are its CBD and sub-centres (Monheim, 1988; Gehl and Gemzøe, 1996; Jacobs, 1961). Central cities still remain the single biggest concentrations of jobs in most cities, despite the suburbanisation of work and the falling percentage of people employed in them (Kenworthy and Laube, 2001; Kenworthy, 2014; Newman and Kenworthy, 2015). The high and generally increasing number of jobs and floor-space means that the central city still significantly shapes transport patterns (Thomson, 1977). Transit systems, especially rail, are focussed on central cities and congestion on radial road routes is widespread. Sub-centres around cities are also crucial to making the city more transit-oriented through development of a polycentric structure with "decentralised concentration" of land uses. These high concentrations of activities occur mostly around urban railway stations as in, for example, Vancouver and Stockholm (Cervero, 1998).

6 · A high quality public realm in the city, which expresses a public culture, community, equity and good governance. The public realm includes the entire transit system and all the environments associated with it

A compelling factor that distinguishes 'good' cities from 'bad' cities is how they address the public realm (Newman, 1990). Mike Davis writes about urban communities that have abandoned their sense of responsibility concerning 'the commons', the most obvious being shared urban spaces, streets, parks, transit systems and so on (Davis, 1990). He suggests Los Angeles has become a highly privatised, fear-driven environment, which he characterises as "The Ecology of Fear" or "Fortress LA". Though an extreme example, Los Angeles demonstrates the wider general proposition that the public realm in cities, especially the streets, is crucial in making them more livable and sustainable and indeed democratic (Barber, 1995; Appleyard, 1981; Jacobs, 1993). Putnam (2001) implies that a good public realm is also critical in the development of social capital. One of the features of much current development in Los Angeles, which is occurring around stations on its growing urban rail system (light rail, metro and commuter rail), is that the public realm is becoming more attractive and inclusive and less "fear-driven".

7 · The physical structure and urban design of the city, especially its public environments are highly legible, permeable, robust, varied, rich, visually appropriate and personalised for human needs

The physical layouts and designs that make the most enduring and loved cities have long been known. A range of authors provide detailed accounts of the design of Greek, Roman, Chinese, Japanese and new world cities such as Boston and Los Angeles, showing the central importance of, for example, permeable street patterns, based on regular or deformed grids and legible streetscapes punctuated by well-placed landmarks and significant buildings (Lynch, 1960, 1981; Kostoff, 1991; Bacon, 1974). Others have developed a suite of measurable design qualities that need to be incorporated into urban development (Bentley et al, 1985). These principles reflect centuries of wisdom in place making, which automobile cities have largely ignored, but are now rediscovering through movements such as The New Urbanism (Calthorpe, 1995; Katz, 1994). Newman, et al (2016) develop a new theory of urban fabrics which makes it critical to recognise, respect and rejuvenate the older walking and transit city fabrics and minimise or reform existing auto city fabrics.

Photo 5: A public park in Seoul where people feel comfortable to stay and interact with each other

Photo 6: Rich and interactive human environments are increasingly linked to good economic performance of a city

Photo 7: Good decisions about the future of cities need to directly involve a diverse range of people in meaningful participation processes

8 · The economic performance of the city and employment creation are maximised through innovation, creativity and the uniqueness of the local environment, culture and history, as well as the high environmental and social quality of the city's public environments

Jane Jacobs showed that cities are the key sites and drivers of national economies and cities themselves cannot survive without a viable economic base (Jacobs, 1969, 1984). Any city aspiring to sustainability cannot ignore its economic dimension. Since Jacobs' time, globalisation has strengthened the role of cities in driving the global economy. The "creative city" approach, whereby cities attempt to find innovative and often more locally-based ways of diversifying and expanding their economies, is now an accepted means of economic progress and innovation (Landry, 2000; Florida, 2002, 2004, 2010, 2012).

9 · Planning for the future of the city is a visionary 'debate and decide' process, not a 'predict and provide', computer-driven process

In the post-World War II period transportation planning has been characterised by the use of computer models designed to predict future traffic growth and to work out how much new road infrastructure will be required to meet that projected demand (derogatorily referred to as "predict and provide"). This approach has had very negative effects on the environment of cities, first in cities of the west, and now increasingly in rapidly developing poorer cities where the approach is still being aggressively applied. This is at a time when its use is seriously waning in the West in favour of a transportation demand management (TDM) approach, which attempts to match transportation demand to existing infrastructure provision. This predict and provide technical methodology and the accompanying political and policy decision making processes have resulted in construction of extensive freeway systems, increasing the level of the car travel and energy demand and generating spiralling emissions (Mitchell and Rapkin, 1954; Kenworthy, 2012). Sustainability demands in cities are fostering a more community-based approach of envisioning the future city and asking "what do we want our city to look like in 20 years from now? What qualities should it have compared today? How should it change and how do we get there?" This is a "debate and decide" approach.

10 · All decision-making is sustainability-based, integrating social, economic, environmental and cultural considerations, as well as compact, transit-oriented urban form principles. Such decision-making processes are democratic, inclusive, empowering and engendering of hope

It is not surprising that for sustainable development to be implemented, quite radical departures from normal planning and decision-making processes in cities will be required. This is why there are many activities in cities around the world that are establishing visions of sustainable development and how these can be realised. The key defining characteristics of these efforts are their engagement with diverse 'communities' or 'stakeholders' that constitute any city today and their capacity to infuse a new sense of hope about urban futures (Newman and Jennings, 2008).

Photo 8: Examples of high density development in Vancouver

ECO-CITY DIMENSIONS IN PRACTICE: SOME GLOBAL EXEMPLARS

This section sets out some examples, among many others, of sound implementation of the above ten eco-city dimensions. Highlighted are: Vancouver, Canada: Freiburg-im-Breisgau, Germany: Portland and Boulder, USA: Perth, Australia and Seoul, South Korea. As expected we find that cities who exhibit one dimension frequently exhibit others since the dimensions are linked. For example, the de-emphasising of road systems and prioritising of higher quality transit systems, are often linked with the development of higher density sub-centres with a better quality public realm. (Please note that 'D' will be used to denote the term 'dimension' in the following material.)

VANCOUVER, BRITISH COLUMBIA

Vancouver is a city located at the core of a metropolitan area. Its popluation of 627,000 is about 25% of the regional total of some 2.5 million people. Perhaps the most distinguishing feature of this North American city is that it has essentially no urban freeways (though the region as a whole does have a modest freeway system)[1].

Vancouver today is a good example of a city that is implementing not only more compact, mixed use urban form (D 1), but it has also prioritised rail transit development, especially new rail infrastructure over new road infrastructure (D 3). The newest rail line is the Canada Line (2009) from the airport to downtown. The city has built up the role of its central area and especially the roles of transit-oriented sub-centres across its metropolitan region (D 5), and is in the process of implementing other dimensions, such as improving the quality of its public realm (D 6) and implementing sustainable urban design qualities throughout much of the urban area (D 7).

Vancouver has also made contributions in the area of environmental technologies through the South East False Creek development which was developed initially as the Winter Olympics Village for athletes in 2010 (D 4). Furthermore it has also made a significant attempt to preserve

agricultural land and natural areas around the city (D 2). The more detailed green preservation achievements in Vancouver itself have been partly shaped by the Greater Vancouver Livable Region Strategic Plan (1996-2011), which created a green belt for the region and limited the amount of suburban land that can be developed[2].

City research has demonstrated that the combination of compact urban form, economic performance and livability has beneficial consequences. The BC Sprawl Report 2004 used indicators of urban form, economic vitality and livability to compare neighborhoods across the Vancouver region (Alexander, Tomalty and Anielski, 2004). It found a statistically significant positive link between higher densities and mixed uses on one hand and positive economic features and enhanced livability. The study suggests a three-way winning scenario for policies that are aimed at creating less auto-dependent living and more walkable and sociable environments (D 8).

Finally, Vancouver has also made an effort to use the principles of "debate and decide" (D 9) and integrated sustainability decision making (D 10) in much of its activities over the last 35 years or so. The scrapping of all freeway plans in the 1970s within the city's boundaries, the planning and consultation regarding development of centres around new Skytrain stations, and, the 2015 decision to remove the Dunsmuir and Georgia viaducts (highways), have all involved, community engagement and commitment to sustainability in decision making.

DIMENSION 1 AND 5 – MIXED-USE URBAN FORM AND TRANSIT-ORIENTED CENTRES

Despite being located in an auto-dependent region, Vancouver has a very lively central and inner city population in places such as False Creek North and South, Yaletown, the city's West End, the Coal Harbor Redevelopment, and many other sites throughout the region (e.g the Arbutus Lands and Fraserlands developments). The absence of high-speed road travel has meant that these premium locations, near to the heart of most amenities and served with speedy transit, have become very popular places to live in order to maintain accessibility and acceptable daily travel times.

TRANSIT NODES ON SKYTRAIN

It has been Vancouver's policy since the mid-1970s to try to concentrate development into transit-rich locations. For example, public consultations with communities affected by Skytrain-linked redevelopments occurred as early as 1978, eight years ahead of the opening of the first Skytrain segment in 1985; just ahead of the 1986 Expo that occurred on the land now known as False Creek North or Yaletown. These discussions facilitated high density development at stations in Vancouver as well as neighbouring Burnaby (Joyce-Collingwood, Metrotown, Edmonds) and further down the line in New Westminster. Such TODs are gradually reshaping the Vancouver region into a genuine polycentric "transit metropolis" (Cervero, 1998).

Over the last twenty-five years, the major success factors of transit development have been: 1. the strong efforts to integrate high density residential and mixed use development into significant nodes around selected stations on the Skytrain; 2. the redevelopment of highly favoured waterfront areas such as False Creek and Coal Harbor; and, even in some cases, 3. the development of strong town centres around bus-only nodes such as Port Moody (soon to have the new Evergreen, Skytrain line). From before its inception, Skytrain's development has gone hand-in-hand with planned high density TOD from which it draws a lot of its patronage.

Part of the success of TOD in Vancouver, Burnaby and New Westminster is the exclusion of Park-and-Ride facilities. South of the Fraser River in the Surrey suburbs, at some stations such as Surrey Central, park and ride facilities surround the station with development set back from the station, producing a poor outcome compared to the larger nodes on Skytrain north of the river which have mixed commercial, office, residential, retail and markets within a short walk of the station. The new housing consists of high rise towers, 3 to 4 storey condominium style developments and townhouses. Some of the housing consists of individual housing cooperatives, which have historically provided more affordable housing options. The TOD at New Westminster is set along an attractive landscaped boardwalk on the Fraser River that includes playgrounds for children and extensive gardens, trees and

Photo 9: Transit-Oriented Development at stations along Vancouver's Skytrain

Photo 10: False Creek development in Vancouver built on land which would have become freeway interchanges

grassed areas. The family units have inner courtyards in which families and friends congregate. Their farmers market, where residents can do their shopping, has open eating areas and a more relaxed, less structured, less sterile atmosphere than a supermarket.

DEVELOPMENT OF NON-TRAIN NODES

As well as the obvious nodes that have sprung up around the Skytrain in the 30 years since its opening, the re-urbanisation trend is characterised by a lot of other new development along the major diesel and trolley bus lines in the city, where many mixed use shopping and business activities already exist. This new development consists of medium to high density housing, including shop-top housing, with special attention to the needs of families wishing to escape the car-dependent suburbs (e.g. False Creek located at the foot of the downtown area and serviced by frequent bus services and some nearby Skytrain stations).

Developments at both False Creek South and North (Yaletown), as well as South East False Creek, the 2010 Winter Olympic Village site, provide examples of how to build high density transit-oriented urban villages in central locations that have, over the years, become more ecologically-oriented. These areas have extensive and beautifully designed open spaces, together with adjacent mixed land uses such as markets, hotels, cultural activities, shops and restaurants. There is great variety in housing forms and styles in these areas, including townhouses, terraced units, medium rise and high rise apartments, with many of the earlier residential developments being cooperative housing. The public spaces and childrens' play areas are traffic free, the only direct road access on the south side of False Creek being essentially from a two-lane road at the rear of the development, with parking mostly under the buildings.

More attention needs to be provided, however, to housing affordability, a major problem all over Vancouver. This is especially so since the end of the housing cooperatives of earlier years, which saw a significant number of affordable housing options spring up in traditionally expensive central and inner areas, many sponsored through the Canadian Mortgage and Housing Corporation (CMHC).

DIMENSION 6 AND 7– THE PUBLIC REALM AND SUSTAINABLE URBAN DESIGN

PEDESTRIAN ORIENTATION

Vancouver does not have a pedestrianised city centre or extensive traffic calming in neighbourhood streets, as in many European cities, apart from the False Creek development which has extensive traffic-free space, discussed below[3]. However, the City of Vancouver has become a highly livable place characterised by a lot of human activity along lively and interesting streets and in its public spaces. One of the most interesting and vibrant public environments is Robson Street, a long avenue that connects the downtown with Stanley Park through the West End. The sidewalks have many pedestrians, notwithstanding the often bumper-to-bumper traffic and high frequency trolley bus services that operate along the street. The street and its land uses work for people.

Punter (2003) describes this strong human dimension and Vancouver's detailed attention to public urban design as a hallmark of Vancouver's success as one of the world's most livable cities. This is in stark contrast to cities in the US, which all too frequently have very hostile street environments due to automobile-orientated development. The West End of Vancouver is the second highest density residential area in North America outside Manhattan and enjoys diverse activities along its main roads. The grid-based, tree-lined residential streets that run across these major streets have numerous pocket parks created from selective street closures between blocks in the fine grained street grid. The area also has Stanley Park and the English Bay foreshore at its doorstep.

The whole of False Creek North and South, and even beyond this area, is knitted together with wide pedestrian and bicycle-only facilities. This pedestrian and bike friendly environment at ground level, below the often towering residential complexes, gives people the option of sustainable transportation, as well as conviviality and convenience. The areas are exemplary in their public realm and commitment to high quality urban design. Vancouver is also reclaiming road space in the CBD for dedicated bike lanes[4].

Photo 11: High quality, interactive public realm in Vancouver

Within these traffic-free neighborhoods where circulation is all by foot, bicycle or other non-motorized modes (e.g. in-line skates), there are local shops, community facilities, child-minding centres, professional suites for dentists and doctors, meeting areas, community playgrounds and sports areas, all within walking or cycling distance of most residences.

DIMENSION 3 - TRANSIT INFRASTRUCTURE, NOT FREEWAYS

In the 1960s Vancouver's transportation plans were similar to those proposed for US cities. If the freeways envisioned in these plans had been built, the land that presently houses these developments would have been alienated with clover-leaf freeway junctions and the quality of life around them would have also been reduced due to fumes, noise and severance.

Vancouver's transformation from a typical auto city really commenced in the early 1970s. The community led a fight to rid the city of all planned freeway construction within the City of Vancouver boundaries. This movement was assisted by a lack of political will to support the highway construction, insufficient funds to build the freeway network, and finally economic issues related to lack of globalisation (Perl et al, 2015).

Transit in Vancouver (buses, trolley buses, Skytrain, ferry and commuter rail) has achieved a lot over the last 30 years. In 1981 transit use was 111 annual trips per person, which had declined to 95 per person by 1991. Then in 1996 trips rose to 118 and by 2006 they had incresed to 134 trips per person per annum. This was just short of its 1961 figure of 138 trips per person, when car ownership in Vancouver was a mere 285 cars per 1000 people compared to the 2006 car ownership of 506 cars per 1000 people. Transit has become more attractive and popular with Vancouverites due to a combination of better, speedier and more diversified services and more attractive ticket offers especially to students. It increased also because many more people are now living within walking distance to transit stops and feeder services to speedier rail, and bus services have improved greatly.

Vancouver, now averaging 150 transit trips per person, enjoys more than double the transit use of the average for 10 large US cities (67 trips per person in 2005). The New York Tri-State metropolitan region is by far the most transit-oriented US urban area and has 168 trips per person, or just 12% more than Vancouver.

Photo 12: Vancouver is going to remove the 1.2 km long Dunsmuir and Georgia viaducts, the only parts of the freeway system ever built

Photo 13: Vancouver is greening some of its main streets and taking road space for new cycle facilities

SUMMARY

Skytrain stations and high density residential precincts in the inner city of Vancouver, have helped to minimise Vancouver's growth in car use in inner areas by increasing transit and non-motorised mode use for a variety of trips. Many people living in these areas can and do walk or cycle to work in the downtown or nearby areas and are able to undertake many shopping, social-recreational and personal business trips by non-motorized modes due to the intensively mixed land uses and high densities in these areas. The attraction of this way of life in Vancouver is underpinned by the quality of the public realm, which is livable and conducive to social interaction and recreational activities.

Other focal points for high density development have been created that are connected by feeder buses to Skytrain stations. Still other attractive high density, mixed use developments have occurred in areas only serviced by buses, such as Port Moody (though the Evergreen Line of the Skytrain is due to open in 2017). Within these centres, pedestrians and cyclists are given attractive and comparatively safe conditions and there exists a civic life in the city spaces that is generally not found in similar suburban areas elsewhere in North America.

Some significant evidence, for the preference of Vancouverites for such well-located, short distance, non-auto travel option sites, is found in the fact that over a 25 year period period the population of the City of Vancouver grew from 431,147 people in 1986 to 603,502 people in 2011 (Canadian Censuses). Noteworthy is the fact that this increase of 40% occurred in the context of falling household occupancy. Also of note, the Vancouver region's urban density declined between 1961 and 1981. Density went from 24.9 per ha in 1961, to 21.6 per ha in 1971 and to 18.4 per ha in 1981. Then at the time that its strong reurbanisation policies began to cut in, it started to increase in density. It went from 20.8 persons per ha in 1991 to 21. 6 per ha in 1996 and finally to 25.6 persons per ha in 2006 (Kenworthy and Laube, 1999; Newman and Kenworthy, 2015).

Other cities that have demonstrated similar achievements to Vancouver in these five dimensions are Stockholm in Sweden, which is one of the world's great "transit metropolises" (Cervero, 1995, 1998). Cities such as Zurich, Bern and Munich are well-known for their good transit systems and attractive public realms, urban design, development of high quality centres and high densities and mixed land uses for more convenient transit, walking and cycling.

FREIBURG – IM-BREISGAU, GERMANY

Freiburg-im-Breisgau in southern Germany also has a strong emphasis on higher density mixed use development, priority to transit, walking and cycling, development of centres based around transit and fine attention to the public realm. As early as 1989 it was being referred to as the Green Planners Dream (TEST, 1989). In addition, Freiburg is noted for its efforts to preserve agricultural land and natural areas amongst urban development (D 2) and in particular its achievements in the area of environmental technologies (D 4). This latter factor has also been important for Freiburg's economy, which now generates significant money from its environmental technology reputation and demonstration projects.

DIMENSION 2 – FOOD GROWING AND NATURAL AREAS

Freiburg-im-Breisgau is a small university city of 222,203 people (2014)[5] nestled in the Black Forest area of southern Germany. The total land area of the city of Freiburg is 15,306 ha. Of this area only 4,861 ha, or 32%, is required for urban development including all transportation functions. Some 42% is devoted to forests, and 24% is agricultural uses, recreational areas, water protection areas and other undeveloped land (Rikort et al, 2014). This means that more than two-thirds of Freiburg's land area is devoted to green uses. Freiburg has an urban density of 46.1 persons per ha (Rikort et al, 2014). The average for the German sample in the author's global cities database is 48 per ha, which is approximately three times the density of typical auto cities in the USA and Australia. It is only possible to achieve this kind of land use by stopping the spread of new urbanisation into greenfields sites. Freiburg identifies growth areas, usually areas ripe for redevelopment, and master plans those areas for higher density residential and

Photo 14: The Rieselfeld development is anchored by the LRT line on which it is located

Photo 15: Vauban is well-served by a LRT line which also helps to green the neighbourhood

Photo 16: Freiburg's pedestrian and cycle-friendly public environments

mixed use development. Then it connects these sites to the rest of the city with transit, mainly LRT, but also buses and cycleways.

As a result of Freiburg's urban development strategy, it has low dependence on cars. For *all* daily trips, in 1999 (latest hard data), 50% were by walking and cycling, transit 18%, leaving only a 32% share for cars[6].

DIMENSION 4 – ENVIRONMENTAL TECHNOLOGIES

Freiburg has created a reputation worldwide as an environmental technology global "hot-spot". In 1975 the State government of Baden-Württemberg decided to build a nuclear reactor. The very intense, but successful opposition to that policy combined a civil society movement with heavy university involvement. As a result, in the 1980s, Freiburg developed its energy supply concept around renewable energies plus curbing demand, including focussing on transit, walking and cycling and the creation of a built form and public realm that favoured these modes and minimised the need to travel (Peirce, 2009). In the 1990s Freiburg further responded to sustainability by basing its future development on a climate protection concept. Since 2007 its climate protection action plan aims to have a 40% reduction of CO_2 by 2030 (compared to 2007 levels). This plan focuses on sustainable transportation and building and construction standards. Freiburg has had low energy construction since 1992, a subsidy programme to encourage the deployment of energy saving construction since 2002, and new stricter building standards since 2008, with formalised energy saving plans in all public buildings[7].

For decades Freiburg's development has been strongly based on citizen action and participation. Citizens are shareholders in solar and wind power stations. There is direct participation in the spatial development plan and the municipal budget. Citizens act as technical experts on committees and there is much citizen-led environmental education and many campaigns. This citizen participation and

Photo 17: Solar photovoltaic arrays appear on many buildings in Freiburg

networking of stakeholders have helped create a vision of sustainable development, which enjoys much consensus across political parties (Salomon, 2009).

Freiburg had the following achievements in this field (2010):

- Cogeneration covering 50% of electricity demand.
- District heating in new city quarters such as Vauban. Vauban uses a biomass burning plant to dispose of some of its organic waste.
- 90 small scale Combined Heat and Power (CHP) cogeneration plants.
- Five 1.8 Megawatt (MW) windmills.
- Several small scale hydro power turbines.
- More than 10 MW of installed photovoltaic power with 10 million kWh output per annum and 15,000 square metres of solar thermal infrastructure.
- The region sells itself as a Solar City with strong research, industry and a network of stakeholders called SolarRegion Freiburg.

Freiburg also has a multi-layered waste management strategy consisting of different types and colours of bins for waste separation at source (common throughout German cities). There are regular waste bins, bio-degradeable waste bins, green paper bins for paper recycling, and yellow sacks for recyclable plastics. It has 380 stations for glass recycling (green, white and brown glass in separate containers). There is separate collection of hazardous wastes not permitted in any bins and places for the collection of electronic waste such as old computers and mobile phones (also throughout Germany). Finally, it has reuse in the form of a produce exchange system.

These principles and more, such as sustainable water management and sustainable transport, are practiced in new extensions to the city such as Rieselfeld and Vauban. Sustainable water management involves channelling the rainwater falling on the site through green swales that also act as a green open space network through the development. There are

also some "holding ponds" for water that are landscape elements amongst the housing and young children play in them. As well, many of the dwellings have photovoltaics and solar hot water systems.

The district of Freiburg-Rieselfeld was developed out of a need to provide for new housing in the late 1980s and early 1990s and accommodates 11,000 people. Rieselfeld was only possible through as extension of Freiburg's LRT system, along which there are several stops serving the new district. The LRT runs on a grassed corridor through the new district, along which is located a linear neighbourhood center with a rich mix of shops, food stores, restaurants, professional suites and other uses, and above those are several floors of housing. The whole of Rieselfeld is accessible by foot from the LRT stops and both the main street and the residential streets connecting to the LRT stops are bicycle and walking friendly. At many times of the day there are a lot of children riding bikes, walking and playing in the streets. Along this main LRT street are civic functions such as a library, churches and a large square where children enjoy water fountains. Rieselfeld is an excellent example of TOD linked in a linear rather than nodal form to new urban development.

Vauban is a redevelopment area, on a site near to the city, including an old French military barracks and linked to the rest of the city by an extension of the LRT system, again running along a green corridor. Some of the old buildings have been retained and recycled into a kindergarten and other civic uses. Vauban is a dense, mixed-use new neighbourhood of 5,000 people strongly focussed on environmental technologies, especially for renewable energy. It has passive and plus energy houses, meaning that these latter dwellings generate net energy, which is fed back into the grid and as already indicated, it has its own power plant burning waste organic material.

It is a "car free" neighbourhood, but if one wants to have a car one has to store it in a solar parking structure on the fringe of the neighbourhood, which generates enough power for the garage's needs, but also feeds excess power into the grid. Vauban is strongly oriented to transit, walking and cycling and one of its most evident features is its family-friendly public realm. Children and parents are seen walking and riding bikes through comparatively safe 30 km/h residential zones. There are also many parks, which are intensively used by parents and children. Overall, Vauban successfully blends, high density housing, mixed uses, green spaces, transit and walking facilities and the use of environmental technologies into a rich and highly livable place.

SEOUL, SOUTH KOREA: FREEWAY AND ROAD REMOVAL (DIMENSION 3)

Seoul undertook perhaps the boldest ever example of freeway removal[8]. In order to resurrect the culturally significant Cheonggyecheon River, the decision was made to tear down 5.8 km of the Cheonggye freeway and the surface street below. That freeway and surface street system together carried 170,000 vehicles per day through the heart of the city. The freeway alignment has been transformed into a linear green heart for the city, a place to promenade and enjoy. All this occurred without any significant traffic disruption.

Prior to removal of the roads between 2003 and 2005, Seoul had already embarked upon a number of strategies to better manage private transportation in the city. In 1996 tolls of about $2 were introduced on two major entry points into the CBD. Traffic fell by 14 per cent and speeds improved by 38 per cent. Traffic returned to pre-toll levels but occupancy improved and average speeds remained higher. In 1997 regular fee increases were introduced for public parking, parking requirements were lowered for commercial buildings and a parking permit system introduced for residential parking. In 2003 a voluntary 'No Driving Day' was introduced, including financial inducements to participants.

The concept for the project[9] started with two engineers considering the idea of restoring the Cheonggyecheon River, because the Cheonggye District had become one of the dirtiest, noisiest parts of the city and would remain this way with the freeway.

The corridor in which the demolished roads were located is served by multiple subway lines, but importantly the city overhauled the bus system. This included an expansion of a bus rapid

Photo 18: Sustainable water management in Freiburg

Photo 19: Child-friendly public spaces in Freiburg

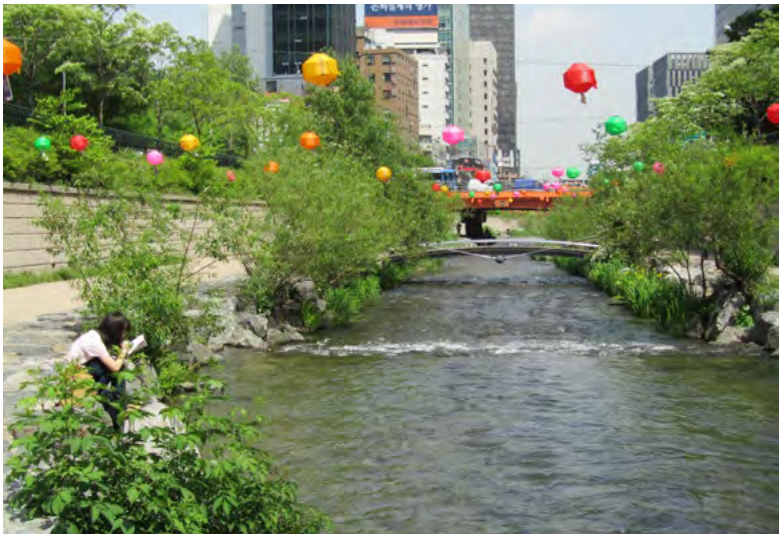


Photo 20: Seoul's green linear heart after the demolition of the elevated Cheonggye freeway and surface road underneath

transit system operating in exclusive median lanes, which had been introduced in 1996. By 2005 there were four routes covering 35 km and by 2007 there were seven routes covering 68 km. Curb-side bus only lanes were also expanded, the fares and timetables were coordinated, including use of a smart card and ITS technology, and services were integrated with the subway system and the services color-coded for ease of use and identity. These changes were also widely publicized leading up to the road removal.

The results were very good. Within months, transit user satisfaction had reached 90 per cent, speeds for the BRT had improved by between 33 per cent and 100 per cent and accidents and injuries on all routes had fallen by a third. But the litmus test of all this was that in five months between January and May 2005 bus patronage rose by almost 1 million per day or almost 25 per cent and the volume of private traffic through central Seoul dropped 9.1 per cent and citywide traffic by 5.9 per cent. The project planner Kee Yeon Hwang also said ..."as soon as we destroyed the road, the cars just disappeared and drivers changed their habits". Other benefits of the project included:

- Average 30 per cent increases of adjacent land value;
- Temperatures in the green corridor are about 4 C below those of areas one-quarter mile away (400 meters);
- Extra water, open space access and recreational opportunities with a jump in the quality of life of city center residents, workers and visitors.
- Re-branding of Seoul's image internationally to one of a more sustainability-focused city
- Long term economic benefits of the project are estimated by the Seoul Development Institute to be $8.5 to $25 billion and 113,000 new jobs.

The success of the project changed the direction of transportation planning in the city and moved it towards transit and non–motorized modes. The project was an example of traffic behaving more like a gas than a liquid. Traffic engineers and transportation planners are trained to think of traffic as a liquid that holds its volume and will flow over everything if blocked or allowed to grow in excess of its current 'container'. However, traffic tends to shrink when road capacity is removed, as has been proven time and again when pedestrian zones have been created (Kenworthy, 2012). The project has inspired Seoul to focus even more on transit and especially to enhance conditions for pedestrians and cyclists and to continue improvements to the public realm.

PORTLAND, OREGON; BOULDER, COLORADO AND PERTH, WESTERN AUSTRALIA – DEBATE AND DECIDE, NOT PREDICT AND PROVIDE AND INTEGRATED SUSTAINABILITY DECISION MAKING

(DIMENSIONS 9 AND 10)

PORTLAND, OREGON

Portland is the most successful and well-known example in the USA of a city that has reshaped itself under a strong vision extending as far back as the 1970s. At this time it established an urban growth boundary to limit sprawl, decided to build a light rail system call Metropolitan Area Express (MAX), which opened its first line in 1986 and scrapped a freeway that would have destroyed 3000 homes (Newman and Kenworthy, 1999). In 2001 it also introduced a separate tram or streetcar system which operates in the inner city. LRT stations and areas around streetcar stops are now a major focus for new growth, with numerous compact, mixed use centres developing along the LRT system and tram system in the inner city, particularly in the Pearl District. Parks and green spaces have been created and property values have risen with strong population growth and company location decisions.

Portland had a visioning process called Region 2040, a broad-based community representation process involving 44 stakeholders developing a vision and strategic goals for the region. At the heart of Portland's growing success over many years has been strong community engagement and empowerment through groups such as 1000 Friends of Oregon who have fought for a sustainability-based vision for their region, focussed on reducing automobile dependence and radically improving transit options[10].

The roots of Portland's performance in land

Photo 21: Portland's downtown market and light rail transit, the result of scrapping the construction of a freeway

use and transportation development dates back to the 1970s when Governor Tom McCall spearheaded a statewide growth management strategy, in particular the establishment and maintenance of urban growth boundaries (UGBs) in Oregon. Portland established such a boundary inside which all urban growth had to occur. This boundary has been linked to transportation since 1991 through the "Oregon Transportation Planning Rule", which applies a growth rule to limit increases in Vehicle Miles of Travel (VMT). The Spring 2009 status report from Tri-Met indicates that between 1996 and 2006 daily VMT increased only 19% while population increased 27% and transit patronage rose 46% (Tri-Met, 2009).

Portland's transit success can also be traced to the land use-transportation integration evident in Portland's 1973 Downtown Plan. A Transit Mall, which opened in 1978 was envisioned as the centrepiece of downtown revitalization and marked the beginnings of a trend to leverage broader community building objectives through transit investment. Other achievements began to punctuate where Portland was going as a city: the conversion of a downtown parking lot to a park, the creation of Pioneer Courthouse Square out of a parking lot, now a major community meeting point in downtown between the one-way pair of streets along which MAX operates, the removal of the Harbor Freeway along the Willamette River in downtown and its conversion to Tom McCall Park. The River Place urban village redevelopment adjacent to the new park, was also built on a commuter parking lot along the river with a hotel, shops at ground level and several floors of apartments above.

Further important steps in Portland's efforts to reinvent itself as a more sustainable and livable city came with successful civil society opposition to the Western Bypass loop of the I-5 freeway through rural lands just outside the growth boundary. Together with the growth management advocacy organization, 1000 Friends of Oregon, a study was undertaken jointly with the USEPA to develop a new approach to the problem. This produced a new planning model called LUTRAQ (Land Use, Transportation and Air Quality). The freeway was scrapped and now transit-oriented development is evident on the Westside light rail line, which was opened in 1998. By that time 7,000 transit-supportive residential units were already under construction in station precincts (Arrington, 2009). Today Portland has 97 km of LRT and 11 km of streetcar. By 2009 over $US9 billion of development had occurred around this transit network and its transit-friendly land use planning (Arrington, 2009).

Portland's 2040 Growth Management Strategy of "build up, not out" is built around transit.

PERTH, WESTERN AUSTRALIA

Perth engaged in a community visioning process in 2003 called "Dialogue With The City", which evolved out of the State Sustainability Strategy involving 42 areas of government, together with business and civil society. The human settlements part of this strategy emphasised innovative and efficient use of resources, less waste output, enhanced equity and livability and a greater sense of place in local communities.

Faced with a huge increase in urban sprawl and car dependence, the State government decided to involve the community on an unprecedented scale to develop a 2030 vision for Perth. The process involved a community survey of over 1700 households and one-day forum involving 1000 participants. A critical part of the forum was a game that each group of 10 people played to plan for the expected increase in in the number of new households. Each decision taken had a flow on effect, which was either positive or negative. People were thus forced to confront the dilemmas of urban planning, trading-off personal lifestyle preferences with systems effects, such as loss of bushland, traffic congestion and other implications[11]. This process resulted in a new plan called "The Network City," which called for around 60% of new dwelling construction to occur within existing built up areas to reduce car dependence and sprawl. The process forced participants to consider sustainability in urban planning.

Perth has also constructed two new rail lines totalling 111 km since 1993, which has involved citizen engagement and heated debate. It also developed a Livable Neighbourhoods design code for suburbs which focuses on walkable communities by changing regulations to reflect priorities such as connectivity of road systems, a sense of place and higher densities and mixed uses in new town centres based around transit[12].

BOULDER, COLORADO

Boulder is a small university town with a 2014 population of around 103,000 people situated in the larger Boulder County area of around 313,000 people. Boulder County is part of the larger automobile-dependent Denver region

Photo 22: Portland's downtown (left, showing Pioneer Courthouse Square) and Pearl District (right, showing the streetcar) have been transformed through pedestrian and transit priority

of about 3.3 million people, though Boulder separates itself from Denver's urban sprawl by a green belt. The city has a progressive history in sustainability terms, being the first US community, in 1959, to introduce a green belt to stop its own urban sprawl and urban encroachment from outside. It did this through a community organization called Plan Boulder, which is still involved in Boulder's development[13]. Boulder distinguishes itself from nearly all American communities of its size in a number of ways, especially through its innovative transit system.

Boulder maintained a "predict and provide" approach to transportation development through most of the post-war period. However, financial, political and physical realities intervened to make this approach unsustainable. In 1996 the Transportation Master Plan set a TDM goal to hold traffic levels to 1994 levels and to reduce single-occupancy vehicle mode share to 25% (Havlick, 2005). The city focussed on travel choices, rather than compulsory car use. This involved improving transit services, creating demand for transit trips, enhancing the bicycle and pedestrian system, marketing and providing good information about the new choices, changing land use and urban design approaches, tackling parking pricing and establishing some dynamic relationships between the city and the University of Colorado ("town-gown" partnership), all in consultation with the Boulder community. It also stopped some large-scale road expansion in neighbouring counties, mainly through public purchase of properties and development rights to prevent development that did not fit with Boulder's growth management and TDM strategies.

A big community-based innovation in Boulder has been the Community Transit Network (CTN), a network of six differently branded types of bus routes that are part of the GO Boulder network, whose goal is to shift 19% of commuters from their cars onto other modes. In 1990 CTN transit ridership was reportedly 5,000 per day and by 2002 had risen to 26,000 per day or a 420 % increase (Bruun, 2004). The routes are referred to as the Hop, Skip, Jump, Bound, Stampede and Dash and buses are accordingly branded and are of different sizes. All carry bicycles at the front. The Hop services are

the shortest routes and the distances get progressively greater towards the Dash[14].

The CTN is the product of a community consultation process. Boulder undertook its successful transit innovations (defining certain major corridors as high-frequency all-day, all-evening, and weekend services) only after a year of extensive public involvement. A citizen group of some 50 community leaders, working with several City of Boulder and transit agency staff, devoted time and energy to this effort, including large public meetings. Significant changes to transit need to be undertaken through public support to ensure usage and ownership of transit systems. They formed a new unit called GO Boulder as a way of circumventing the Public Works Department, which was operating on traditional principles. They also established the City of Boulder Transportation Committee, which ensured citizen interest in the issues[15]. It finally took approximately 10 years to establish the CTN, and each route involved about 1 year of citizen-involved planner per route.

The CTN is now a well-supported community-based system using buses that are family-friendly and bus drivers are employed as community ambassadors. Strong transit use was developed through: innovative Neighborhood and Business Ecopasses[16] which give purchasers unlimited transit access at cost-effective rates; marketing and education; seamless interfaces between bus, bike and pedestrian facilities; good connections to regional services and transit-supportive land use; and, good urban design (Bruun, 2004).

CONCLUSIONS

There are many principles that need to be used to deliver ecologically based urban and transportation planning. The ten dimensions discussed here are by no means exhaustive but are certainly central to efforts towards greater urban sustainability. This paper has provided some insights into Vancouver, Portland, Freiburg im Breisgau, Boulder, Perth and Seoul who have practiced various combinations of these principles with reasonable degrees of success. ◆

All photos courtesy Jeffrey Kenworthy

ENDNOTES

1 The Vancouver region's average road traffic speed in 2006 was 38.6 km/h, whereas metro areas in the USA and Australia average between 43 km/h and 52 km/h (Newman and Kenworthy, 2015).

2 See for example: http://www.metrovancouver.org/services/regional-planning/metro-vancouver-2040/resources/Pages/default.aspx accessed April 10, 2016

3 Vancouver does have the Granville Street Mall, a transit only mall running several blocks in the downtown along which run a number of bus routes.

4 See http://vancouver.ca/streets-transportation/improving-our-cycling-network.aspx accessed April 12, 2016

5 http://www.citypopulation.de/php/germany-badenwurttemberg.php?cityid=08311000
accessed April 11, 2016

6 http://www.freiburg.de/pb/,Lde/231648.html accessed April 11, 2016

7 See: http://www.ecotippingpoints.org/our-stories/indepth/germany-freiburg-sustainability-transportation-energy-green-economy.html. Accessed April 11, 2016

8 See: http://www.seattle.gov/transportation/docs/ump/06%20SEATTLE%20Case%20studies%20in%20urban%20freeway%20removal.pdf accessed April 11, 2016

9 The full story of this project is in a 25 minute documentary called Seoul: The Stream of Consciousness (see www.e2-series.com accessed April 11, 2016).

10 e.g. see later Land Use, Transportation, Air Quality or LUTRAQ at https://www.friends.org/resources/reports accessed April, 11, 2016

11 see http://www.21stcenturydialogue.com/index.php?package=Initiatives&action=Link&file=dialogue_with_the_city.html accessed April 11, 2016 and Marinova, et al, 2004

12 see http://www.planning.wa.gov.au/dop_pub_pdf/LN_Text_update_02.pdf accessed April 11, 2016

13 http://www.planbouldercounty.org/ accessed April 11, 2016

14 see https://bouldercolorado.gov/transportation/transit-system-plan accessed April 11, 2016

15 The 2009 Mayor, Will Toor, started his civic involvement with this committee

16 see https://bouldercolorado.gov/goboulder/eco-pass-program accessed April 11, 2016

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