

RESILIENT INFRASTRUCTURE CITIES

By

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Resilience

Resilience is increasingly being used as a way to describe human activities that are smart, secure and sustainable. They are smart in that they are able to adapt to the new technologies of the twenty first century, secure in that they have built-in systems that enable them to respond to extreme events as well as being built to last, and sustainable in that they are part of the solution to the big questions of sustainability such as climate change, peak oil, and biodiversity. Resilience thinking has been applied mostly to regions and natural resource management systems but can also be applied to cities (Walker, Reid and Salt, 2006).

The question of what kind of infrastructure helps cities to be more resilient is the focus of this chapter. Seven characteristics are outlined to help define these features and they are illustrated from around the world (Newman, Beatley and Boyer, 2009). These are then applied briefly to Singapore as a city that is developing as something of a model in its resilience in the Asian context but has some needs to continue on this journey.

Innovations in Resilient Infrastructure Cities

Globally, there are seven features of resilience that are emerging in infrastructure. These are described as seven archetypal cities:

- The Renewable Energy City;
- The Carbon-Neutral City;
- The Distributed City;
- The Biophilic City;
- The Eco Efficient City;
- The Place-Based City;
- The Sustainable Transport City.

These city types are obviously overlapping in their approaches and outcomes, but each provide a perspective on how attempts to improve the resilience of a city can be achieved.

While no one city has shown innovation in all seven areas, some are quite advanced in one or two. The challenge for urban planners is to apply all of these approaches

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together, to generate a sense of purpose through a combination of new technology, city design and community-based innovation in resilient infrastructure.

The Renewable Energy City

There are now a number of urban areas that are partly powered by renewable energy techniques and technologies, from the region to the building level. Renewable energy enables a city to reduce its ecological footprint, and if using biological fuels, can be part of a city's enhanced ecological functions.

Renewable energy production can and should occur within cities, integrated into their land use and built form, and comprising a significant and important element of the urban economy. Cities are not simply consumers of energy, but catalysts for more sustainable energy paths, and can increasingly become a part of the earth's solar cycle.

While some solar city projects are underway, including Treasure Island in San Francisco, there are presently no major cities in the world that are powered entirely by renewable energy. Movement towards a renewable-energy future will require much greater commitment from cities themselves at all levels, including the local and the metropolitan.

Masdar City in the United Arab Emirates is an important first example of a city built from scratch with 100 per cent renewable energy and zero car use (in theory). It is being built with a 60 megawatts solar photovoltaic plant to power all construction, and eventually a 130 MW solar photovoltaic plant for on-going power as well as a 20 MW wind farm and geothermal heat pumps for cooling buildings. Electric automatic pod cars on an elevated structure will be the basis of the transport. Masdar has begun to be built (Revin, 2008).

North Port Quay in Western Australia will be home to 10,000 households and is designed to be 100 per cent renewable through solar photovoltaic, small wind turbines called wind pods and a nearby wave power system. The development will be dense and walkable with an all-electric transport system featuring electric public and private transport, all linked to renewable power through battery storage in vehicles. The concept has had a mixed response and will be several years in its planning phase as such developments are not easy to accept into town planning schemes designed around fossil fuel based development.

Urban planning is necessary to create the infrastructure needed to support solar and wind power at the scale necessary to help power a city. While finding locations for large wind farms near urban areas has been controversial (such as the wind farm proposal that was defeated off the coast of Cape Cod, Massachusetts), there are significant opportunities to harness solar and wind power. Studies are also now showing that wind, like photovoltaic solar can be integrated into cities and their buildings.

Hydro power has been used in cities such as Vancouver, Canada and Christchurch, New Zealand, for decades. Hydro power is growing slowly due to the impact of large dams, but geothermal power appears to be offering a similar level of base load renewable power.

New model cities that are 100 per cent renewable are needed, but retrofitting existing cities is just as important. Cape Town is moving to 10% renewable and Adelaide has gone from zero to 20 percent renewable energy in ten years by building four large

wind farms. In Europe, Freiburg and Hannover have become demonstrations on how to bring renewables into their city planning (Scheurer and Newman, 2008; City of Hannover, 1998).

The shift in the direction to the renewable city can occur through many actions: demonstration solar or low energy homes created to show architects, developers, and citizens that green can be appealing; procurement actions that source regionally produced wind and other renewable energy to power municipal transit, lights and buildings; and green building standards and requirements for all new public as well as private buildings.

Along with incentives (financial and otherwise), solar cities recognize the need to set minimum regulatory standards. Barcelona has a solar ordinance, which requires new buildings, and substantial retrofits of existing buildings, to obtain a minimum of 60 per cent of hot water needs from solar. This has already led to a significant growth of solar thermal installations in that city.

Transport can also be a major part of the renewables challenge. The more public transport moves to electric power, the more it can be part of a renewable city. Calgary Transit's creative initiative called 'Ride the Wind' provides all the power needed for its light rail system from wind turbines in the south of Alberta, Canada. Private transport can now also be part of this transition through a combination of electric vehicles and new battery storage technology, together called 'Renewable Transport' (see Went, James and Newman, 2008; and [www.sustainability.curtin.edu.au/renewable transport](http://www.sustainability.curtin.edu.au/renewable_transport)). Not only can electric vehicles use renewable electricity to power their propulsion, they can also be plugged in during the day and, through their batteries, as their power systems store four times their consumption. Thus they can provide a critical role in enabling renewables to build up as a much higher proportion of the urban energy grid. There is also a growing belief that natural gas, which can be created from CO₂ and sunlight, will be the renewable freight and industry fuel of the future.

Renewable power enables cities to create healthy and liveable environments while minimising the use and impact of fossil fuels. But, by itself, this will not be enough to ensure resilient urban development.

The Carbon-Neutral City

Carbon neutral can become the goal for all urban development, just as it has become for some businesses and households. This will require a three step process:

- reducing energy use wherever possible — especially in the building and transportation sectors;
- adding as much renewable energy as possible, while being careful that the production of the renewable energy is not contributing significantly to greenhouse gases; and
- offsetting any CO₂ emitted through purchasing carbon credits, particularly through tree planting.

In 2007, the head of News Corporation, one of the biggest media empires in the world, announced that his company would be going carbon neutral. This has led to some remarkable innovations within the company as it confronted the totally new territory of becoming a global leader in energy efficiency, renewable energy and carbon offsets (www.newscorporation.com).

Many businesses, universities and households are now committed to minimizing their carbon footprint and even becoming carbon neutral. But can it become a feature of whole neighbourhoods and even complete cities? There are those who suggest it is essential if the world is to move to 'post-carbon cities' (Lerch, 2007).

There are a number of initiatives that focus on helping cities to reach these goals, including ICLEI-Local Governments for Sustainability's Cities for Climate Change, Architecture 2030, The Clinton Foundation's C-40 Climate Change Initiative and UN-Habitat's Cities for Climate Change Initiative (CCCI). And as mentioned in the above section, many municipalities have started to offer incentives and/or require that new buildings meet certain green-building standards. Minimizing carbon at the building level has momentum, as it is easier to integrate the technology into new buildings, and the benefits have been proven - not just in energy savings, but in increased productivity and fewer sick days in green office buildings.

In Sydney, Australia, the State of New South Wales, through its Building and Sustainability Index programme, has mandated that new homes must now be designed to produce 40 per cent fewer greenhouse gas emissions, compared with an existing house (after initially requiring 20 per cent and finding it was relatively easy to achieve), as well as 40 per cent less water use. The programme aims at reducing CO₂ emissions by 8 million tonnes and water use by 287 billion litres in ten years (Farrelly, 2005). This is an important role for urban planning, through the assessment process, which can help to set up carbon neutral suburbs. The next phase of this project is called Precinx and seeks to establish the statutory planning governance for carbon neutral neighbourhoods and sub divisions.

Zero energy buildings and homes go well beyond what is required by any green building rating system. These have been built in the Netherlands, Denmark and Germany for at least ten years, and there are now increasingly positive examples in every region of the world.

The United Kingdom government has decided that all urban development will be carbon neutral by 2016, with phasing in from 2009. The Beddington Zero Energy Development initiative is the first carbon-neutral community in the UK. It has extended the concept to include building materials and, as it is a social housing development, it has shown how to integrate the carbon neutral agenda with other sustainability goals, making it a more resilient demonstration.

Malmö, Sweden, has stated that it has already become a carbon neutral city; Växjö, Sweden, has declared its intention to become a fossil fuel-free city, and Newcastle, in the UK, and Adelaide, in Australia, also aspire to be carbon neutral. Each has taken important steps in the direction of renewable energy.

Vancouver's new Winter Olympic Village has been built as a model North American demonstration in carbon neutral urban development.

The link to the green agenda of a city is very direct with respect to the carbon neutral approach of bioregional tree planting schemes. By committing to be carbon neutral, cities can focus their offsets into bioregional tree planting, as part of the biodiversity agenda as well as climate change.

In all Australian cities, the carbon and greenhouse gas emissions associated with many municipal motor pools are being offset through innovative tree-planting initiatives and through organizations such as Green Fleet, which has recently planted its 2-millionth tree. Firms, such as airlines, offer carbon neutral services and schools

as well as many businesses are committed to being carbon neutral. The carbon offsetting is accredited through a Federal Government scheme called Greenhouse Friendly and provides a strong legal backing to ensure that tree planting is real, related to the money committed and are guaranteed for at least 100 years as required by the Kyoto Convention. Many of the carbon offsetting programmes are going towards biodiversity plantations that are regenerating a bioregional ecology around cities. A particular example is the Gondwana Links project, which is regenerating an ecological link over 3,000 km between the coastal ecosystems of the Karri forest to the inland woodlands by joining up various reserves across the whole south coast of Western Australia. The project is driven by many big firms using their carbon offsets from energy use to create this biodiversity-based tree planting (Newman and Jennings, 2008).

Preserving and planting trees helps to sequester carbon that is emitted. Tree cover also helps to naturally cool buildings and homes and can reduce the use of energy for artificial cooling. Tree planting as part of a carbon neutral programme can be built into the normal functions of the city, as in Cairo (see Duquennois and Newman, 2008; UN Habitat, 2009). Other urban initiative to provide greater tree coverage through offsets are the Sacramento Municipal Utility District in the US State of California, Atlanta's beltway project and Los Angeles with its 1 million trees program.

All these are good programmes, but none are committed yet to a comprehensive city-wide carbon neutral approach that can link tree planting to a broader biodiversity cause. If this is done, cities can raise urban and bioregional re-forestation to a new level and contribute to reducing the impact of climate change, simultaneously addressing local and regional green agenda issues.

The Carbon Neutral City will receive a big boost when a global compact on carbon trading can be achieved as this will enable the voluntary carbon trading market to become mainstream.

The Distributed City

The development of distributed power and water systems aims to achieve a shift from large centralized power and water systems to small-scale and neighbourhood-based systems within cities. The distributed use of power and water can enable a city to reduce its ecological footprint, as power and water can be more efficiently provided using the benefits of electronic control systems and community-oriented utility governance.

Most power and water systems for cities over the past 100 years have become bigger and more centralized. While newer forms of power and water are increasingly smaller scale, they are often still fitted into cities as though they were large. The movement that tries to see how these new technologies can be fitted into cities and decentralized across grids is called 'distributed power and distributed water systems' (Droege, 2006).

The distributed water system approach is often called 'water sensitive urban design'. It includes using the complete water cycle, i.e. using rain and local water sources like groundwater to feed into the system and then to recycle 'grey' water locally and 'black' water regionally, thus ensuring that there are significant reductions in water used. This system can enable the green agenda to become central to the infrastructure management of a city, as stormwater recycling can involve swales and artificial

wetlands that can become important habitats in the city. Grey water recycling can similarly be used to irrigate green parks and gardens, and regional black water recycling can be tied into regional ecosystems. All these initiatives require ‘smart’ control systems to fit them into a city grid and also require new skills among town planners and engineers, who are so far used to water and energy management being a centralized function rather than being a local planning issue (Benedict and McMahon, 2006).

In large cities, the traditional engineering approach to providing energy has been through large centralized production facilities and extensive distribution systems that transport power relatively long distances. This is wasteful because of line losses, but also because large base load power systems cannot be turned on and off easily, so there is considerable power shedding when the load does not meet the need. However, renewable, low-carbon cities aim at developing more decentralized energy production systems, where production is more on a neighbourhood scale and both line losses and power shedding can be avoided. Whether from a wind turbine, small biomass Combined Heat and Power plant (as in London’s new distributed energy model), or a rooftop photovoltaic system, renewable energy is produced closer to where it is consumed, and, indeed, often directly by those who consume it. This distributed generation offers a number of benefits, including energy savings, given the ability to better control the power production, lower vulnerability and greater resilience in the face of natural and human-made disaster (including terrorist attacks). Clever integration of these small systems into a grid can be achieved with new technology control systems that balance the whole system in its demand and supply from a range of sources as they rise and fall and link it to storage, especially vehicle batteries through vehicle-to-grid, or ‘V2G’, technology. A number of such small-scale energy systems are being developed to make cities more resilient in the future (Sawin and Hughes, 2007).

There are now many cities that are able to demonstrate small scale local water systems that are very effective. The many developing country cities that already have distributed water supplies from community boreholes and small scale sewage treatment can look to a number of cases where these have been made safe and effective without being turned into expensive centralized systems (Ho, 2002). In Malang, East Java, a small scale community sewage system was fitted into a squatter village to provide sanitation for 500 families (Newman and Jennings, 2008).

Distributed power and water provision in cities needs community support. In Toronto a possible model similar to those outlined above in developing cities has been created. Communities began forming ‘buying-cooperatives’ in which they pooled their buying power to negotiate special reduced prices from local photovoltaic companies that had offered an incentive to buy solar photovoltaic panels. The first co-op was the Riverdale Initiative for Solar Energy. In this initiative, 75 residents joined together to purchase rooftop photovoltaic systems, resulting in savings of about 15 per cent in their purchase cost. This then spread across the city. The Toronto example suggests the merits of combining bottom-up neighbourhood approaches with top-down incentives and encouragement. This support for small-scale distributed production—offered through what are commonly referred to as standard offer contracts (often referred to as ‘feed-in tariffs’ in Europe), has been extremely successful in Europe, where they are now common. The same can be done with new technologies for water and waste, such as rain water tanks and grey water recycling.

One other model example is the redevelopment of the Western Harbour in Malmö, Sweden. Here the goal was to achieve distributed power and water systems from local sources. This urban district now has 100 per cent renewable power from rooftop solar panels and an innovative storm water management system that recycles water into green courtyards and green rooftops. The project involves local government in the management and demonstrates that a clear plan helps to drive innovations in distributed systems (City of Malmö, 2005).

Distributed infrastructure is beginning to be demonstrated in cities across the globe. Utilities will need to develop models with city planners of how they can carry out local energy and water planning through community-based approaches and local management.

The Biophilic City

Biophilic cities are using natural processes as part of infrastructure. Growing energy and providing food and materials locally is therefore becoming part of urban infrastructure development. The use of photosynthetic processes in cities reduces their ecological impact by replacing fossil fuels and can bring substantial ecological benefits through emphasis on natural systems.

There has been a positive trend in planning in the direction of an expanded notion of urban infrastructure that includes the idea of ‘green infrastructure’ based on photosynthetic processes. Green infrastructure refers to the many green and ecological features and systems, from wetlands to urban forests, that provide a host of benefits to cities and urban residents — clean water, storm water collection and management, climate moderation and cleansing of urban air, among others. This understanding of green infrastructure as part of the working landscape of cities and metropolitan areas has been extended to include the photosynthetic sources of renewable energy, local food and fibre.

Renewable energy can be tapped from the sun and wind and geothermal sources using small-scale decentralized technology, as described in the previous section. However, renewable energy can also be grown through biofuels. The transition to growing fuels is drawing on crops and forests that can feed into new ways of fuelling buildings and vehicles. Farms and open areas around cities are being developed as the source of renewable energy, especially the production of bio-fuels. However, biofuels are also being produced as part of improving the urban environment. This means more intensive greening of the lower density parts of cities and their peri-urban regions with intensive food growing, renewable energy crops and forests, but greening the high density parts of cities as well.

The City of Vaxjö in Sweden has developed a locally based renewable energy strategy that takes full advantage of its working landscapes, in this case the abundant forests that exist within close proximity of the city. Vaxjö’s main power plant, formerly fuelled by oil, now depends on biomass almost entirely from wood chips, most of which are a by-product of the commercial logging in the region. The wood, more specifically, comes from the branches, bark and tops of trees, and is derived from within a 100 km radius of the power plant. This Combined Heat and Power plant (Sandvik II) provides the entire town’s heating needs and much of its electricity needs. Its conversion to using biomass as a fuel has been a key element in the city’s aspiration to become an oil-free city. Clearly, each city can develop its own mix of local renewable sources, but Vaxjö has demonstrated that it can transition from an oil-

based power system to a completely renewable system without losing its economic edge. Indeed, cities that develop such resilience early are likely to have an edge as oil resources decline.

The metropolitan landscape can be viewed as the pallet for a creative mix of solar design and renewable energy projects, and every city and region will have its own special opportunities and resources and in doing so will help create a more resilient city.

One of the most important potential bio-fuel sources of the future will be blue-green algae that can be grown intensively on roof tops. Blue-green algae can photosynthesize, so all that it requires is sunlight, water and nutrients. The output from blue-green algae is ten times faster than most other biomass sources, so it can be continuously cropped and fed into a process for producing bio-fuels or small scale electricity. Most importantly, city buildings can all utilize their roofs to tap solar energy and use it for local purposes without the distribution or transport losses so apparent in most cities today. According to one advocate of this approach, '*every roof should be photosynthetic*', meaning a green roof for biodiversity purposes, water collection, photovoltaic collectors or biofuel algal collectors. This can become a solar ordinance set by town planners as part of local government policy.

Few cities have done much to take stock of their photosynthetic energy potential. Municipal comprehensive plans typically document and describe a host of natural and economic resources found within the boundaries of a city — from mineral sites, through historic buildings, to biodiversity — but estimating incoming renewable energy (sun, wind, wave, biomass or geothermal) is usually not included. In advancing the renewable energy agenda in Barcelona, the city took the interesting step of calculating incoming solar gain. As a former sustainable city counsellor noted, this amounted to '*10 times more than the energy the city consumes or 28 times more than the electricity the city is consuming*' (Puig, 2005). The issue is how to tap into this across the city.

As well as renewable fuel, cities can incorporate food in this more holistic solar and post-oil view of the future. Food, in the globalized market place, increasingly travels great distances — apples from New Zealand, grapes from Chile, wine from South Australia, vegetables from China. 'Food miles' are rising everywhere and already food in the US travels a distance of between 1,500 and 2,500 miles from where it is grown to where it is consumed. Any exotic sources of food come at a high-energy cost. The growing, processing and delivering of food in the US consumes vast amounts of energy on par with the energy required to power homes or fuel cars (Starrs, 2005).

There are now good examples of new neighbourhoods and development projects that design-in, from the beginning, spaces for community gardens that attempt to satisfy a considerable portion of food needs on-site or nearby. Growing food within cities and urban (and suburban) environments can take any number of forms. Community gardens, urban farms, and edible landscaping are all promising urban options (Halwiel and Nierenburg, 2007). Prominent and compelling examples of edible urban landscaping have shown that it is possible to trade hardscape environments for fruit trees and edible perennials. In the downtown Vancouver neighbourhood of Mole Hill, for instance, a conventional alleyway has been converted to a green and luxurious network of edible plants and raised-bed gardens, in a pedestrianised community space, where the occasional automobile now seems out of place. New urban

development can include places (rooftops, sideyards, backyards) where residents can directly grow food. This has been a trend in developed cities, as new urban ecological neighbourhoods have included community gardens as a central design element (for example, Viikki, in Helsinki, South False Creek in Vancouver, Troy Gardens in Madison), but is perhaps most famous in Cuban cities over the past few decades, in response to being cut-off from oil imports (Murphy, 1999).

Urban agriculture is also widespread in other developing country cities, where it provides food and income for many poor households. Cities need to find creative ways to promote urban farming where it is feasible, without creating tension with redevelopment for reduced car dependence through increased density. This may mean that a city can utilize the many vacant lots for commercial and community farms in areas that have been blighted (for example the estimated 70,000 vacant lots in Chicago). However, if these areas are well served with good transit and other infrastructure, then such uses should be seen as temporary and, indeed, can be part of the rehabilitation of an area, leading to the development of eco-villages that are car free and models of solar building, as in Vauban. Many cities have embarked on some form of effort to examine community food security and to promote more sustainable local and regional food production. These can be integrated into ecologically sustainable urban and regional rehabilitation projects (Beatley, 2005) and can utilize the intensive possibilities of urban spaces, as in urban permaculture (see Newman and Jennings, 2008).

In Madison, Wisconsin, a model urban garden called Troy Gardens has emerged from excess land owned by a state-owned mental hospital. Dubbed the Accidental Eco-village by those involved in its transformation, the land was being sold in 1995 when the community who used it as a garden and park stepped in and formed an association to try and buy the land. Through partnerships with other NGOs and the University of Madison Department of Urban and Regional Planning, the Friends of Troy Gardens was able to create a diversity of uses that enabled the money to be found. Thus on the site now is a mixed income co-housing project involving 30 housing units, a community garden with 320 allotments, an intensive urban farm using traditional Hmong agricultural techniques for a community supported agriculture enterprise, and a prairie restoration scheme which is regenerating local biodiversity (Campbell and Salus, 2003).

Progress in moving away from fossil fuels also requires serious localizing and local sourcing of building materials. This, in turn, provides new opportunities to build more photosynthetic-economies. The value of emphasizing the local is many-fold and the essential benefits are usually clear. Dramatic reductions in the energy consumed as part of making these materials is, of course, the primary benefit. It is also about strengthening local economies and helping them to become more resilient in the face of global economic forces and it is also about re-forming lost connections to place.

At the Beddington Zero Energy Development project in London, more than half of the building materials for the project came from within a 35-mile radius, and the wood used in construction, as well as a fuel in the neighborhood's Combined Heat and Power plant, comes from local council forests. A biophilic approach to urban use of fibre will mean an added reduction in fibre miles as well as potential to help re-grow bioregions.

The Eco Efficient City

In an effort to improve eco-efficiency, cities and regions are moving from linear to circular or closed-loop systems, where substantial amounts of their energy and material needs are provided from waste streams. Eco-efficient cities reduce their ecological footprint by reducing wastes and resource requirements, and can also incorporate green agenda issues in the process.

A more integrated notion of energy and water entails seeing cities as complex metabolic systems (not unlike a human body) with flows and cycles and where, ideally, the things that have traditionally been viewed as negative outputs (e.g. solid waste, wastewater) are re-envisioned as productive inputs to satisfy other urban needs, including energy. The sustainability movement has been advocating for some time for this shift away from the current view of cities as linear resource-extracting machines. This is often described as the eco-efficiency agenda (Girardet, 2000).

The eco-efficiency agenda has been taken up by the United Nations and the World Business Council on Sustainable Development, with a high target for industrialized countries of a 10-fold reduction in consumption of resources by 2040, along with rapid transfers of knowledge and technology to developing countries. While this eco-efficiency agenda is a huge challenge, it is important to remember that throughout the industrial revolution of the past 200 years, human productivity has increased by 20 000 per cent. The next wave of innovation has a lot of potential to create the kind of eco-efficiency gains that are required (Hawkins et al., 1999; Hargrove and Smith, 2006).

The urban eco-efficiency agenda includes the 'cradle to cradle' concept for the design of all new products and new systems like industrial ecology, where industries share resources and wastes like an ecosystem (McDonough and Braungart, 2002). Good examples exist in Kalundborg, Germany and Kwinana, Australia (Jennings and Newman, 2008).

The view of cities as a complex set of metabolic flows might also help to guide cities dealing with situations (especially in the shorter term) where considerable reliance on resources and energy from other regions and parts of the world still occurs. Policies can include sustainable sourcing agreements, region-to-region trade agreements, urban procurement systems based on green certification systems, among others. Embracing a metabolic view of cities and metropolitan areas takes global governance in some interesting and potentially very useful directions.

This new paradigm of sustainable urban metabolism (seeing them as complex systems of metabolic flows), requires profound changes in the way cities and metropolitan regions are conceptualized as well as in the ways they are planned and managed. New forms of cooperation and collaboration between municipal agencies and various urban actors and stakeholder groups will be required. Municipal departments will need to formulate and implement integrated resource flow strategies. New organizational and governance structures will be necessary, as well as new planning tools and methods. For example, municipal authorities that map the resource flows of their city and region will need to see how this new data can be part of a comprehensive plan for integrating the green and brown agendas.

One extremely powerful example of how this eco-efficiency view can manifest in a new approach to urban design and building can be seen in the dense urban neighborhood of Hammarby Sjöstad, in Stockholm. Here, from the beginning of the

planning of this new district, an effort was made to think holistically, to understand the inputs, outputs and resources that would be required and that would result. For instance, about 1000 flats in Hammarby Sjöstad are equipped with stoves that utilize biogas extracted from wastewater generated in the community. Biogas also provides fuel for buses that serve the area. Organic waste from the community is returned to the neighborhood in the form of district heating and cooling. There are many other important energy features in the design as well. The neighbourhood's close proximity to central Stockholm and the installation (from the beginning) of a high-frequency light rail system have made it truly possible to live without a private automobile (there are also 30 car-sharing vehicles in the neighbourhood). While not a perfect example, it represents a new and valuable way of seeing cities, and requires a degree of interdisciplinary and inter-sectoral collaboration in the planning system that is unusual in most cities (Newman, Beatley and Boyer, 2009).

Eco-efficiency does not have to involve just new technology, it can also be introduced into cities through intensive use of human resources, as in Cairo's famous Zabaleen recycling system (see Newman and Duquenois, 2008). There are many other examples of how cities across the third world have integrated waste management into local industries, buildings and food production (Hardoy et al, 2001).

The Place-Based City

Cities and regions are increasingly understanding sustainability more generally as a way of developing their local economies, building onto a unique and special sense of place, and as a way of nurturing a high quality of life and a strong commitment to community. The more place-oriented and locally self sufficient a city's economy is, the more it will reduce its ecological footprint and the more it will ensure that its valuable ecological features are enhanced. The Place-Based City will increasingly be the people-oriented motivation for the infrastructure decisions that are made in each of the other city-types.

Local economic development has many advantages in the context of sustainable development, including the ability of people to travel less as their work becomes local. Finding ways to help facilitate local enterprises becomes a major achievement for cities in moving towards a reduced ecological footprint. Initiatives designed to help small towns in the US to grow their own jobs have been developed (Sirolli, 1999). An approach for creating local enterprises that build on the passions and resources of the local community and support local businesses in their early vulnerable steps has also been developed. The inaugural Enterprise Facilitation project, which is designed to create local jobs, was pioneered in the small rural town of Esperance, Western Australia, in 1985, but has since spread across three continents. The success of this initiative is reflected in the words of its Chair:

We are proud to say almost 800 businesses – or 60 per cent of the entrepreneurs – we met are still running successful, sustainable operations and have contributed more than \$190 million in revenue to the local economy. We have averaged almost 40 new business start ups a year consistently in the last 20 years, which is quite a track record given Esperance has a population of just 13,500 people. (Sirolli, 1999)

What the pioneers of these initiatives have both found, time and time again, is that place really matters. When people belong and have an identity in their town or city, they want to put down their roots and create local enterprise.

Local economic development is a first priority for most cities. As part of this, many cities are placing increasing emphasis on local place identity, as social capital has been found to be one of the best ways to predict wealth in a community (Putnam, 1993). Thus when communities relate strongly to the local environment, the city's heritage and its unique culture, they develop a strong social capital of networks and trust that forms the basis of a robust urban economy.

This approach to economic development, which emphasizes place-based social capital, has many supporters, but very few relate this to the sustainability agenda in cities. For example, energy expenditures — by municipalities, companies and individuals — represent a significant economic drain, as they often leave the community and region. Producing power from solar, wind or biomass in the locality or region is very much an economic development strategy that can generate local jobs and economic revenue from land (farmland) that might otherwise be economically marginal, in the process re-circulating money, with an important economic multiplier effect. Energy efficiency can also be an economic development strategy. For example, research on renewable energy and the creation of related products have developed into a strong part of the economy in Freiburg, Germany.

All the efforts at localizing energy, food, materials and economic development, remain dependent on the strength of the local community. The Beddington Zero Energy Development project shows the critical importance of thinking beyond the design of buildings and seeing urban development through a more holistic community-oriented design lens. However impressive the passive solar design and smaller energy demands of this project are (300 mm insulation, an innovative ventilation and heat recovery system, for instance), much of the sustainability gain will come from how residents actually live in these places. Here, residents are being challenged to re-think their consumption and mobility decisions — there is a car-sharing club on site, for example, a food buying club, and a community of residents helping each other to think about creatively reducing their ecological impacts and footprints is emerging. This is actually a hallmark of European green projects and an important lesson for projects elsewhere.

A study which examined a range of European urban ecology innovations concluded that when the innovations came from a close and committed community, they became ingrained in people's lifestyles, giving the next generation a real opportunity to gain from them. However, many architect designed innovations that were imposed on residents without their involvement tended to fall into neglect or were actively removed (Scheurer, 2003).

Sense of place is about generating pride in the city about all aspects of the economy, the environment and the culture. The Magic Eyes project in Bangkok has illustrated how a solid waste project can be facilitated through sense of place (UN Habitat, 2009).

Sense of place in a city requires paying attention to people and community development in the process of change – a major part of the urban planning agenda for many decades. This localized approach will be critical to integrating the green and brown agendas. It creates the necessary innovations as people dialogue through options to reduce their ecological footprint, which in turn creates social capital that is the basis for on-going community life and economic development (Beatley and Manning, 1997; Beatley, 2005). City dwellers in many countries already increasingly want to know where their food is grown, where their wine comes from, where the

materials that make up their furniture come from. This can increasingly move towards every element of the built environment. Thus, as well as a slow movement for local foods, a slow fibre and slow materials movement for local fabric and building purposes can also help create a sense of place and bring the green and brown agendas together.

City economies in the past had their own currencies and it has been argued that national currencies often fail to express the true value of a city and its bioregion (Jacobs, 1984). Transforming urban economies towards a more bioregional focus has been assisted in some places by adopting complementary currencies that provide an alternative to national currencies and by establishing local financial institutions. It has been argued that a complementary local currency not only facilitates change, but also creates a community with a mutual interest in productive exchange among its members in the bioregion (Korten, 1999). In this way, a community affirms its identity and creates a natural preference for its own products. Over a thousand communities around the world have issued their own local currencies to encourage local commerce. How this has been related to urban planning is set out in Newman and Jennings (2008) using the example of Curitiba.

Most developed cities have created development bonuses similar to Curitiba's that are part of the non-monetary economy of the city. For example, in Vancouver, the city requires that 5 per cent of the value of a development be directed into social infrastructure. This is worked out by the developer and council in discussion with the local community who may want more landscaped streetscapes, more pedestrianised areas or a community meeting space, even an art-house cinema. Social housing is worked out on the basis of receiving a density bonus for more development rights. The more Vancouver exercises these complementary currency requests, the more the development process works to create better public spaces to go with the private spaces developed by the market. Thus sustainability can be made to mean something at a very local level through the planning system.

All cities have the opportunity through their planning systems to create their own currencies that work in a parallel but complementary way with normal money. These 'sustainability credits' are not owned by the developer or by the city but they are in fact, owned by the community, as it is their values that are expressed in the development bonuses granted. Thus cities can create community banks of sustainability credit through their planning systems. Most cities in developing countries do not have much to invest in their public spaces hence the whole city economy suffers. Curitiba showed how cities could break that mould. Through the planning system, cities can create their own sustainability currencies for what they most need as determined by their local citizens – they just need to define them as 'development rights'. These new 'sustainable development rights' could be related to biodiversity credits, greenhouse reduction credits, salinity reduction credits, affordable housing credits or anything else that a community can create a 'market' for in their city and its bioregion. Increasingly these credits can be related to the mainstream economy (just as carbon credits are) in order to fund the infrastructure needed for the resilient city.

The Sustainable Transport City

Transport is the most fundamental infrastructure for a city as it creates the primary form of the city (Newman and Kenworthy, 1999). Cities, neighbourhoods and regions

are increasingly being designed to use energy sparingly by offering walkable, transit-oriented options, more recently supplemented by vehicles powered by renewable energy. Cities with more sustainable transport systems have been able to increase their resilience by reducing their use of fossil fuels, as well as through reduced urban sprawl and reduced dependence on car-based infrastructure.

The agenda for large cities now is to have more sustainable transport options so as to reduce traffic whilst reducing greenhouse gases by 50 per cent by at least 2050, in line with the global agenda set through the International Panel on Climate Change. For many cities, the reduction of car use is not yet on the agenda, apart from seeing it as an ideal to which they aspire. Unfortunately, for most cities, traffic growth has been continuous and appears to be unstoppable. To reduce a city's ecological footprint and enhance its liveability, it is necessary to manage the growth of cars and trucks and their associated fossil fuel consumption.

Figure 1 Private passenger transport energy use per person in selected cities, 1995

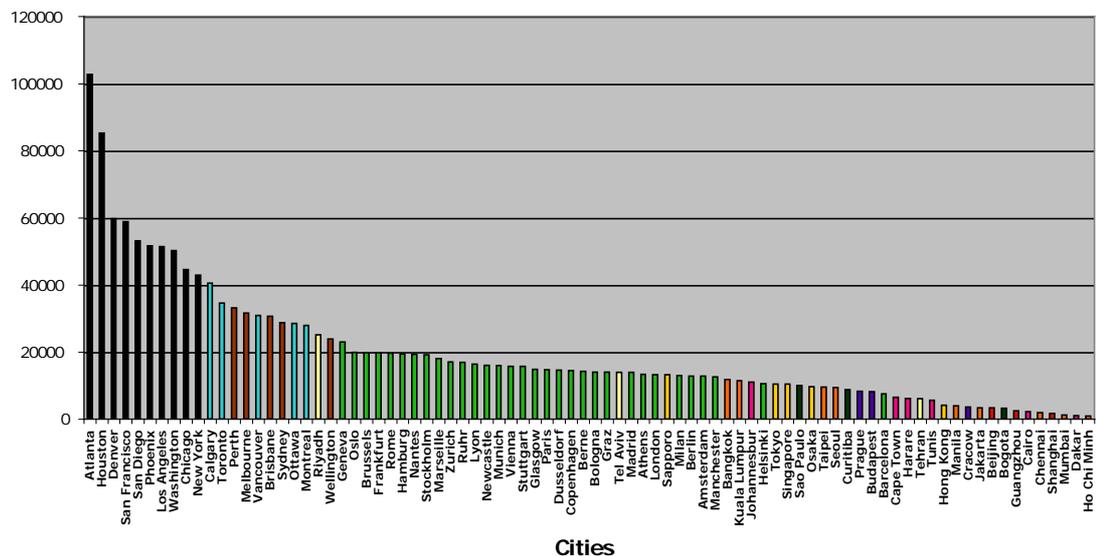


Figure 1, which shows the variations in private transport fuel use across 84 cities, illustrates that there is a very large difference in how cities use cars and petroleum fuels (Kenworthy and Laube, 2001). A number of studies have shown that these variations have little to do with climate, culture or politics, and even income is very poorly correlated, but they have a lot to do with the physical planning decisions that are made in those cities (Newman and Kenworthy, 1999; Kenworthy et al 1999). There is debate about the relative importance of urban planning parameters, though within the profession there is increasing awareness that sustainable transport will only happen if much greater attention is paid to: urban form and density; infrastructure priorities, especially relative commitment to public transport compared to cars; and street planning, especially provision for pedestrians and cyclists as part of sustainable mobility management. These issues are also addressed in the Chapter on Transport by Peter White.

Urban form and density planning

Very high density city centres mean that most destinations can be reached with a short walk or they can have highly effective public transport opportunities due to the concentration of people near stations. If densities are generally lower, but higher along corridors, it is still feasible to have a good transit system. If, however, low densities are the dominant feature of a city, then most activity needs to be based around cars, as they alone can enable people to reach their destinations in a reasonable time. Public transport finds it hard to be competitive, as there are just not enough people to justify reasonable services. Most low density cities are now trying to increase their densities in order to reduce their car dependence (see Newman, Beatley and Boyer, 2009).

Density is a major tool available to planners in cities. It is best used where a city has good transit or wants to build transit, as the resulting Transit Oriented Developments (TODs) can reduce car use per capita among its residents by half and save households around 20 per cent of their income, as they have on average one less car (often none) (Cervero, 2008). TODs are thus an affordable housing strategy as well. In the US, according to a study by Ewing et al (2007) shifting 60 per cent of new growth to compact patterns would reduce CO₂ emissions by 85 million metric tons annually by 2030. TODs reduce ecological footprint in cities and undermine the kind of car-based sprawl that eats into the green agenda of cities. Thus the TODs strategy can enable a city to put in place a clear urban growth boundary and to build a green wall for agriculture, recreation, biodiversity and the other natural systems.

If cities are dense, as in many developing countries, but do not have adequate public transport and allow too much traffic to develop in their streets, then they can easily develop dysfunctional transport systems. However, their density will always enable them to provide viable public transport solutions if they invest in them, whereas low density cities are always struggling to provide other options. High density means easier non-car based access, but it can also mean much greater congestion whenever vehicles are used. If the vehicles in these confined spaces are poorly maintained diesel engines, then serious air pollution can result - so cities need to be very serious about managing the source of such emissions (see Jain, 2004; Rosencranz and Jackson, 2002; UN Habitat, 2009).

Infrastructure priorities and transit planning

The 'transit to traffic' ratio measures how effective public transport is in competing with the car in terms of speed. The best European and Asian cities for transit have the highest ratio of transit to traffic speeds and have achieved this invariably with fast rail systems (Kenworthy, 2008). Rail systems are faster in every city in the study sample by 10–20 kph over bus systems that rarely average over 20 to 25 kph. Busways can be quicker than traffic in car saturated cities, but in lower density car dependent cities, it is important to use the extra speed of rail to establish an advantage over cars in traffic. This is one of the key reasons why railways are being built in over 100 US cities and, in many other cities, modern rail is now seen as the solution for reversing the proliferation to the private car. Rail is also important because it has a density-inducing effect around stations, which can help to provide the focussed centres so critical to overcoming car dependence, and they are also electric, which reduces vulnerability to oil.

Across the world, cities are building modern electric rail systems at vastly increasing rates, as they simultaneously address the challenges of fuel security, decarbonising the economy in the context of addressing climate change, reducing traffic congestion sustainably, and creating productive city centres. The trend towards fast electric rail in cities is now being called a 'Mega Trend' (Rubin, 2008). Chinese cities have moved from their road building phase to building fast modern rail across the nation. China is committed to building 120,000 km of new rail by 2020. Investment will rise from 155 billion Yuan (US\$22b) per year in 2006 to 1000 billion per year by 2009 (US\$143b), with around 6 million jobs involved. These projects are part of China's response to the recent global economic downturn (Dingding, 2008). Beijing now has the world's biggest Metro.

Delhi is building a modern electric metro rail system, which has considerably boosted the city's pride and belief in the future. The 250km rail system is being built in various stages and will enable 60 per cent of the city to be within 15 minutes walking distance of a station (Jain, 2008).

In Perth, Australia, a 172 km modern electric rail system has been built over the past 20 years, with stunning success in terms of patronage and the development of TODs; the newest section runs 80 km to the south and has attracted 50,000 passengers a day, where the bus system carried just 14,000 a day – the difference is that the train has a top speed of 130 kph and averages 90 kph, so the trip takes just 48 minutes instead of over an hour by car. London, especially with its congestion tax which is recycled into the transit system, and Paris have both shown European leadership in managing the car (see Newman, Beatley and Boyer, 2009).

While greening buildings, developing renewable fuel sources and creating more walkable communities are critical resilient infrastructure of the sustainable transport city, investing in viable, accessible transit systems is the most important component for them to become resilient to waning oil sources and to minimize the contribution of urban areas to climate change. Transit not just saves oil, it helps restructure a city so that it can begin the exponential reduction in oil and car use so necessary for a sustainable future (Newman, Kenworthy and Glazebrook, 2008).

Street planning and mobility management

If cities build freeways, car dependence quickly follows. This is because the extra speed of freeways means that the city can quickly spread outwards into lower density land uses as the freeway rapidly becomes the preferred option. If, on the other hand, a city does not build freeways but prefers to emphasise transit, it can enable its streets to become an important part of the sustainable transport system. Streets can be designed to favour pedestrians and cyclists and wherever this is done, cities invariably become surprised at how much more attractive and business-friendly they become (Gehl and Gemzoe, 2000; Gehl, Gemzoe et al 2006.).

Sustainable mobility management is about 'streets not roads' - the streets are used for a multiplicity of purposes, not just maximising vehicle flow. The emphasis is on achieving efficiency by maximising people movement, not car movement, and on achieving a high level of amenity and safety for all street users. This policy also picks up on the concept of integration of transport facilities as public space. One of the ways that US and European cities are approaching this is through what are called 'complete streets' or, in the UK, 'naked streets'. This new movement aims to create streets where mobility is managed to favour public transport, walking and cycling, as

well as lower speed traffic. The policy often includes removing all large signs for drivers which means they automatically slow down: in Kensington High Road in London the traffic accident rate has halved because of this.

Building freeways does not help create a resilient city. It will not help a city save fuel, as each lane rapidly fills, leading to similar levels of congestion that existed before the road was built (Nolan and Lem, 2001; Standing Advisory Committee on Trunk Road Assessment, 1994.). Indeed, studies have shown that there is little benefit for cities in terms of congestion when they build freeways. There is no overall correlation between delay per driver and the number of lanes of major roads built per head of population for the 20 biggest cities in the US (Urban Transportation Monitor, 1999).

Thus, for urban planners, the choices for a more sustainable city are quite stark, though politically they are much harder, as the allure of building more road capacity remains very high. Many cities that have confronted the provision of a freeway have been global leaders in the move towards more sustainable transportation. Copenhagen, Zurich, Portland, Vancouver and Toronto all had to face the cathartic experience of a controversial freeway. After a political confrontation, the freeway options were dropped. They decided instead to provide other greener options and hence the building of light rail lines, cycleways, traffic calming and associated urban villages began to emerge. All these cities had citizen groups that pushed visions for a different, less car-oriented city and a political process was worked through to achieve their innovations. Similar movements are active in Australia (Newman and Kenworthy, 1999).

Freeways have blighted the centres of many cities and today there are cities that are trying to remove them. San Francisco removed the Embarcadero Freeway from its waterfront district in the 1990's after the Loma Prieta earthquake. It took three ballots before consensus was reached, but the freeway has been rebuilt as a friendlier tree-lined boulevard involving pedestrian and cycle spaces. As in all cases where traffic capacity is reduced, the city has not found it difficult to ensure adequate transport, as most of the traffic just disappears. Regeneration of the land uses in the area has followed this change of transportation philosophy (Gordon, 2005).

Seoul, in Korea, has removed a large freeway from its centre that had been built over a major river. The freeway had become controversial because of its blighting impacts on the built environment as well as the river. After a mayoral contest where the vision for a different kind of city was tested politically, the newly elected mayor began a five year programme that entailed:

- Dismantling of the freeway;
- Rehabilitation of the river;
- Restoration of a historical bridge over the river;
- Restoration and rehabilitation of the river foreshores as a public park;
- Restoration of adjacent buildings; and
- Extension of the underground rail system to help replace the traffic.

The project has been very symbolic, as the river is a spiritual source of life for the city. Now other car saturated Asian cities are planning to replace their central city freeways (<http://www.metro.seoul.kr/kor2000/chungaehome/en/seoul/2sub.htm/>).

What these projects have shown and encouraged is to '*think of transportation as public space*' (Burwell, 2005). With this changed approach to city planning, the

small-scale systems of pedestrian movement and cycling become much more important. Pedestrian strategies enable each centre in a city to give priority to the most fundamental of human interactions: the walking-based face-to-face contact that gives human life to a city and, in the process, reduces ecological footprint.

Cycle oriented strategies can be combined with the development of greenways that improve the green agenda and lower ecological footprint. Enough demonstrations now exist to show that pedestrian and bicycle strategies work dramatically to improve city economies and to integrate the green and brown agendas. Pedestrian and bicycle strategies in Copenhagen, most Australian cities, London, New York and San Francisco and Bogota, as well as the dramatic changes in Paris with the Velib bicycle scheme and the growing awareness that it works in developing country cities as well, are all testament to this new approach to cities (Newman and Kenworthy, 2007).

Urban planning for resilient urban infrastructure development

The above seven Resilient City types suggest that in order to create resilience in cities, there will need to be:

- Renewable energy strategies showing how to progressively tap local resources. Such strategies should involve recognition of renewable resources in and around a city as part of the capital base of the city and establishing ordinances on buildings that facilitate the application of renewable energy.
- Carbon neutral strategies that can enforce energy efficiency, integrate with the renewables strategy and direct the carbon offsets into the bioregion. This can be enforced through planning schemes that mandate standards for significant reductions in carbon and water in all development, that prevent the loss of arable and natural land in the bioregion, and direct planting to areas that are most in need of revegetation.
- Distributed infrastructure strategies that enable small-scale energy and water systems to flourish. This can be built into the requirements for urban development and can be facilitated by providing incentive packages with new buildings for technologies such as photovoltaic cells, grey water systems and water tanks, with local plans for the governance of community-based systems, as well as region-wide strategies for recycling sewage.
- Biophilic or green infrastructure strategies that include the photosynthetic resources of the city and which can enhance the green agenda across the city through food, fibre, biodiversity and recreation pursuits locally. This can be achieved through development controls that focus on how the roof tops (and walls) of buildings can be used for photosynthetic purposes, as well as zoning areas for urban photosynthetic activity, including growing bio-fuels, food and fibre, and biodiversity in and around the city.
- Eco-efficiency strategies linking industries to achieve fundamental changes in the metabolism of cities. This can be done by taking an audit of all the wastes of the city and seeing how they can be re-used through stakeholder participation and government facilitation.
- Sense of place strategies to ensure the human dimension is driving all the other strategies. This can be assisted by local economic development strategies, by place-based engagement approaches to all planning and development processes and by the innovative use of 'sustainability credits', or complementary

currencies, to implement local sustainability innovations as development bonuses. These credits can help the resilient infrastructure requirements of the resilient city.

- Sustainable transport strategies incorporating: (i) quality transit down each main corridor which is faster than traffic; (ii) Dense TODs built around each station; (iii) pedestrian and bicycle strategies for each centre and TOD with cycle links across the city; (iv) plug-in infrastructure for electric vehicles as they emerge (v) cycling and pedestrian infrastructure as part of all street planning; and (vi) a green wall growth boundary around the city preventing further urban encroachment.

Application to Singapore

Singapore is often held up as an Asian exemplary city in terms of urban planning and development. How does Singapore compare in terms of resilient infrastructure development? Below is a quick assessment of where the city is and some of the gap areas:

- Renewable energy strategies in Singapore are not well developed with no clear plan yet for Singapore that will address this agenda. Wind power is weak so solar and wave technologies will be needed as the focus with some geothermal possibilities. However it is also possible to link into broader regional renewable energy approaches such as the Desertec Pan-Asian Energy Infrastructure that stretches between China and Australia using High Voltage Direct Current (HVDC) distribution systems (www.desertec-asia.com). This concept enables the region to use the best available renewables without significant transmission losses and is supported by the Asian Development Bank's 'Infrastructure for a Seamless Asia (2009) report. Singapore could be a leader in developing this concept and showing what would be needed in terms of small scale local systems of renewables as the support base.
- Carbon neutral strategies that can enforce energy efficiency are beginning to be created though no attempt has yet been made to direct carbon offsets into the bioregion. A Carbon Plan is needed for Singapore.
- Distributed infrastructure strategies that enable small-scale energy and water systems to flourish have not been considered because Singapore is one of the few Asian cities to have a fully sewered city, a fully reticulated water supply system and complete grid for electricity covering all buildings. As the small-scale systems for water, energy and waste become more mature it will be possible to put these back into the city whilst retaining the central grids for back-up.
- Biophilic or green infrastructure strategies are beginning through one of the best landscaped cities in tropical Asia and also through some of the innovative architecture of Ken Yeang. An urban agriculture strategy is not yet in place.
- An Eco-efficiency strategy is one of the best in the world as the city is now a leader in recycling 100% of its sewage back into potable water. All other wastes are managed with considerable efficiency due to strict regulations.
- Sense of place strategies to ensure the human dimension of resilience is part of

the policy mix are now apparent in Singapore. Urban design and development is constantly being re-evaluated in terms of their cultural relevance and contribution to the 'tropical island of excellence'. This now needs to have a perspective that can link the cultural dimension of Singapore into the provision of resilient infrastructure as a source of pride and opportunity.

- Sustainable transport strategies are one of the great contributions of Singapore to the global transport and land use debate, especially in the Asian region (see other chapter in this book on transport). They have been able to create: (i) quality transit down each main corridor which is faster than traffic; and (ii) Dense TODs built around each station. However the priority for pedestrian and bicycle strategies has not been as high a priority as perhaps they deserve but instead tremendous effort has gone into the congestion management system in the city. Plug-in infrastructure for electric vehicles has not yet been considered but is an obvious next step for the city's innovation. A growth boundary around the city preventing further urban encroachment is constantly managed as the city has so little land to waste.

Conclusion

The resilient city of the future is becoming an agenda that cannot be neglected as the global issues accelerate such as climate change, peak oil, water, waste, biodiversity and urban quality of life. The resilient city will need to build infrastructure to support the seven city types outlined if it is to respond to this agenda. Examples have been provided of how each agenda is underway, however no city has begun to work equally on all seven areas. Eventually this will be required. Singapore has shown leadership in the Asian region on some of these issues but for it to continue to be a 21st century model it will need to adopt some of these emerging paradigms of resilience. This is a challenge but also a great opportunity.

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