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E-mail: j.whitelegg@btinternet.com

http://www.eco-logica.co.uk

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Editorial

Only ten years into the new millennium the awareness is growing that the transport sector will have to change fundamentally in the coming decades. Two mega trends make a major system shift inevitable. First, climate change has taken hold of the public agenda. Earlier doubts about the existence of the greenhouse effect have been wiped away by new proof about large-scale human impact on the world's climate. Awareness is growing that emissions have to be reduced – and that the transport sector can no longer avoid drastic measures. Second, rising oil prices is opening up the eyes of policy-makers and market parties that the century of cheap energy is coming to an end. Without major changes, this will especially impact the transport sector, given its poor track record in energy conservation.

Both mega trends point out that we are heading for a post-carbon age, an age in which our energy needs have to be fulfilled without a heavy reliance on fossil fuels, and without relying on an unlimited absorption capacity of the climate system. This post-carbon age challenges the very organisational basis of our post-industrial societies: a high level of mobility facilitated by high-quality infrastructures and low transport costs. This calls for a fundamental reconceptualisation of our transport system. Three possible scenarios come to mind.

In the first, perhaps optimistic, scenario, science and technology are able to develop new energy sources that can replace fossil fuels. These are not only renewable and environmental friendly, but also enable individual motorized mobility. The switch to sustainable energy sources will marginalize environmental concerns and unleash an even stronger growth in mobility at regional and global levels, resulting in a new spatial structure at global, regional and local scale.

In a second scenario, the search for replacement energy sources is unsuccessful and governments are unable to develop a feasible alternative for individual motorized mobility. The result is a structural shortage of energy for the transportation sector, forcing businesses and people to reduce their mobility and develop new organisational models. The result is a forced re-organisation of the spatial order towards compact cities, mixed land uses, and self-contained cities and regions.

In the third scenario, the energy needs of the transport sector are pushed down through a fundamental restructuring of the transport system. Efficient, low-energy, collective transport systems will replace current car-based systems. Long distance travel will move from fast modes (airplane, high speed railway) to slow speed (regular trains, zeppelins). The new modes will develop into the backbones of a renewed spatial order, resulting in a new centres and new peripheries.

This special issue of *World Transport Policy & Practice* is an outcome of the conference *Planning for the Carbon Neutral World: Challenges for Cities and Regions*, held 15-18 May 2008 in Salzburg, Austria. The conference, organised by SCUPAD – Salzburg Congress on Urban Planning and Development – brought together (transport) planners, architects, urban designers and other professionals, from both practice and academia. It provided a platform to discuss and explore, from an economic, land use and transportation perspective, possibilities to develop carbon-neutral cities (for more information, please visit www.scupad.org).

Five excellent contributions presented at the transportation workshops during the SCUPAD conference are brought together in this special issue. Each of the paper explores how we can deal with transport in a post-carbon society. The issue opens with a conceptual contribution, by *Ronald Rovers*, providing a novel way to approach the city as an urban organism or 'orbanism'. *Petra Hirschler and Nina Svanda* explore how the dependency of the transport sector on fossil fuels has changed over time in Vienna, depending on the complex interaction between transport and urban development policies. They show how Vienna's policies have created a robust urban environment that provides substantial possibilities to reduce transport-related carbon emissions in the (near) future. Then, *Ernst Schriefl*, *Uwe Schubert, Franz Skala and Gernot Stöglehner* give an overview of a number of approaches and concepts on urban development, which can help cities and regions reshape their spatial structure a basis and *condition sine qua non* for a less carbon dependent urban transport system. *Kris Wernstedt and Aurash Khawarzad* take a more pragmatic approach and explore the public acceptability of combined land use and transport strategies that can reduce carbon emissions. They find that, even under current market circumstances in which carbon emissions are not charged for, there is a substantial willingness-to-pay among the wider public for urban environment that enables low-carbon transportation. The special issue closes with a contribution by *David Prosperi*, who explores how airports and the air sector, a major contributor to greenhouse gas emissions, could adapt to a post-carbon society.

Taken together, the papers provide an optimistic view about human's ability to build a path towards a carbon-neutral future, but also make clear that it will require a major transition of the still-dominant transport and land use practices of 20th century towards practices and institutions that take energy use and carbon emissions as a guiding principle, if real change is to come about.

Karel Martens

Institute for Management Research
Radboud University Nijmegen
The Netherlands
k.martens@fm.ru.nl

Abstracts & Keywords

Post Carbon - or Post crash – managing the Orbanism

Ronald Rovers

At the end of the 19th century when industrialisation took over more agriculture based society, links were broken between urbanised areas and the hinterland. From that moment on cities could grow unlimited, relying on provisioning from distant independent sources. It has not only led to unlimited urban growth but also to unlimited consumption of resources and unlimited pollution. The rate of urbanisation is still growing, as well as the consumption patterns of its inhabitants. The pressure on the resource provisioning is starting to create problems. Food, water energy and materials are the main flows involved. Water is mainly a local issue, food and materials have become global issues, with energy as resource to facilitate the distribution. Energy has now main attention as a resource in stress, with a main focus at the side effect of climate change due to fossil energy consumption. However, for energy there is an alternative, which is using the overall source, the sun, food and materials resources are under increasing stress as well, though not yet recognised as such.

Keywords: closed cycles, urban, harvest, resources.

Changing dependencies on fossil fuel: the case of Vienna

Petra Hirschler, Nina Svanda

Vienna's radial concentric urban development produced a sustainable, crisis proof urban structure which is possibly independent from motorised individual traffic within the last 100 years. Furthermore the Transport Master Plan and the Urban Development Plan will improve the accessibility of locations and thus their attractiveness. They are in line with the urban development strategies which generally reduce the need for mobility like a compact city and a polycentric urban structure.

Keywords:
Urban development, accessibility, mobility, urban structure.

Urban Development for Carbon Neutral Mobility

Ernst Schriefl, Uwe Schubert, Franz Skala, Gernot Stöglehner

"Carbon neutral mobility" is based on a concept of mobility (defined as the number of accessible destinations) different to that for "fossil mobility" (defined as the ability to cover distances).

Different approaches towards further carbon neutral development of mobility and the interrelated urban design (Carfree Areas, Transit Oriented Development, Post Carbon Cities and Ecocity) show principles and measures for planning sustainable and liveable settlements, offering many benefits for health, safety and well-being of their inhabitants.

Keywords: urban design, Ecocity, pedestrians, public transport, Carbon Neutral Mobility, Peak Oil

Integrated Transport and Urban Design Choices to Reduce Carbon Emissions: Public Attitudes in the Washington, DC USA Metropolitan Area

Kris Wernstedt

We examine individual-level preferences for housing options with different integrated transportation and design features that affect carbon emissions. These features entail subsidised shared cars, adjacency to mass transit facilities, higher residential densities, reduced residential energy consumption, and mixed residential, retail, and commercial use. Our study relies on a survey of more than 270 residents in the Washington DC (USA) metropolitan area. We find that respondents exhibit statistically significant preferences for the provision of parking for private vehicles rather than subsidies for shared car use, nearness to transit, lower residential densities, lower energy costs, and mixed use development, as well as a strong willingness to tradeoff among these features.

Keywords: urban, Washington DC, land use, residential, choice experiment, smart growth

Greening the World's Airports

David C. Prosperi

An earlier version of this paper was presented by David C. Prosperi and Jeanette Tavarez, under the title Green Airports, at the 40th SCUPAD Congress in Salzburg, Austria, May 15-18, 2008.

The purpose of this paper is to review, assess, and identify research areas regarding the greening of airports. The paper necessarily includes air travel *per se*, but the major focus here is on airports in particular, although it necessarily involves attributes "in and around" airports. Although there are a few references to the general topic of air travel and sustainability (Longhurst et al., 1996; Gillingwater, 2003), the topic of greening airports is virtually ignored in the professional and academic literatures.

Keywords: air travel, aiports, sustainability, post-carbon society

Post Carbon - or Post crash – managing the Orbanism

Ronald Rovers

At the end of the 19th century when industrialisation took over from a more agriculture-based society, links were broken between urbanised areas and the surrounding countryside. Cities could grow to an unlimited degree from this moment onwards relying on provisioning from distant independent sources. This has not only led to unlimited urban growth but also to an unlimited consumption of resources and pollution.

The rate of urbanisation is still growing as is the consumption of urban residents. The pressure on resource provisioning is starting to create problems. Food, water, energy and materials are the main flows involved. Water is mainly a local issue while food and materials have become global issues with energy as the resource to facilitate distribution. Now, energy has the main attention as a resource under pressure while the main focus is on the side effect of climate change due to fossil energy consumption. However, for energy there is an alternative, which is using the overall source: the sun. Food and material resources are under increasing pressure as well although this has not been recognised as such yet. [1,2]

We should, however, realise that materials (and food) resources are at the basis of society's development. Without resources there is no construction, and without a built environment there are no related problems such as climate change, health issues, comfort, etc., and no GDP growth. The bottom line is: the planet comes before people who come before profit.

There is an example on a small scale: This what the Easter Islanders have experienced in real life. They ran out of wood that was needed for building and maintaining fishing boats (for food) and the end result was decline and extinction. (Pointing, 1991) It is an island in the ocean and the world is an island in space.

We are currently very quickly depleting the energy and material stock created in periods in which we did not use these resources. A moment will come when we will have to start to only again consume what will be regenerated in the same time period with regard to every resource.

We are now on the eve of change where the balance between need and provisioning (of materials and food facilitated by (transport) energy) will be disrupted due to unhealthy situations regarding air quality in urban areas with a high degree of consumption, changing external conditions due to climate change and limits in provisioning from far-away places due to limits in resources and energy for transporting these materials.

If the human race wants to continue its way of life, it has to adapt to the resources available otherwise the resources will adapt themselves to humans. We will either have a human-induced "post-carbon" society or a nature-induced "post-crash" society.

Since urbanisation is continuing at a rapid pace, the key is to change the 'metabolism' of urban development *or a 'system crash' will force cities to find very fast new ways to survive.*

Closing resource cycles

Before we elaborate further on the role of cities in the change with regard to a post-carbon society, we must first explore the overall situation and preferred direction of development. We should be aiming at operating using a closed cycle resource management system since this is only way to maintain the balance in our system. This was already implied in Brundtland's definition: Children should have the same choices as we have. The only possibility for that is not to deplete any source, and since the Earth in itself is a closed system regarding material resources, there are no resources from outside the system to add to the stock or, in other words, we must shift to a closed cycle management of resources.

The use of the Earth' mineral resources will decrease stocks on a human timescale even though they are renewed on a geological timescale. A sustainable and durable management of materials will have to be based on a closed cycle approach to resources that can be renewed linked to the timeframe in which these 'borrowed' resources pass through that cycle and the energy necessary to create and manage that process.

Within such a resource system, nothing can be called sustainable unless it has served a function for a specific period in a way that the system had time to recover from it. If the time to renew the potential of the system is too short, the system is not sustainable and will change.

The balance is dictated by the (management of the) amount of resources: which resources are in which function for how long. With more people and, therefore, a growing demand, resources will have to maintain their functions over a longer period of use to maintain a balanced situation.

The idea is not to create a system that does not require resources. That would be impossible since life itself requires resources. Resources also influence the 'metabolism' to which they belong. However, the idea is to acquire or maintain a balance where resource management is at its basis.

Improvement cannot just be implemented by starting to base our activities on a 'resource' approach should we consider current consumption patterns and population growth; we would only be reducing impact and not balancing things in that case. Instead, we need a functional approach; we must provide, for example, shelter in any way that is possible with regard to buildings and construction. Each step must be optimised on its own but they must also be limited by an integral approach and service of functions.

A first step in creating such a closed cycle is, of course, returning everything that has 'come out': there is no such thing as waste, only resources in different forms, locations and composition and re-use and recycling of everything to the highest degree to provide a 'function'.

This also implies the least degradation of products and sources, that is to delay increasing the entropy of mass *(to avoid 'levelling earth')* and to avoid an additional input of energy to act in such a way. *Only during a last phase can the energy content of mass be transformed into energy and related nutrients*

The input side is determined by available sources. These are sources that do not deplete the stock. This is related to stock growth per unit of time (instead of stock depletion) in addition to an input of energy that is the lowest possible to maintain and manage the cycle.

Closing the cycle is not a guarantee in itself that we will manage to ensure that our way of life can survive with the available resources. Even with re-growable or renewable resources: a wooden beam can survive its re-grow time and stay in function much longer. That does not mean that the global wood stock is sufficient to support all our 'beam' needs. A system approach using different levels is, therefore, needed to harmonise each step with the other steps. In order to manage the cycle according to the available resources, closed cycle management has to also address total volumes, time frames of use and the energy input to operate the cycle. Energy/transport as a service is a second order problem: it is basically a side effect of inefficient organisation. It has been and can be solved using creative organisation methods and by reshuffling activities during the connections and on both sides of these connections.

When things are structured, 4 main steps are involved:

1 Close the cycle (make resources part of that cycle);
2 Reduce the volume of resources in that cycle;
3 Reduce the speed by which goods are going through the cycle;
4 Reduce the energy required to drive/maintain the cycle.

Sub 1
Closing the cycle means that an approach is created related to a balanced input and output over time that, in turn, is related to providing a service. Once goods and materials are in the cycle, they will stay in the cycle and items may only be added to the cycle if they do not reduce the absolute stock. If the absolute stock is reduced, the assessed system will change.

Sub 2
Reducing the volume in the cycle is directly related to the reduction of total consumption and in particular to a shift from materialised provisions of functions to a serviced way of providing functions. (An example: Our dream is not to have a washing machine but we do want our laundry cleaned: have launderettes instead of 3 billion individual washing machines.)

Sub 3
Delaying the speed of goods going through the cycle provides more time for restoring the original stock and to maintain or even expand the potential. This argument does not just apply to refuting production for a fixed service life. Any recycling at any moment will require additional energy and resources and, therefore, reduces the total stock.

Sub 4
Reduction of energy to drive the cycle is in line with the general energy policy. All materials will consume energy before they are fit-for-purpose or for re-use and the amount of energy used should be reduced. This can be achieved by reducing the volume of the cycle and the distances involved that products travel during the cycle steps, by implementing industry improvements and by switching to renewable energy in the same way (time, volume and stock) as for mass in general. In fact it is a resource reduction for driving the cycle itself where energy is a specific form of a mass resource.

The role of transport

Please keep in mind that we are not directly referring to transport. It is all about the energy invested to provide a function to a specific location. It is about providing the basic resources to society: food, water and materials. Having them transported is a luxury problem and it is based on the inefficiency of our system organisation that has steadily grown in size. Step 4 is mainly about improving the system operation where less energy is invested to relocate goods (which is partly a space organisation problem as we will see below.)

Transport sometimes can be regarded as a prime activity, for instance, “travelling”.

Notwithstanding the fact that this is a 'comfort service' rather than a 'surviving society' service, it cannot be dealt with by changing, for example, distances because that would change the provided/required function. When this is the case, it should be treated like any other prime function: the service should, however, be provided after being optimised and following a closed cycle approach.

The Orbanism

The next step is to analyse how to ensure such a closed cycle resource management is practised. In today's society we recognise three different levels that are critical for such management. First there is the bottom level were people produce and consume (products from) resources.

It is at this level that functions have to be provided in the form of materialised products. These products must be provided whilst having the highest performance and must lead to the lowest quality loss in society. However, it is impossible to drive for an overall closed cycle management at this level since the influences and system limits of operation are very small.

At the highest system level we have Earth. This provides the limits and borders for the overall system to operate in. A maximum is set by the bearing capacity of Earth's resources. Should we also wish to avoid depletion, a full shift towards renewable and re-growable resources will have to be established. This, however, also has limits: the re-growable capacity has a limit with regard to the world's geo-biosystem.

We also have the in-between level, increasingly represented by urbanised regions. People and activities concentrate more and more in these areas.

Measures can be taken here to avoid resource consumption by replacing the materialistic function provision with a serviced provision since there is a sufficient volume of supply and demand.

In the ideal situation, the Earth's geo-biosystem sets limits for the local system to operate in and defines the resources available to add products or buildings to the system.

Urban 'metabolism' is the key that can be regarded as an organism: cities are becoming massive organisms that swallow huge amounts of resources and spit out large streams of residues that are unused, distorted and lost in dilution.

This urban organism, what I call the *Orbanism*, is what we have to tame and we must teach it to behave as a normal organism that maintains its habitat in order for the species to survive.

It is the 'orbanism' that has to change from a consuming to a producing way of life.

The built environment

How to practise a closed cycle approach is illustrated based on the analyses of a built environment starting point. The built environment as a whole forms the basis of activities in an urban setting where the basic functions are provided and most flows are converted and reduced

As has already been analysed in the closed cycle approach, providing functions should be the starting point. Within this context, servicing is a key issue. In terms of building and construction, space provision is the key. This can eventually be virtual space and not necessarily physical space. A building is not always required should we wish to have a coming together [4]. If the function, however, is physically provided, it should have a very long service life with re-use at the highest level: as a building. (Figure 1a)

Only if this is absolutely impossible for reasons to be specified, can it be dismantled for re-use at the highest level: i.e. when providing a window function, as a window frame or when providing a separation function (1b), concrete slabs as concrete slabs as has been demonstrated in Berlin.

Partial functions can only be treated as materials again only when the quality of these partial functions prevents this. They should then be upgraded to new products to serve new functions. (1c)

Buildings that are to be newly constructed should initially be compiled from (1b] and (1c).

Another possible source in this stage could be residues from other industries that should be upgraded to building products (1d).

This will, of course, not be sufficient in many practical situations and primary materials will have to be supplemented to the cycle that are derived from renewable resources (within the time constraints explained above) (1e).

It is obvious that we can only speak of a closed cycle if resources in (1f) are avoided that consist of non renewable resources additions to the cycle. If these resources are used, the total stock will decrease.

Similar cycles can be drawn for the water and energy resources, though in different time frames, and even for products. They show the same pattern that starts from a function provided as a service before materialising, being re-used and/or recycled and being added from renewables.

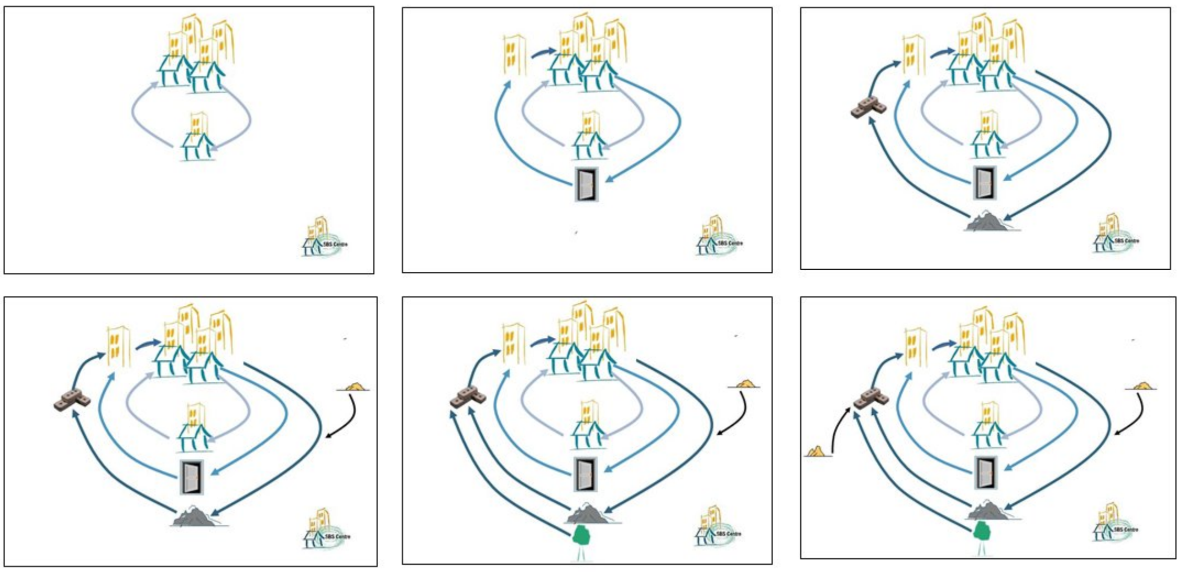
These cycles will have to be operated within the limits set by the global system for an equal amount of resources for the urban system sizes.

Vitality of the orbanism

Urban environments have grown without giving much thought to the closed cycle management of resources. It is, however, necessary to know how much of the resources required can be provided from within the system itself to, on the one hand, limit the inflow of virgin resources during a transition towards a 'post-carbon' era and, on the other hand, to measure how far the orbanism can survive in case of a crash of the provisioning system.

By analysing all the potential inside the system and comparing it with demand and the already implemented potential, we can show the vitality of the orbanism.

Figure 1a -1f



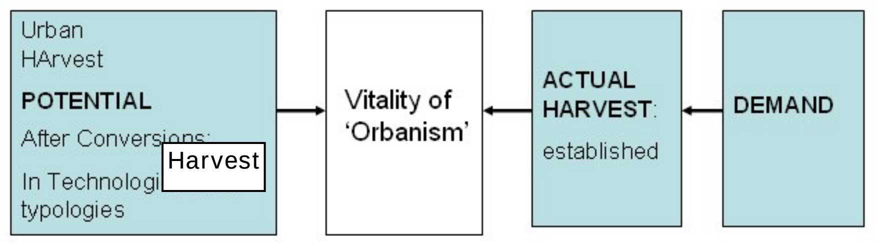


Figure 2: Potential harvest versus demand and actual harvest gives the vitality of the orbanism

Harvesting the orbanism

Urban Harvest is a model to explore this potential as part of the closed cycle management with regard to harvesting every resource from within the urban system (Rovers, R. 2007) as it has been defined.

Urban Harvest strategy is defined as:

To collect any renewable primary or secondary resources within an urban environment system and to (re-)use these within that urban environment system.

Urban Forest: all solids from day-to-day consumption

Urban Rivers: all liquids from day-to-day consumption

Urban Energy: all flows containing energy

Urban Farm: all edible resources from within the system

Urban Quarry: all solids from the built/constructed environment over time; primary and secondary

Urban Space: all space that is available in the urban environment over time

Urban Harvest (UH) does not look at consumption or inflow in the system. It is regarded as a given situation from only the perspective of how this demand can be supplied from within the system itself as primary and secondary resources. A higher proportion of these resources will reduce the need for resources from outside the system to flow in.

Thus, they already will influence "transport and related energy demand ("to drive the cycle"). Note that in the 6 defined UH streams there is none directly related to transport. Transport is, as explained above, regarded as a second order effect: it is not transport that is needed in itself but relocating goods and/or people, which is related to the management of mobile and non-mobile space.

In other words: providing volume and speed to have a service at a specific moment and location, that is, the time/space relation is a key process in the cycle.

Transport is, therefore included in Space except for the energy part: Space is a core resource that comprises both Indoor and Outdoor Space. Outdoor, in turn, is divided in static (any open public space) and dynamic (mobile) space (empty seats and goods capacity).

It is the space capacity to move people and goods which is the core cycle while fuel is part of the energy issue that drives that process. This means that it can be treated twofold in the Urban Harvest approach where the energy involved in making space move is part of the Urban energy stream: how to fulfil demand in the most optimised way.

This is the basic starting point. We have, however, not yet carried out specific research into this mobile space organisation.

The Urban environment is regarded as an impersonal productive area, which produces or can produce resources of different kinds in different quantities and qualities. These are measured independently of their way of production, use or treatment without significantly influencing or changing the way in which that environment works. For example, buildings are not demolished to create space for biomass growing. This built and un-built environment is, however used to accommodate the harvest of resources. Research aims at developing a practical approach/tool for cities.

Calculations in Urban Harvest start from the total available potential without restrictions. For instance, the total amount of rain as collectable water harvest or the total amount of radiation as a potential energy source. This provides the Potential (P). The potential has to be converted to a useful form such as radiation via PV panels to create electricity. This is the conversion step called the Max Tech potential (MT). The last step is to re-introduce this potential into an urban environment. Since one of the principles is not to significantly change the urban environment, it has to be applied in the actual setting: for instance on roofs or other existing surfaces. The total available area combined with the potential gives the practical Urban Max Tech (UMT).

The total can be seen as the maximum potential energy harvest in a worst case scenario: If the urban organism (*orbanism*) is cut off from its supplies of resources, it will be what it can supply itself as a maximum. If this maximum is more that it totally consumes, the orbanism could survive without adapting. If, however, this maximum is insufficient, the orbanism has to find other resources or adapt the way it operates. In this way, *the orbanism's 'vitality' can be measured to overcome a crisis for each resource stream*

Currently, small scale pilots in the field of energy are being carried out and a large-scale field pilot is being carried out through PhD research as part of the SREX research programme. [5]

A strategy needs to be developed for dealing with resource competition: roof surfaces can be claimed for energy harvests but also for urban farming, rainwater potential, etc. There is no general approach for this: each urban environment will have to decide which resources are most urgently needed to be addressed.

(Existing) roads could have a similar role as roofs: They can be used to a larger extent as tracks for mobile space. They could generate the energy to move space or provide energy to functions around the roads. This is part of the Urban Harvest research as the illustration shows but it is also an issue to be considered in energy analysis for optimising the quality of energy use. For instance, in the SREX project [6]. This creates a relation between the type of energy, the best fit for demand and the optimised ('transport') distance between generation and use. Roads are in this regard a highly appreciated location.

Carbon neutral orbanisms

The idea and realisation of closed cycle managed cities or, in the case of energy, 'post-carbon cities' or 'carbon-neutral cities' will require an enormous effort to establish, especially when all energy consumption is taken into account such as in industry and transport.

In practice, the potential within city boundaries cannot always be fully explored or implemented and strategies sometimes rely on resources outside the system boundaries. Currently, this has become reality with regard to many cities that have opted for a zero-carbon approach. Variations on this theme exist such as zero-CO_2 or even zero-energy cities and zero-fossil fuel cities.

A consensus, however, has not yet been agreed on defining these strategies. It is very important that claims on resources or effects outside a system's borders (city) are unique and guaranteed to prevent double counting and free rides when we consider the closed cycle approach and the 3 different levels on which this has to be implemented.

We found that office construction was being promoted in the assessed area during a recent project since the new location would significantly reduce commuting linked to CO_2 emissions when compared to the original scattered locations ('reducing the inefficiency in the system'.) This, however, is only viable, when construction in the scattered locations is then forbidden. It is obvious that these original planned locations will be developed during a later stage anyway making the claims useless and, therefore, constituting a free ride. More of these examples have been identified and this has led to a first conclusion that any system claiming resource emissions or compensations outside its own system should assume responsibility for those claims or, in other words, expand its own system to include those claimed areas. Otherwise, these claims should be made from areas that operate a similar system approach and have available a surplus.

The Earth's resources can only be claimed once, that is, with regard to their time of functional use until they are replaced or re-grown. Otherwise, the balance will be disrupted and it will change into an unpredicted form.

A post-carbon city definition implies the inclusion of boundaries with regard to land as well as the sectors and consumers involved. There is a difference between transport/travelling as a luxury activity (for example, people going on holiday) and between transport that is needed for relocating resources and goods (including people in the form of labour resources) in this approach.

The transported resources and goods are due to the importing system but there can be some discussion on how to allocate the energy/fuel involved to transport; is it part of the importing system or of the exporting system? The decision was taken that a system is responsible for all energy consumed by vehicles registered in that system with regard to the CO_2-neutral city programme in the Netherlands. This means that the exporting system is responsible for the fuel implications of transport (assuming that vehicles are registered there). The goods are due to the importing system. People form a labour resource with regard to people commuting and, therefore, the same approach as with vehicles applies: the resource implications are to be borne by the system where they are registered. (The same applies if they work in system 2.)

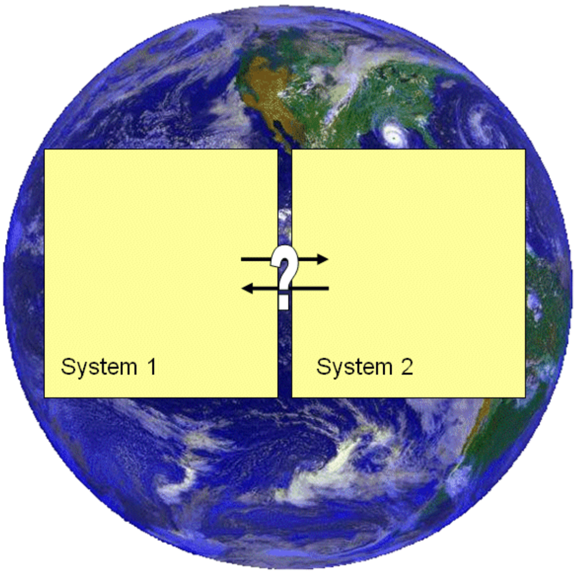


Figure 3: Imports to system 1 count for system 1: the transport related energy to the exporting system 2.

It should be noted that a carbon-neutral approach does not imply a closed cycle approach. Closing cycles start from causes (resource consumption) while carbon (or CO_2) approaches only deal with one of the impacts of resource use. In the case of energy they will eliminate the climate change effect but not prevent depletion of resources.

It would, therefore, be better to also develop strategies for energy neutral or zero-energy

cities (post fossil fuel cities) dealing with depletion. (As has been the case in the Netherlands pilot programme; see the related paper in this publication.)
Energy should only be supplied from streaming resources to avoid further pressure being exerted on land use, which will be needed for food and, in line with a closed cycle, for materials for a 'bio-based material society': hydropower, wind and direct solar conversions. (We may not agree on what exactly renewable is and on the role of biomass but this should be excluded for energy purposes since land is needed for food and mass production and energy is the only issue that has the possibility of using an extraterrestrial source. Both issues are explored in other papers under development.)

A (draft) definition of an 'energy-neutral city', or a 'post fossil fuel city' (pointing at the cause) could, therefore, be:
"Not more energy is used by registered use and users than is generated in or supplied to the defined (urban) system by streaming renewable energy sources based on generation on a real time basis with potential imported energy coming from a surplus of an energy neutral managed area /system." [7][8]

Post-carbon or post-crash
The question is will we be able to create a post-carbon or post fossil fuel society ourselves or will nature force us to operate in such a way, after the system has failed? That is, will we have a 'post-crash' way of life?
The results will be the same since in both cases a closed cycle approach is needed. In the first case, we can have a smoother transition. Should we not opt for this, we will have to face a post-crash era in which we will be forced to use our resources practising extreme economy. This is, in fact, what we should be doing right now. However, should we be forced, we will have to change abruptly. [8]
Transport is crucial in this regard: the more people and goods that are transported, the more dependant we will be on sources that are far away and the more energy we will need to drive the whole system. If a limited system/region is addressed, it is very possible that the transport related to that system will be a strong indicator of the vulnerability to a crash of that system. This could constitute an interesting study.

Our conclusion should be that it is time that cities explore their vitality to be prepared for a smooth transition and for abrupt change scenarios. We have already seen an example during the so-called Japanese EDO period. From around 1600 to 1850, the country was shut off from outside sources by its rulers and operated in a closed cycle manner for 250 years. It was, in fact, a bio-based economy, with full re-use of everything where solar energy was the main source for all needs. It is, therefore, possible but how fast can we implement a complete 'make-over' for our societies?

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Author details

Ronald Rovers
Professor Built Environment
Polytechnic University Zuyd, Heerlen
The Netherlands
Formerly: Urban Environment Group, Wageningen University, Netherlands
r.rovers@sustainablebuilding.info

Changing dependencies on fossil fuel: the case of Vienna

Petra Hirschler, Nina Svanda

From past to present

Vienna, as well as the most European cities, enlarged in a radial concentric dynamic. The city shape is almost circular with two main natural borders – the river Danube in the North and the Wienerwald in the West. The first settlements in the Vienna Region date back to the late Bronze Period. In the mid-11th century Vienna gained importance, as it rose from an insignificant border fortress to an ducal residence.

In the mid of the 19th century the city of Vienna enlarged by space and doubled it's inhabitants (up to 430.000 people) through the incorporation of 34 former suburbs by a municipal charter. Furthermore the city walls were demolished in 1860 and the first big urban development project – the Ringstraße – was started. Within the Habsburg Empire Vienna gained more and more importance as well as growth, so by 1900 the metropolis had 1,6 million inhabitants and was the 4th largest city in Europe. To secure and preserve the landscape in the city, the Vienna green belt was laid down in 1905.

At the end of the monarchy in 1918 the population raised up to 2,2 million. This fast growth leads to huge lack of housing beside other structural problems. However, after World War I, many inhabitants returned to their ancestral countries, resulting in a decline in the Viennese population. At the height of the immigration, about one third of the people living in Vienna were of Slavic or Hungarian descent. During the term of the so called "Red Vienna" 64.000 flats were built by the City of Vienna for 220.000 persons. Some of these municipal estates are still landmarks of Vienna's architecture like for example Karl Marx Hof or Rabenhof.

After World War II and the establishment of the Iron Curtain, with limited cultural and economical exchange to the neighbouring countries, the population decreased continuously. This trend changed with the opening up the border in 1989 and especially with the enlargement of the European Union. Nowadays, the population is growing again and according to the population forecast of Statistic Austria will reach around 2, 2 million again in 2075.

Urban development and mobility

Urban development and mobility are interlinked and affect each other not only nowadays. Also in the historic evolution of Vienna the changing use of transport played an important role. In the industrial age while walking was still the main means of transport, public transport started developing by the omnibus (horse-drawn vehicles with fixed routes, journey times and fares). As a fact of this people could reach a distance of 2,5 km in about half an hour. So from the city centre it was possible to travel almost to the second ring (Linienwall) of the city within this time. Especially the suburbs developed rapidly. More and more people started to commute between the suburbs and the city centre as well as the transport of goods increased. With further growth the city walls became a limiting factor and were demolished, as already mentioned.

Within the next development phase from around 1870 till the turn of the century the tramway drawn by horses, became an efficient means of transport. Most of the suburbs were connected to the centre and nevertheless the city kept growing in concentric circles. The "old" omnibus network was still in use, but the tramway had much more capacity. So the half an hour radius expanded up to 4 km and included all the suburbs. The development of the railway on the one hand had no effects on inner city transportation, as a municipal railway system did not exist that time, but on the other hand lead to a further spatial division of residential and economic areas as most of the industry developed along the railway lines in the east and south.

At the beginning of the 20th century the electrification of the tramway led to the largest tramway network in Viennese history at the mid 20th century. The network was even enlarged to the north across the river Danube. The steam operated light railway was important for the western city development along the river Wien. The most important means of individual transport that time was the bicycle. The half an hour radius grew up to 6 km. The big municipal estates increased the density.

The last phase of change in the means of transport started 1960 in Vienna. The subways for the densely built-up areas as well as the municipal railway for the outskirts are the still efficient public transport systems. Due to the enlargement of the city, the public transport network got coarsely meshed on the edges. The growing importance of the individual transport in the cities all over the world had also effects on Vienna. Pedestrian traffic lost importance and was reduced to the walk to the next public transport stop or parking lot, nevertheless in comparison to other cities in the world the Vienna's modal split is outstanding. However the trend to mono functional city development enforced by cars was also noticeable in the 1970ies. Within half an hour people nowadays travel up to 15 km – this also includes towns in the surrounding of Vienna.

Means of transport

In principle, the denser the route network and the more frequent the connections, the more people use public transport. In Vienna nowadays no location is in more than 15 minutes walking distance from a public transport stop. Analysis show that already in 1930 one third of the modal split related to public transport in Vienna, even though it had changed dramatically in the last 120 years.

With 120 lines (subway, trams and buses) Vienna offers today a public transport network with over 4.500 stops on almost 1.000 km of routes. In 2006 772 million passengers used public transport in Vienna. Previously in the 1940s it was possible to transport the same amount of passengers. The public transport is operated by the Vienna Public Transport company still owned by the city and founded in the 19th century. Already in 1929 the tramway network reached its biggest spatial extension with 106 lines and 292 km. From the mid 20th century, with growing importance of individual transport, the tramway network was and still is reduced. In former times tramlines were substituted by busses and nowadays with the extension of the subway system they are closed down as well. The construction of the first subway started in 1969 and still goes on to especially connect the edges of the city by a high-capacity public transport.

Till the beginning of the 20th century using public transport was still a luxury good. In 1967 a tariff association was establish in Vienna, which was enlarged to the "Verkehrsverbund Ost-Region" in 1984 including also the hinterland of the city. This transport policy made public transport more and more attractive for inhabitants and also commuters.

3. Traffic prevention through planning decisions

One important aspect for the sustainable reduction of the dependency on fossil fuels is a spatial planning strategy creating long-term favourable conditions for energy-saving lifestyles and economic systems. Lifestyles and economic systems are closely linked to our types of settlements and land use. Compared with the traditional setting they are now characterized by a relaxation of ties to fixed locations. Due to development in the traffic sector goods and services can now be produced and consumed almost anywhere at any time. Traffic induces land use, but land use also induces traffic (Bergman, 1993). Essential principles of a sustainable land use system are density, mixture of functions and decentralised concentration.

In Vienna the direction for the urban development and the development of the city's traffic system are set by two main instruments: The Transport Master Plan Vienna 2003 and Urban Development Plan Vienna 2005.

Transport Master Plan Vienna

The Transport Master Plan Vienna - adopted by the municipal council of Vienna in autumn 2003 – sets the priorities for the future transport policy in Vienna. The master plan assumes a comprehensive understanding of mobility which also includes the spatial layout of uses as well as time relevant organisation of activities.

The Transport Master Plan Vienna is based on the following exemplarily picked development trends and challenges of mobility development (until the year 2013):

- The population in Vienna and especially in the city-region of Vienna will grow. (For the period of 2001-2030 a population growth of 11 % for Vienna and 17 % for the city region has been estimated. Meanwhile the population forecast assumes a population growth of 16 % for the city of Vienna between 2007 and 2030).
- Within Vienna a higher population dynamics is expected in the periphery parts.
- Alone the population growth in Vienna will generate approximately 190.000 additional journeys until 2015.
- Due to the especially high population dynamics in the hinterland a further growth of traffic extending beyond the urban boundaries is expected.

The Transport Master Plan Vienna pursues the transport policy model of "Intelligent mobility". This intelligent mobility combines the following principles and goals: Sustainability, Innovation, Cooperation, Acceptance and Effectiveness.

An important component to meet the goal of sustainability is traffic prevention. Traffic prevention aims at the spatial layout of uses in terms of mobility saving urban development and planning. Building on Viennas history from the Gründerzeit, as a pedestrian city for 2 million people therewith the preservation as well as the creation of mixed urban quarters and strengthening the high quality of life are pursued. Traffic prevention does not stand for limitation of mobility. It only reduced the need for mobility by maintenance and strengthening of urban densities and qualities. Thus the Transport Masterplan provides an important supplement for urban development planning. (Stadtentwicklung Wien 2003)

Urban Development Plan Vienna (STEP05)

The Urban Development Plan Vienna is an instrument used in strategic urban planning and urban development defining in general terms the further orderly expansion of the city. *"It lays down the distribution of building land and green land, and delineates development areas and defines their relationship to the overall transport infrastructure (subway, rapid transit lines, tramway lines and high-capacity railway and motorway routes)."* (Vienna City Administration, Municipal Department 18, 2005, Page 14) Additionally, it illustrates the spatial-functional relationship between the city and the region.

The STEP05 addresses urban development in regional dialogue – the functional integration of relationships of the city with the region - and pursues amongst others the goals

- to concentrate settlement development along high-capacity public transport means,
- to prudently use the resource of land,
- to encourage the vertical mix of uses and prevent functional and social segregation.

The spatial planning strategy of the city of Vienna aims at the compact city and a polycentric urban and regional structure to generally reduce the generation of traffic. People shall be enabled to manage their daily ways with little time and effort and as possible without a car. (Stadtentwicklung Wien 2005)

Vienna as a compact polycentric city?

As already mentioned, most of the central European towns Vienna is built radial concentric as a result of the building history. Nevertheless Vienna is a polycentric city as well. The polycentric structure of Vienna includes all the former suburbs, nowadays districts, with economic, political and cultural features. As a fact of that this small centres kept all the basic functions in an economic, political, educational and cultural sense.

The most important building period in Vienna was the so called "Gründerzeit" (Wilhelminian style between 1848 and 1918) which is till this day formative for the townscape. In this period 70 percent of the existing buildings have been demolished and replaced by a building development with higher density. In this period also the excellent tramway network and the system of shopping streets – in Vienna the supply with goods and services can be handled by foot - were developed, which generate important quality characteristics of Vienna.

This hierarchic graded system of shopping streets and centres of the town (with the city, 23 main shopping streets and approximately 100 secondary shopping streets) is supplemented by a ring of 5-6 new main centres at the edge of the high density building areas. This development is supported by a radial subway system aiming at the city centre. This polycentric model of settlement development shall offer a "town of short ways" – a sustainable, crisis proof urban development which is independent from motorised individual traffic.

The planning model of „compact city" is the guiding principle for the land use and the structural development of Vienna according to the municipal department 18 – Urban Development and Urban Planning. In order to fulfil the sustainable use of land the urban planning department defines three target categories for the desired density of development in Vienna:

- Compact construction in the densely built-up urban zone (at least three to four stories) – "*in centrally located areas accessible by high-capacity public transport the targeted building density is even higher.*" (Vienna City Administration 2006, Page 014)[1]

[1] Further special requirements for high rise buildings are laid down in the „High Rise Building Scheme 2002".

- Development along axes/concentrations in areas adjacent to densely built-up urban zone and accessible by high-capacity public transport with medium-scale building density.
- Remaining areas suitable for building, where due to location and existing structures lower densities are sensible. *"This area is* dominated *by loosely built-up spaces, and in areas bordering the countryside features a high proportion of green space with single family homes and small plots of land with weekend chalets."*

(Vienna City Administration 2006, Page 015)

In the last decades till the fall of the Iron Curtain Vienna's development was basically orientated towards the south and west. "*The spatial structures that grew out of the conditions prevailing in the post-war Europe and largely oriented on the West and South are being replaced by an open, permeable region in Central Europe that has economic and cultural relations in all directions*." (Vienna City Administration, Municipal Department 18, 2005, Page 26)

Nowadays the urban development is characterised by impulses and dynamics all over the city place. Furthermore "*Vienna will continue to pursue a policy of compact structural development, and sustainable and economically viable urban expansion."* (Vienna City Administration 2006, Page 015) The planning prerequisites for this are set as follows:

- Monitoring the growth of individual motorised traffic,
- preserving nature and valuable space on the outskirts of the city for recreational purposes,
- supporting and applying building methods that save space and energy (especially in the newly developed urban areas) and making city districts better accessible *"by extending the underground railway network and introducing new, modern tram lines to encourage the development of new business locations, new office centres and modern communities with mixed demographics"*. (Vienna City Administration 2006, Page 015)

Location in the urban area and choice of transportation

Naturally the choice of transportation types correlates with the location in the urban area. Differences between densely built up areas, the periphery and the hinterland are in evidence. In high density urban areas with a mixed use environmentally friendly means of transport have a considerably higher proportion of the overall traffic. Nevertheless the proportion of motorised personal transport in the periphery was reduced from 50 % to 46 % between 1993 and 2001 for the benefit of public transport.

This reduction was achieved by a mixture of measures concerning traffic policy and space structures like the consequent extension of the public transport network, parking space management and a modest expansion of the road network as well as a consistent uprating of the intensity of use around underground stations. In the inner city within the Gürtel area motorised personal transport decreased by 3,7 % between 2004 and 2006. (Stadtentwicklung Wien 2003, Der Standard 23./24. Februar 2008)

Infrastructure and location: Spatial and temporal priorities of Vienna's urban development

"In the next few years the planned investments in the development of infrastructure as provided for by the Transport Master Plan will improve the accessibility of locations and thus their

attractiveness." (Vienna City Administration, Municipal Department 18, 2005, Page 57). Based on this infrastructure planning and in line with the objectives of the compact city and the sustainable urban development the Urban Development Plan has defined spatial and temporal priorities for the settlement development of Vienna in the future. Based on the period for the realisation given in the infrastructure planning two phases for the development of the urban area are defined:

- Phase 1 until 2010 includes the locations made accessible by the extension of the subway line in the 2nd district, which was opened on the 10th of May where also the stadium for European soccer championship 2008 is located which will then also be easily accessible by high speed public transport. Furthermore the high potential of the area Erdberger Mais, the local area Stadlau-Mühlgrund and the areas between Zentrum Kagran and Großfeldsiedlung-Brachmühle are targeted for development.

- In Phase 2 starting in the year 2011, the focus of urban development will gradually shift to the areas of Hausfeld-Flugfeld-Aspern and the construction of the Vienna Central Train Station as well as the development of a new city district in the area of the former Vienna South/East Train Station. (Stadtentwicklung Wien 2005)

Traffic shift to environmentally-friendly traffic

Another main objective is the increase of the proportion of environmentally-friendly transport (bicycle, pedestrians, public transport) to the total traffic performance. The proportion of the individual motorised traffic shall be reduced from 35 % to 25 % until the year 2020. Since the end of the year 2006 the use of public transport (35 %) exceeds the use of motorised personal transport (34 %). (Stadtentwicklung Wien 2003, Der Standard 23./24. Februar 2008) Last year the number of cars declined for the first time although population increased in Vienna. (Der Standard 6. Mai 2008)

Vienna has an extensive tram and bus network - the tram network being third largest in the world. In the most populated areas of Vienna, transportation systems are run so frequently (even during off-peak hours), that any familiarity with departure timetables is virtually unnecessary. The convenience and flexibility of the public transport is therefore reflected through its popularity.

In addition to the massive expansion of the subway and tram network (in the year 2009 the Vienna subway network will include approximately 75 km and 100 stations) measures to speed up and prioritise the public transport as well as the upgrading of the comfort act to increase the attractiveness of public transport. (Stadtentwicklung Wien 2003) In the year 2007 476,6 million passengers used the subway. With the opening of the extension in the 2nd district and the EURO2008 more than 500 million passengers are expected for the year 2008. (Der Standard 6. Mai 2008)

In the year 2006 the net of cycle-tracks covers approximately 1.000 km. This means that the cycle network was doubled since 1992. The proportion of cyclists of the overall traffic volume in Vienna ranges – depending on season and location in the urban area – from 2.5% to 8%. At several sections of the net as for example at the Mariahilferstraße the proportion of cycle transport already reaches 20%. In the city centre the share of cyclist as well as pedestrians is the highest in comparison with the other districts. In 2005 for the first time one million cyclists were recorded at the Opernring. Until 2020 the proportion of cyclist on the overall traffic shall be raised to 8%.

With this Vienna is still far away from other Austrian cities like for example Salzburg with 16%. Even though small and medium towns like Salzburg have a structural advantage over bigger cities and in Vienna cycling is competing against public transport – which is with 35% very high in international comparison, there is still a lot of potential for cycling in Vienna. (Stadtentwicklung Wien 2008)

To stabilise pedestrian traffic at the present high level a comprehensive interconnecting pedestrian network should be created taking into account the pedestrian-based economy. Structural measures for the safety of crossings, opening-up of gaps, pedestrian-friendly circuits of traffic lights, unrestricted passage of different levels and a minimum pavement width of 2.00 meters are examples to improve quality of life for pedestrians and increase their road safety. (Stadtentwicklung Wien 2003, Fohler-Norek 2006)

3. Utopia and mobility – Vienna 2030

Traffic, transportation and mobility as well as their social frameworks evolve through current changes. But how will the future look like? Due to limited resources mobility will be a luxury good? Is it the end of transport? Even tough 2030 looks far ahead experts worked on scenarios for transport in Vienna 2030 (Stadtentwicklung Wien 2008). Awareness that new solutions are needed is rapidly increasing. The scenarios present a broad overview of considerations in future Viennese urban mobility.

Utopia 1: No mobility - nobody needs to move, nobody wants to move

Imagine mobility is a luxury good. It' is expensive and hard travel on a large scale. But people don't need to. Within short distances it's possible to live, work and get all the supplies. The pedestrian city is back and Vienna, with its compact and polycentric structure is already prepared.

Utopia 2: Light mobility - the revival of the pedestrian and cyclist city

Imagine the basic means of transport are bicycles and promising bicycle derivatives, as well as new vehicles, for small-scale transportation. Bicycles are used for the transport of goods and only very few trucks still operate within the city. Bicycles are quick and flexible, especially for the transportation of small and medium loads. Already today many cities in Asia show that this system is effective and sustainable, even though the possibilities for technological improvement are manifold, e. g. start support, loading space, auxiliary drive. Also, the pedestrians of the future don't necessarily walk – they slide, roll, kick or flap. New technologies like the already available segways and scooters, but also many more new inventions, expand the walking distance and are cool status symbols. The compact and polycentric city structure of Vienna support light mobility, as most of the daily goods and services can be reached in "walking" distance, as well as the mixed use is one of the guiding principles for urban development.

Utopia 3: New mobility - future technologies for transport

Imagine new designs for transportation systems, services and vehicles. Some of these are already available on the market, others are not. Together, they represent an interesting key to the transition from the current muddy situation to a conceptually streamlined future that is less congested and requires less energy input.

Imagine Vienna 2030 in the post petroleum age will be a mixture of the three utopias…

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Author details

Petra Hirschler, DI
hirschler@email.archlab.tuwien.ac.at
Nina Svanda, DI
svanda@email.archlab.tuwien.ac.at
Centre of Regional Planning and Regional Development, Department of Spatial Development and Infrastructure & Environmental Planning, Vienna University of Technology.

Urban Development for Carbon Neutral Mobility

Ernst Schriefl, Uwe Schubert, Franz Skala, Gernot Stöglehner

Introduction

Urban development of the last decades was guided by the thinking, that the ability to bridge long distances in transport of persons and goods is an indication of high development standards of a culture, increasing mobility. Mobility has become a value in itself. Travel distances have increased along with travel speeds and people generally now have to cover greater distances than they used to in order to fulfil the same needs as before: getting to school and to work, doing the shopping, visiting friends and family, etc. Most of this mobility is depending on cheap fossil fuel, so we call this kind of mobility the "carbon mobility". Now the basis of this development, cheap fossil energy, is questioned by two interrelated factors: the limitation of fossil resources becoming more evident (Schindler/Zittel, 2007) and climate change.

The possibilities of society (policy, economy, citizens) to react on this challenge can be aggregated in two main scenarios:

- Continuing business as usual (producing sprawl) with a little more emphasis on efficiency of technologies (e.g. the motors of cars) as well as on using alternative fuels (addition of "bio"-fuels) without questioning key systems for mobility.
- Adapting urban development to reduce distances, ensuring accessibility by transport modes independent of fossil resources and at the same time creating a liveable environment - may be forced by circumstances or achieved by precautionary and voluntary attempts.

As an assumption of this paper the possibility to sustain long-distance transport of persons and goods in post-carbon times according to scenario 1 will be considered very unlikely for several reasons:

First, many calculations of renewable energy supplies point out that carbon neutral societies can only work on a much lower level of energy consumption due to the following arguments:

- there are limitations in the potential availability of renewable energy sources
- the energy density of renewables is low compared to fossil energy, thus much land (and also much material in the case of photovoltaic, e.g.) is required to capture renewable energy
- supply of wind and solar energy fluctuates in a considerable range due to meteorological conditions, thus large backup and storage capacities are required
- the establishment of a renewable energy infrastructure is a huge investment, both in monetary and energy terms. It is questionable to what extent this investment is possible in a world with scarcer fossil energy supply

Second, many technical developments to increase the efficiency of transport means like cars still work on combustion processes that cause nitrogen oxides, further ozone and harm the ozone layer as well as support climate change.

Third, many bio-fuels [2] cause a lot of negative environmental effects (devastation of rain forests) as well as problems in food supply due to increasing prices.

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[2] In the German language the term bio-fuels is misleading because it might be easily associated with organic production which is not true. Therefore, the term agrofuels (German: Agrotreibstoffe) would be more precise.

Therefore, the aim of our paper is to discuss the usefulness, feasibility and sustainability of short distances according to scenario 2. To tackle these developments a shift in the definition of mobility [3] is necessary. In this context, mobility is defined by the ability to reach a great number of destinations within the shortest possible time while covering the shortest possible distance. Short travel times are thus not a function of high travel speeds but mostly of short distances. These are of special importance for destinations to be reached frequently (e.g. workplace or daily supply shopping).

Buildings are the products with the far largest material-input and the longest lifetime. Their location influences transport demand, their construction heating demand, both met at present to a large extent by fossil fuels. To ensure mobility in the post-carbon era requires, due to the long lifetime of the built structure, a strategy for both the urban pattern of new development and an appropriate transformation of the huge amount of existing structures.

Options for post-carbon mobility are examined, identifying appropriate urban patterns, considering key factors of mobility requirements like the spatial distribution of functions and corresponding settlement structures on the examples of four approaches: Ecocity, Post Carbon Cities (including Transition Towns), Carfree Areas, Transit Oriented Development. Several groups of measures for interlinking urban development and carbon neutral mobility are derived from the concepts addressing aspects of transport of persons and transport of goods and discussing benefits from the approaches and the measures.

[3] Generally 'mobility' is defined in the Glossary of the European Environment Agency http://glossary.eea.eu.int/EEAGlossary/M/mobility [accessed January 2005] as *"The ability of groups or individuals to relocate or change jobs or to physically move from one place to another".*

2. Urban development approaches for carbon neutral mobility

The presented approaches are dealing with different levels: Carfree Areas, and Transit Oriented Development are focusing on the transport sector, Post Carbon Cities on the whole energy sector (including transport and land use planning issues) while Ecocity aims at integrating the most important sectors of urban development.

2.1 Ecocity

This is an integrated approach towards an ecological urban environment.

The term „Ecocity" is used differently, for both *concepts* for transforming existing cities towards ecological objectives and *realised* ecological urban patterns – there is no standardised definition.

For the EU-project ECOCITY (Urban Development towards Appropriate Structures for Sustainable Transport) the following characteristics of an Ecocity were formulated:

An ECOCITY is composed of compact, pedestrian-oriented, mixed-use quarters or neighbourhoods, which are integrated into a polycentric urban system in public-transport-oriented locations and consist of solar-oriented buildings with high insulation standard. It is powered as far as possible from renewable energy sources and water is used efficiently (including a rainwater management). In combination with attractively designed public spaces, integrating green areas and objects of cultural heritage to create varied surroundings, an ECOCITY should be an attractive place to live and work. Such sustainable and liveable structures contribute to the health, safety and well-being of the inhabitants and their identification with the ECOCITY. (Gaffron/Huismans/Skala, 2005).

To intensify the implementation of agreed principles and to demonstrate the feasibility and desirability of future urban living compatible with sustainability requirements, model settlements for specific sites in the European municipalities Bad Ischl (Austria), Barcelona (Spain), Györ (Hungary), Tampere (Finland), Trnava (Slovakia), Tübingen (Germany) and Umbertide (Italy) were designed.

The Ecocity neighbourhood in Bad Ischl was planned for about 2000 inhabitants. The objective to design appropriate urban patterns for sustainable (carbon neutral) mobility was met for public transport by selecting the site for the ECOCITY model settlement to reinforce the development axis between the centre of Bad Ischl and the neighbouring municipalities Strobl and St. Wolfgang. As an alternative to urban sprawl a new compact sub-centre for the municipality was designed within a radius of 300 m around the stop of a planned public transport line in the centre.

A core topic was the appropriate location of facilities: those necessary for a balanced mixed use were concentrated in a central area to create short distances from all parts of the sub-centre and to allow easy trip chaining (see the following map Fig.1)

One of the Ecocity-pioneers was Ecocity Builders, a non-profit organization dedicated to reshaping cities, towns and villages for long term health of human and natural systems. The goal is to build thriving neighbourhood centres based on human needs and "access by proximity", convenient to walking, bicycling and transit, while reversing automobile driven sprawl development. An approach of Ecocity Builders to implement this goal is the Ecocity Zoning Map: - indicating potential areas for higher density and diversity as well as for removal of car-dependent development - illustrating the transformation of a city towards centres linked by public transport and bicycles, with natural watercourses restored and auto dependence virtually eliminated (Register, 2002).

2.2 Post Carbon Cities

The main focus of "Post Carbon Cities"-initiatives lies on preparing for uncertainties caused by diminishing supply of fossil fuels (this phenomenon has become popular under the notion of "peak oil") and climate change.

This focus of attention is one of the main differences compared to other initiatives focussing primarily on ecology and sustainability. The proposed measures and outcomes of decision processes might not differ that much – measures preparing for the time after the oil peak usually also have positive ecological impacts.

The key problem posed by both peak oil and global warming is ultimately one of uncertainty (Lerch, 2007), creating changes in economies and ecosystems at the global, regional and local levels that cannot be easily predicted and involving a wide variety of risks and vulnerabilities for local governments.

The main strategy to strengthen local resilience (offering protection against these riscs) is *re-localization* which aims to increase community energy and food security, strengthen local economies, and improve environmental conditions, social equity and participation. This means the use and reliance on local or regional resources, the resulting short transport distances of resources, pre-manufactured goods and consumer goods as well as more locally and regionally available jobs. "Post Carbon Cities"-initiatives are currently situated in North America (USA and Canada), countries with enormous oil dependency and thus high vulnerability in this respect.

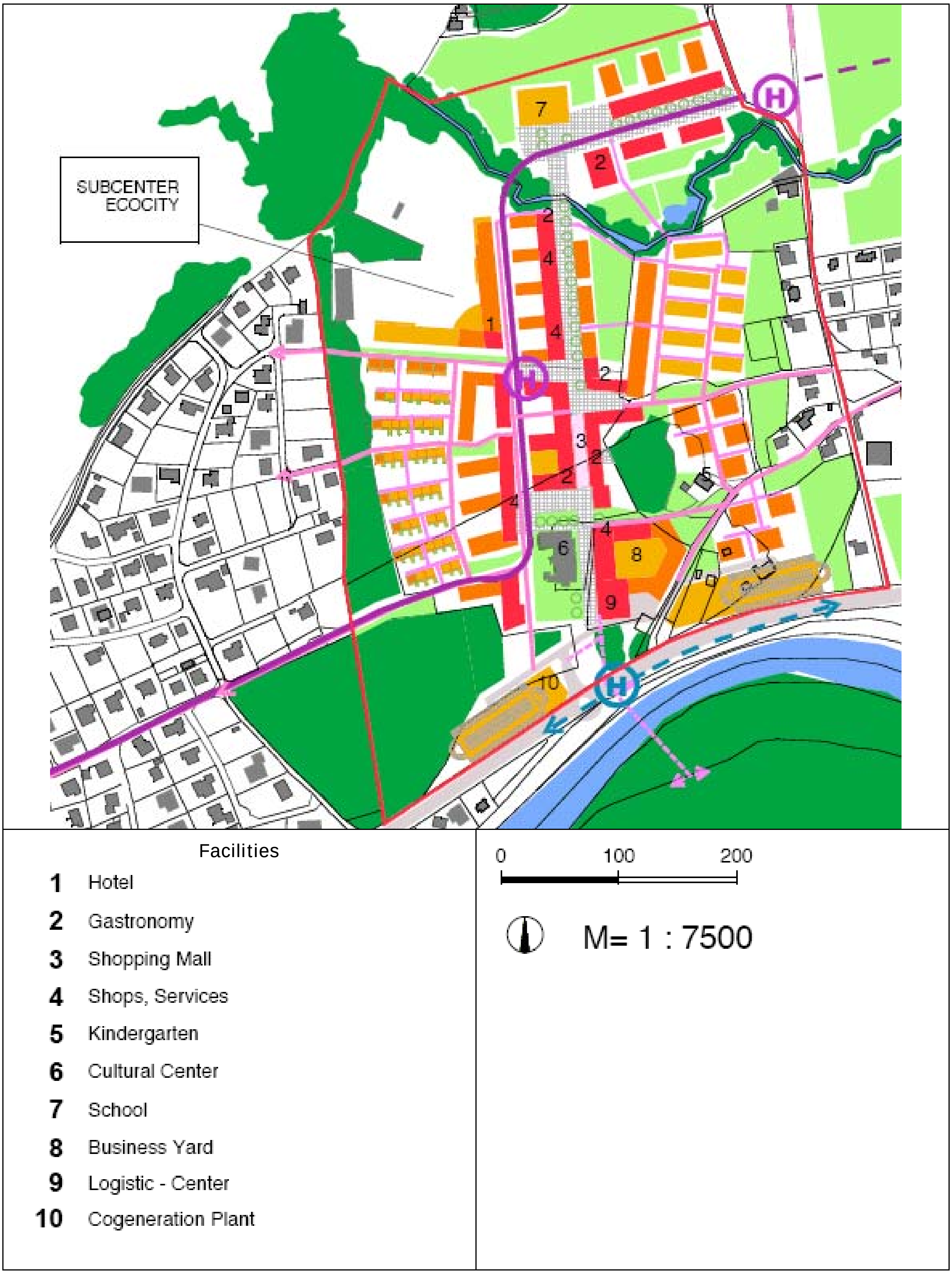

Figure 1: Location of mixed use facilities, Ecocity Bad Ischl

Examples of principles to be integrated into local government's decision-making and planning processes to comprehensively address energy and climate uncertainty over the long term, identified by (Lerch, 2007) and (Moerman, 2006) are:

- Fundamentally rethink your municipality's land use and transportation practices, from building and zoning codes to long-range planning

- Every new development should pass the $500-a-barrel test. (-> can the development "survive" when oil costs $500 a barrel?)
- Promote electrical public transportation systems (if energy is available at all it will more and more in the form of electricity)
- Encourage serious energy conservation and efficiency in the private sector, as a shift to new energy sources and technologies did not yet succed to reduce dependence on fossil energy sources significantly

To implement the necessary measures they recommend
- to prepare both a long-range plan and an emergency plan to be prepared for both gradual depletion and sudden shortages.
- to attack the problems piece-by-piece and from many angles, using multiple, proven solutions at different scales.
Similar initiatives in Europe (esp. England) are grouped in the "Transition Network" (http://transitiontowns.org/TransitionNetwork/).

Two crucial points of the idea are:
that we used immense amounts of creativity, ingenuity and adaptability on the way up the energy upslope, and that there's no reason for us not to do the same on the downslope if we collectively plan and act early enough there's every likelihood that we can create a way of living that's significantly more connected, more vibrant and more in touch with our environment than the oil-addicted treadmill that we find ourselves on today.

2.3. Carfree Areas

This is a sectoral approach, tackling with the need for and presence of individual motorized transport in an area one of the key problems of a carbon neutral society, but as usual for transport issues strongly linked to urban planning.

The "Institut für Landes- und Stadtentwicklungsforschung des Landes Nordrhein-Westfalen" included definition and main objective of carfree housing in a short formulation:

Carfree Housing means a special offer for households not owning cars, with the intention to create benefits for them. (Dittrich/Klewe, 1996)
Essential characteristics of a carfree area are:
- that an appropriate design of urban pattern for pedestrians, cyclists and public transport ensures good accessibility of all important destinations (e.g. infrastructure facilities for mixed use) without the need for and presence of private cars
- that driving private cars within the area is not permitted and inhabitants should not own conventional cars for private use
- that the number of parking spaces is greatly reduced (less than 0,2 per dwelling e.g. for a car-sharing-service, which is often provided) and they are located at the edge of the area.

Another term – "Carfree Environments" – is used by the World Carfree Network [4] and

[4] World Carfree Network (WCN) brings together organisations dedicated to promoting alternatives to car dependence and

defined as *places that do not accommodate (permit the entry of) automobiles. An "environment" can be an entire village, town or city; a portion of a village, town or city; or a place such as a resort.* A possible step towards a carfree environment is an area with peripheral parking, keeping public space within the area carfree.

Only an area of sufficient size allows the advantages of carfree living (space for people, safety, lack of noise pollution, etc.) to be experienced. Most projects implemented until now are (too) small: blocks of houses or single multi-storied buildings.

Carfree Areas should be a step of the transition towards carfree cities to avoid future dependence on fossil fuels.
The largest existing example of a carfree area is "GWL-terrein" in Amsterdam, Netherlands (completed 1998) with 600 dwellings (rental, ownership) and several businesses in an area of about 6 ha.
(http://wwwistp.murdoch.edu.au/publications/projects/carfree/carfree.html#gwl%20terrein)

2.4. Transit Oriented Development

This sectoral approach, linking a transport mode and urban planning, is promoted in the USA by New Urbanism (http://www.cnu.org/) and the Centre for Transit-Oriented Development (http://www.reconnectingamerica.org/html/TOD/).
Transit Oriented Development, according to the TDM Encyclopedia of the Victoria Transport Policy Institute (Canada), (http://www.vtpi.org/tdm/tdm45.htm) *refers to residential and commercial centres designed to maximize access by public transport and non-motorised transportation, and with other features to encourage public transport ridership.*
It is essential to make the development of the transportation and the settlement system compatible by co-ordinating the extension of local transportation systems and the extension of a settlement.

The best conditions for an attractive and economically sustainable local public transportation system arise by choosing appropriate locations for future urban development (see also point 3).

The public transport system should preferably be based on tram lines (light rail) using modern, reduced noise low-floor trams, thus an attractive mean of local transport, as opposed to a regular train which tends to separate the two sides and be noisier.
Rail oriented urban development can come in different forms:

- Extension (and filling in) of existing quarters around public transport stops already in use
- Development of new quarters around new stops of already existing lines
- Development (and filling in) of new quarters along settlement axes and construction of new lines

Such quarters may be referred to as "Tram-Cities".

An example is the city extension "solarCity" in Linz-Pichling (also as a model project for solar energy use), brought about also a new tram line, integrating growing parts of the town in the tram network and resulting in short

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automobile-based planning at the international level and working to reduce the human impact on the natural environment while improving the quality of life for all; http://www.worldcarfree.net/

intervals of less than 5 minutes in the core of the city.

Figure 2: solarCity aerial view
Source: Magistrat der Landeshauptstadt Linz

Moreover the environment of an Ecocity improves the social conditions, promoting contacts.

Post Carbon Cities emphasise the concept of "re-localisation" in a broad sense, implying also to tackle the issues of re-localising food, energy supply and the economy as contribution to a Carbon Neutral Society. Important for the acceptance of these approaches is, that their realisation does not detract from the well-being of the inhabitants, quite the reverse it increases their quality of life in a Liveable City (see benefits point 4).

2.5. Summary

What all of these approaches have in common are high-quality walking environments (Pedestrian-City) with short distances. They are interrelated, Pedestrian-City and Tram-City (transit oriented development) being the basis for a Carfree-City with a minimal on-site automobile presence, resulting in minimised energy demand for transport.

The second large proportion of energy demand in a city, caused by buildings (especially for heating) is minimised by low-energy construction and solar architecture in a Solar-City.

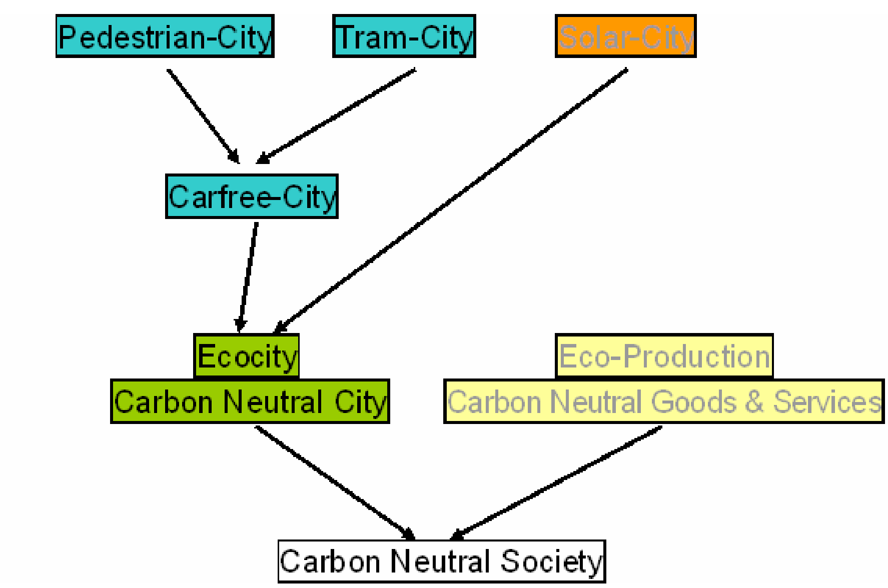

Figure 3: Elements of a Sustainable and Carbon Neutral City and Society

In the following brief overview some of the ideas considered and (at least partially) implemented in the approaches are summarised.

Sustainable transport (Carfree-City) and sustainable buildings (Solar-City) are the key elements of an Ecocity (where also other resources, especially water, are used carefully) and make it also carbon neutral.

In this paper the emphasis is on transportation and urban planning concepts.

The ideas and discussion of the last decades how to organise "attractive" and "sustainable" settlements and which elements are important in the evolving concepts are summarised in Figure 3.

3. Urban development measures for carbon neutral mobility

3.1 Design of urban patterns

The location of new urban development is of great importance for the efficiency of a transport system. As stated above the urban pattern needs to be appropriate for pedestrians and public transport to make mobility carbon neutral.

The various distances to be covered via the modes walking, cycling and public transport result in areas of different size being influenced – while walking and cycling should determine the structure of small settlements (quarters of a city, villages, small towns), public transport is important for the location of these small settlements within a larger city or a region.

The question as to what makes a settlement **attractive for pedestrians** can be answered in a nut-shell:

A compact city of short distances, achieved by:

- An appropriate/qualified urban density given by attractive multi-storied buildings
- Mixed land use, characterised by a well balanced ratio of residential and business use. Location of necessary facilities, particularly for everyday needs, in a central area to create short distances from all parts of the quarter allowing combined trips (more detailed see point 3.3)
- Limitation of the total area for a quarter, roughly defined by a 300 m radius around the centre.

Attractive public space characterised by:

- A net of streets and squares with buildings showing varied facades as well as open space elements and architecture in a high aesthetic quality;
- Limitation of automobile traffic to only absolutely indispensable trips within the quarter
- Pathways for prams, wheel-chairs and shopping trolleys free of obstacles
- Seamless weather protection for pedestrians (arcades, etc.), particularly in the central area.

Most important for making an urban pattern **appropriate for public transport** is the selection of suitable sites for new construction respectively for a new settlement to achieve:

- a linear polycentric development (with attractive destinations at both ends)
- a decentralised concentration in walking distance around stops (stations)
- Such patterns are essential for the efficiency of public transport.
- Additional important requirements are
- a balanced ratio of dwellings and working places in such neighbourhoods around stops to achieve a more even distribution of passengers in both directions
- concentrating parking lots at the edge of such neighbourhoods resulting mostly in longer distances from dwellings than the public transport stop

Main supra-regional roads with heavy car traffic are not suitable for the location of sites for future development because of the great negative impacts (noise, separation) and thus they are not suitable for a public transport route, where future development should be concentrated.

3.2 Decentralised Concentration as principle for location of new development

This means to find a balance of centralisation and decentralisation – to minimise the length of trips as many of the necessary facilities for different purposes (working, shopping, leisure time) as feasible should be decentralised and concentrated in quarters or neighbourhoods of sufficient size.

Following this principle the Austrian spatial development concept (Österreichisches Raumentwicklungskonzept 2001) aims at a clear structure of new settlement areas in the urban ring instead of creating non-structured sprawl - important urban functions should be concentrated in well defined locations and the transportation infrastructure should be planned accordingly. The development of the settlement system should not lead to growth of the core city but rather to a distribution to several decentralised settlements, well equipped with services and well connected by public transport. In rural areas this development should take place mainly in those central places of the communities which have good public transport connections to the superior centres.

Following the principle of decentralised concentration also means to avoid the further implementation of elements of sprawl as large shopping-centres or detached single family houses.

3.3 Location of facilities within settlements

The spatial distribution of all different facilities in the settlement area is determined by the best opportunities for supply with goods and for the accessibility by the users (Lung, Mayerhofer, Skala, 1998).

Facilities with demand for transport of greater quantities of goods respectively heavy products (ecologically-compatible production enterprises) should be situated at the boundary of a settlement unit with access to a railway.

Facilities with demand for transport of goods as well as for good accessibility by the users (shops) should be situated in central sites along an axis, but also near to a main road, allowing short distances for goods distribution.

3.4 Places of work in mixed use

The example of Steinbach an der Steyr, a small municipality in Upper Austria shows the success of improving the settlement structure, especially the mix of uses by creating new places of work in a predominantly residential settlement. A sustainable development concept including many smaller projects (basing on the local strengths) was elaborated there to tackle declining economy and population. The increased number of places of work resulted in a significant increase of internal work trips and a reduction of commuter trips.

Table 1: Places of work and commuting in Steinbach

	1991 (1992)	2001	%
Inhabitants	1812	1867	3
Employed	134	251	87
Places of work	36	56	56
Internal trips	74	185	150
Commuters out	588	462	-21
Commuters in	20	4	-80
Trips total	714	756	
Trips/inhabitant	0,39	0,40	

Sources: Statistik Austria, Arbeitsstättenzählung 15. Mai 2001 Steinbachhttp://www.statistik.at/blickgem/az5/g40920.pdf Amt der Oö. Landesregierung, OÖ. VERKEHRSERHEBUNG 2001 - http://www.ooe.gv.at/cps/rde/xchg/SID-3DCFCFC3-1E2AD5A1/ooe/hs.xsl/29857_DEU_HTML.htm

4. *Benefits of carbon neutral urban development*

For the general public all approaches to a carbon neutral urban development (point 2) offer reduced air and noise pollution and a lower risk of injuries by traffic accidents. There is more space for people in an attractive, quiet, safe and wholesome environment (car-free streets and squares, a great variety of green areas), promoting a slower-paced, more relaxed, wholesome and thus more sustainable lifestyle. This allows more personal interaction with neighbours, resulting in the presence of more people in public areas, thus creating a greater sense of community and possibly lower crime rates.

Living in close proximity to various facilities in mixed-use neighbourhoods means shorter routes to public transport stops, to jobs, to school, for shopping, recreation, etc., thus saving time and energy. Varied green areas (an important factor for residents' satisfaction), integrated into compact settlements as well as the surroundings are easily accessible and solar architecture provides convenient temperatures and daylight for high indoor comfort. A balanced social mix and social services and facilities for all groups of residents foster their well-being.

These benefits can be experienced by all people, but they are of additional importance for some individual groups: carbon neutral urban patterns privilege **non-drivers** (who are disadvantaged by car-dependent transport and land use patterns), increasing their mobility and accessibility options. An internal pathway system free of private cars and barriers but with sufficient social control combined with short distances, creates an attractive and safe environment for **children** (to play safely outdoors and walk on their own) as well as for the mobility of **senior citizens** and the **handicapped**. [5]

5. Conclusions

It is likely that constraints of energy resources will limit the transport capacity for persons and goods. To adapt to the framework of a post-carbon society, a rethinking of settlement policies and spatial planning paradigms on all planning levels (international, national, regional and local) is a necessary precondition and shall include:

- fostering of decentralisation, mixed use, short distance supply, local and regional material and energy supply structures and economic cycles
- prevention of sprawl and long distance supply structures.

These goals would help to reduce the transport necessity of persons and goods so that the remaining transport demands could be satisfied in a more environment friendly and carbon neutral way. Furthermore, these strategies might also contribute to a higher quality of life.

Furthermore, re-localisation in all fields of supply with basic goods (especially food and energy) will be necessary to get towards a Carbon Neutral Society.

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Author details

Ernst Schriefl (Energieautark, Wien)
Uwe Schubert (Institute for Regional Development and the Environment, WU Wien)
Franz Skala* (Institute for Ecological Urban Development, Wien)
Gernot Stöglehner (University of Natural Resources and Applied Life Sciences Vienna)
*Institut für ökologische Stadtentwicklung
1200 Wien, Gerhardusgasse 26, E-mail: office@oekostadt.at, Tel.: 01/374 97 97

Integrated Transport and Urban Design Choices to Reduce Carbon Emissions: Public Attitudes in the Washington, DC USA Metropolitan Area

Kris Wernstedt

1. Introduction

A wide array of jurisdictions around the world have committed to significant carbon reductions using a range of tools. These include both hardscape approaches such as design requirements for green retrofits and large investments in more climate friendly transportation systems, and softer solutions such as congestion pricing and public education. Yet, meshing technical solutions, land use changes, and financial constraints presents formidable challenges, particularly in existing agglomerations. In addition, public support for large-scale, sustained interventions remains uncertain.

This paper discusses efforts to reduce carbon emissions through integrated strategies that include transport, energy, and urban design interventions. In particular, we report survey research that examines public attitudes in the Washington, DC metropolitan area in the United States (U.S.) toward urban design and transport strategies that can promote such reductions. These strategies entail higher residential density allowances/floor area ratios, the subsidisation of shared cars to increase the number of households without automobiles,[6] improved building design to reduce energy consumption, provision of nearby transit stops, and the development of mixed use. In addition to presenting a series of questions on individual experiences and attitudes toward climate change issues and transport options, we employ a set of choice experiments to examine tradeoffs among the options.

The substantive part of our paper starts in section 2, where we summarize local climate planning efforts in the U.S. We introduce our study area, survey design, and the logic of the choice experiments in section 3. We analyze survey results in Section 4. In section 5, we offer summary comments and suggest further areas for research.

2. Background

Metropolitan areas are major contributors to carbon emissions, accounting for roughly 75 percent of the world's energy consumption and producing 80 percent of its greenhouse gases. According to the American Institute of Architects, buildings alone account for over 40 percent of global carbon dioxide emissions, more than either the transportation or industrial sectors alone (Shapiro, 2007). The size, shape, and type of the built environment matter. Moreover, with roughly 50 percent of the world's population currently living in cities, and expectations that this will climb to 60 percent in the next 20 years, the carbon footprint of the urban built environment will continue to be critical. Significant reductions of carbon emissions worldwide require that metropolitan areas play a pivotal role.

[6] Car sharing in this context entails having access to short-term, generally hour-by-hour car rentals, with fuel and insurance included in the rental rate. A wide range of private companies offer carsharing throughout Europe and North America. We refer in the text and our survey to these arrangement as zipcars, the name of the dominant carsharing company in the U.S. We are motivated to examine this transportation option since some developers in our study area have argued that the potential savings from decreasing the number of underground parking spaces in new multifamily residential structures—each space may cost $30,000/space to construct—could be used to subsidize zipcars that multiple households could share.

While the U.S. government lags much of Western Europe on climate change policies and practice, a wide range of different-sized American cities have developed formal efforts to reduce carbon emissions. As of 2008, 850 city mayors have endorsed the U.S. Mayors Climate Protection Agreement and committed to Kyoto targets of reducing emissions in their cities to seven percent below 1990 levels by 2012 (www.usmayors.org/climateprotection/list.asp). Meeting these targets may prove costly—and the gains from any lower greenhouse gas concentrations that result from the potentially costly efforts necessarily must be shared with the global community—but the roster of signatories is growing. In addition to evincing a moral commitment to slowing climate change, Engel and Orbach (2008) argue that several ancillary political and competitive benefits may explain the widespread local government interest.

For these and other cities, opportunities exist for significant carbon reductions through mixed climate strategies at the intersection of urban form, transportation, and energy, particularly in economically robust regions of the U.S. Demand for new development and redevelopment of existing building stock in some U.S. cities is astonishing, with projections calling for the development of nearly 60 million residential units and 9 billion square meters of commercial and industrial construction nationwide between now and 2030 (Nelson, 2004, 2006). These figures suggest that the potential to fundamentally reshape large portions of the built environment even in mature urban areas of the U.S. is high. The possible gains from mixing energy efficiency improvements, compact urban forms, mixed use, enhanced public transportation, and other elements of smart growth are thus also promisingly high in metropolitan areas undergoing reinvestment and expansion.

We neither fully understand public attitudes toward such reshaping nor the relative desirability of its constituent elements, however. How important is mixed use relative to higher density, for example, or what tradeoffs are individuals willing to make in giving up privately owned vehicles in return for subsidized public or shared transport? Knowing the answers to these questions may yield better strategies to reduce carbon emissions through integrated efforts in transportation and housing. We explore these themes in a survey of residents in the metropolitan area surrounding Washington, DC, which projections indicate will have one of the largest amounts of growth of any major U.S. urban area in the next 20 years.

3. Study Area and Survey Design

Our study area encompasses the Washington-Baltimore-Northern Virginia metropolitan area (hereinafter WBNV Metro). Spread over 25,000 square kilometers, the more than 8 million residents in WBNV Metro constitute the nation's 4th most populated metropolitan region. Projections for 2030 suggest a nearly 40 percent population increase by the year 2030, the highest growth rate of the country's eight largest metropolitan regions. More than 2 million housing units and 280 million square metres of commercial or institutional space are expected to be built in this span.

Locating this growth and providing infrastructure to accommodate it — including a transportation system to maintain the mobility that integrates the WBNV Metro economic system across what is likely to be a less compact area — pose challenges to intermediate and long-range planning and may have far-reaching carbon footprint implications. Moreover, much of the construction will constitute replacement of current space — 40 percent of the 2 million housing units and nearly 60 percent of the commercial and institutional space — and thus has the potential to significantly reshape the existing urban fabric. Complicating carbon reduction efforts, however, are the multitude of independent government units operating within the WBNV Metro area. Just in the 3,000 square kilometers core urbanized area, for example, more than 20 local governments exist, each exercising generally independent land use and development controls.

Survey Design

Our survey questionnaire seeks information from residents in the core-urbanized area of WBNV Metro about attitudes toward climate change, use of transportation, and the relative strength of different preferences regarding proposed transportation and land use/density strategies in the region that have carbon implications. We rely on indirect preference elicitation, asking respondents to choose among different strategies or bundles of changes that provide alternative scenarios of residential density, mixed use, person transportation choices, transit, and energy efficiency. In particular, we utilise choice experiment methods, which are widely adopted by marketing, transportation, and environmental valuation researchers for investigating individual decisions (Louviere, Hensher, & Swait, 2000). In brief, this method presents individuals with a series of hypothetical choices, with each choice requiring a selection of one of two or more alternatives. In our case, we present two alternatives, each of which has five characteristics or attributes, with the value of the attributes differing between the alternatives. Table 1 displays these attributes and their possible values.

The context that we present to respondents is a decision about purchasing one of two owner-occupied condominiums in the Washington DC region that differ only in the attribute levels that we present (every other characteristic is identical). We also tell respondents that governments, business leaders, and non-profit organizations in the region are promoting these places to live to reduce carbon emissions and climate change impacts, that the different locations and housing units all have the same effect on reducing carbon emissions, and that the direct cost of each place is the same, except for the specific conditions we detail in the attributes (see Figure 1).

Table 1: Attributes Contained in Choice Experiments

Attribute	**Levels**
height of structure	3 floors (ground floor plus 2 floors of housing)
	5 floors (ground floor plus 2 floors of housing)
	10 floors (ground floor plus 2 floors of housing)
ground floor	office space
	grocery, retail shopping, or restaurant space
private transportation	1 parking space for each unit, included in unit purchase
	no parking space but zip car available with 250 free hours year
annual energy costs	$1,000/year
	$1,500/year
	$2,000/year
distance to transit	¼ mile
	2 miles

Obviously, everything else being equal, respondents always will choose some attribute levels over others. For example, individuals will prefer lower energy costs to higher energy costs. However, we are less interested in whether an individual prefers a certain level over another (direct questions would reveal that more readily) than in the implicit trade-offs between different attributes. For example, up to what level of cost difference do respondents continue to prefer living close to a transit stop? The forced choices in our choice experiments help reveal these tradeoffs, which are expressed as the relative weights of different attributes.

Table 1: Example of Choice Experiment

Policy Conditions	**A**	**B**
Height of Structure	10 floors	3 floors
Ground Floor	office	grocery, retail, restaurant
Private Transportation	no off-street parking for own car but zip car w/ 250 free hours/year	no off-street parking for own car but zip car w/ 250 free hours/year
Annual Energy Cost	$1,500/year	$1,500/year
Nearest Metro Rail Stop	1/4 mile	2 miles

Which of these alternatives do you find more attractive?

____ A
____ B
____ Don't know
____ Refused to answer

The questionnaire includes four sections. These collect information on 1) demographic and socioeconomic characteristics of respondents; 2) attitudes and awareness of climate change; 3) transportation behavior; and 4) preferences regarding residential environment choices. Our interest centres on the latter preference tradeoffs that comprise our choice experiments, but the other three sections both allow us to examine whether respondent characteristics systematically affect preferences and permit us to compare our convenience sample to the population at large.

4. Survey Results

We administered our survey with a hard copy instrument in face-to-face interviews over a two week period in April-May 2008. Enumerators intercepted individuals in residential, commercial, and street settings and asked them if they would be willing to complete the survey. For those agreeing, the survey took roughly 15 minutes to complete. Given our recruitment method, it is important to note that our respondents represent a convenience sample. Consequently, our results are indicative but not necessarily generalisable to the wider WBNV and U.S. metropolitan contexts.

Summary Characteristics

Table 2: Summary Statistics*

*based on 278 respondents (some questions yielded fewer responses)

VARIABLE	% sample
female	58
household income greater than $60,000/year	73
household income greater than $100,000	44
college or post-graduate degree	84
living in condominium	39
living in structure with more than 2 floors	55
single occupant car is transport mode most often used	58
metrorail or metrobus is transport mode most often used	29
very willing to walk or bike more in future to reduce global warming	52
choiceleft, the lefthand policy package is chosen	47
choiceright, the righthand policy package is chosen	53

Table 2 shows the background characteristics of our 278 respondents. As the Table displays, the majority of our respondents (58 percent) are female, and about three-quarters (73 percent) have more than $60,000 in annual household income. For comparison purposes, in the Washington-Arlington-Alexandria area as a whole,[7] a slightly smaller portion (52 percent) of those 18 years and older are female, and a lower percentage of residents 18 years and older earn more than $60,000/year (63 percent). Nearly 85 percent of our respondents also have received bachelor or higher college degrees (compared to 42 percent in the Washington-Arlington-Alexandria area), the most unrepresentative of our respondent characteristics and a bias driven by our university location. Thirty-nine percent of our respondents live in condominiums — the residential environment posited in our scenarios — and a majority live in structures with three or more floors (all of the scenarios in our choice experiments entail 3 floors or more). We followed these background questions with several on climate and transportation themes. Fifty-eight percent of respondents indicated that a single occupant car is their most dominant mode of transport for work, [8] while almost 30 percent indicated that metrorail/metrobus is. However, more than two-thirds of respondents indicated that more or improved public transit was the most important transportation need for the future. About one-half indicated that they would be very willing to walk or bike more in the future to reduce their impact on climate change if more facilities were in place to support this.

To assess the tradeoffs that individuals are willing to make among transit, private vehicle ownership, energy efficiency/cost, building structure, and land use, we present three regression models.

[7] The Washington-Arlington-Alexandria metropolitan area is a subset of the larger WBNV Metro that comprises our study area. However, it corresponds more closely to the area that our survey enumerators canvassed so we use it here for comparison purposes.

[8] A telephone survey of more than 350 individuals in Northern Virginia conducted in 2004 for Virginia's long range transportation planning indicate that 89 percent of respondents in the region identify vehicles as the one mode of transportation they most often use.

Five-Attribute Model (Regression 1)

In our simplest model, we include the five attributes that we presented in our questionnaire (see Table 1) for our full sample. Respondents yielded 1,594 observations.[9] The last two lines of Table 2 show that respondents selected either of the two choices in each experiment in roughly similar proportion; that is, the left-hand side choice was selected 47 percent of the time and the right hand side the other 53 percent of the time. Neither side systematically and significantly dominated the other, satisfying an important survey design criterion. Table 3 provides the coefficient values for each of these attributes in our basic model run. Several results stand out.

First, all coefficients (except that for the intercept term) are significant at the 0.01 level and the pseudo R^2 for the logistic regression is 0.22. This R^2 value represents the percentage improvement that including the five attributes provides for explaining respondents' choices of alternatives over a model without the five attributes (*i.e.,* a model that assumes individuals choose each of the different alternatives with identical frequencies).[10] The interpretation of the five coefficients is as follows.

(1) attribute	**(2) Coeff.**	**(3) t-statistic**	**(4) p value**
number of floors	-0.0559	-3.78	0.000
ground floor use	0.9139	10.25	0.000
annual energy costs	-1.1010	-10.44	0.000
private transportation	-0.8344	-10.25	0.000
distance to transit stop	-1.4384	-14.26	0.000
intercept	-0.0638	-1.08	0.281

Table 3: Basic Model (Regression 1)
n=1,594 observations, pseudo-R^2 = 0.22

As the *number of floors* in a structure increases (from 3 floors at a minimum, to 5 floors, and to 10 floors at a maximum), the benefit to respondents of the condominium being purchased decrease. Everything else being equal, respondents prefer lower structures. This finding is not surprising but it nonetheless needs to be qualified with the context of the scenario we presented. We specifically told respondents that the carbon emission benefits of all of the different choices would be equal, a condition perhaps at odds with a reality where taller buildings (allowing higher densities and with more shared wall space) likely entail fewer overall carbon emissions due to reduced vehicle miles traveled and energy demand.[11]

The *ground floor use* attribute comprises a dummy variable, meaning it is represented as a binary, either/or choice. Since we coded the variable as a "0" for office space and a "1" for grocery, retail, and restaurant space, the positive value of the coefficient indicates greater benefits from the grocery, retail, and restaurant usage. We also would expect this since it represents a mixed use that individuals can take advantage of in their

[9] Survey questionnaires presented 6 experiments and with 278 completed surveys, the maximum number of observations is 1,668. However, not all respondents completed all choice experiments. Experiment #4 had the lowest number of responses (262) while experiment #2 had the highest number (272).

[10] This pseudo R^2 represents McFadden's R^2. Long (1997, p. 104) discusses the suitability of this measure for assessing model fit. The 0.22 value is consistent with similar published studies that use stated preference and binary logit data.

[11] In future work, we plan to present visual images of the alternative condominium structures, which should provide firmer ground for exploring preferences for density.

daily lives that does not depend on the ground floor hosting their own work space. The large magnitude of this coefficient relative to the coefficient for the *number of floors* also indicates greater unit weighting on ground floor usage. For instance, the coefficients suggest that the individual benefits derived from shifting from office space to grocery, retail, or restaurant space are equivalent to the magnitude of the disbenefits imposed by increasing a building by 16 stories (0.9139/0.0559). These 16 stories lie outside the bounds of our data, admittedly, so such extrapolation is injudicious. The point, however, is that the benefits of changing ground floor use from office to grocery, retail, or restaurant appear substantial and could offset disbenefits imposed by additional floors.

The third attribute, *annual energy costs*, comprises an interval measure, although we present it at only three levels ($1,000/year, $1,500/year, and $2,000/year). As expected, the coefficient is negative; that is, as energy costs increase, the respondents perceive disbenefits. The coefficient is close to 1.0—a Wald test can not reject at a 0.10 confidence level the null hypothesis that it equals 1.0—which suggests that individuals get roughly a $1/year in benefits from every $1/year saved.[12] We scaled the units of the energy costs in thousands of dollars. Thus, a $1,000 dollar decrease in energy costs yields roughly the same benefit—or its value is perceived the same—as switching from office space to grocery, retail, or restaurant space on the ground floor (1.10 compared to 0.91, not a statistically significant difference at a 0.10 level).[13]

Our first transportation attribute, the *private transportation* dummy variable in row 4 of Table 3 captures the benefits perceived from trading off a private vehicle parking space against subsidized access to a shared zipcar (Table 1). We coded a parking space for each unit as "0" and a subsidised zipcar as a "1," so the negative coefficient means the zipcar options yields disbenefits as compared to the parking space for a private vehicle. The magnitude of the coefficient indicates a strong preference relative to the *number of floors* variable, although since *private transportation* is represented as a binary variable, the comparison strictly holds only for the two levels of the variable. It may be that greater subsidisation of the zipcar (*e.g.*¸500 free hours/year) would shift the coefficient positive; that is, the results do not indicate whether respondents perceive zipcars negatively but rather that they prefer the parking space over the specific zipcar package we offered.

Finally, our *distance to transit stop* variable has a negative coefficient, as we would expect. Since we coded our ¼ mile distance in Table 1 as a "0" and our 2 mile distance as a "1," the negative relationship suggests disbenefits from purchasing a condominium that is further from a transit stop. The magnitude of the coefficient indicates the high importance to our respondents of being ¼ mile, and therefore within walking range, rather than 2 miles from transit (which would require other transport). However, as with

[12] In a follow-up question after the six choice experiments, we asked respondents if they preferred energy cost savings, preferred a cash payment of equivalent value, or found both of these options equally attractive. Roughly 41 percent indicated a preference for energy cost savings, 21 percent a cash preference, and the rest found the two equally attractive.

[13] We can estimate the annual dollar value of each attribute by computing the ratio of the attribute's coefficient to the energy coefficient and multiplying by $1,000. Thus, from the values in Table 3, each additional floor has a negative value of $56; moving from an office-residential mix to a grocery-retail-restaurant-residential has a positive value of $910; giving up a private parking space for a shared zipcar has a negative $830 value; and living ¼ mile rather than 2 miles from a transit stop yields a $1,440 value.

the other dummy variables, the magnitude of the coefficient also reflects our particular scaling. We do not know, for instance, the value of being located ½ mile away from transit or 1 mile away, although we likely can safely assume that closer is better. How much better, we do not know, absent inclusion of a continuously scaled attribute to capture distance from transit.

Dominant Transportation Mode, Single Occupant Car vs. Metrorail/Bus (Regression 2)

The relationships estimated in our first regression may not necessarily hold for all individuals in the sample. To test whether it does, we can divide our respondents into sub-samples and run separate regressions on these. In particular, we can look at transportation use and attitudes, and examine whether these factors correlate with attribute preferences.

Table 4 (see page 46) presents the results of separate regressions for individuals who indicated that a single occupant car is their dominant mode of transportation to work (car, shaded rows), and those who indicated that metrorail or metrobus is their dominant mode (metro-user, un-shaded rows). Both sub-samples by design reduce the number of observations included in the regressions, yet all but one of the attributes (*number of floors* in the metro-user regression) remain highly significant and keep the same direction of relationship (*i.e.*, positive or negative).

Not surprisingly, those respondents who use metrorail or metrobus as their dominant transport indicate more relative disbenefits from being further away from a metro stop than those who use a single occupant car (the difference between -1.95 and -1.21, respectively, in going from ¼ mile from a transit stop to 2 miles from a transit stop), a statistically significant difference at the 0.05 level. The difference between these two sub-samples of the value of the *private transportation* also appears large—changing from -1.08 in the case of the car dominant subsample (which is the second highest magnitude among the coefficients) to -0.85 with the metrorail/bus respondents (-0.85, the second lowest magnitude among the coefficients). This is not statistically significant at the 0.10 level, however. Similarly, the coefficients of the two sub-samples' *annual energy costs* attribute appear different, but when different income levels are controlled for, this difference becomes statistically insignificant.

Walking and Biking as an Alternative to Driving a Car (Regression 3)

Table 2 (see page 40) shows that roughly one-half of the respondents in our sample indicated a strong willingness to walk or ride a bike more and drive a car less to reduce their impact on global warming. Our third regression model separates respondents into two sub-samples based on whether respondents replied that they would be (a) "very willing" to do this; or (b) only "somewhat willing" or "not willing." The estimation results from separate model runs of these two sub-samples appear in Table 5 (see page 46). The coefficients for all attributes in the two sub-samples in Table 5 follow the pattern of the models described above. For both sub-samples, the *number of floors*, *annual energy costs*, *private transportation*, and *distance to transit stop* attributes are all significant and negatively related to the benefits derived from the condominium choice, while the *ground floor use* attribute is significant and positively related (indicating a preference for grocery, retail, or restaurant use on the ground floor rather than office use). However, the magnitude of several of the coefficients differ between the two models. Those respondents who appear "very willing" to walk or bike more derive relatively greater benefits from a ground floor devoted to grocery, retail, or restaurant use rather than office space (coefficient equals 1.17), than do those who are not very willing to walk or bike more (coefficient equals 0.71). A Wald test rejects the equivalence of these coefficients at a 0.02 level.

The coefficients of two transportation variables also appear to differ between Table 5's two sub-samples. Similar to the results from the car and metro-user comparison, individuals indicating a stronger willingness to walk or bike lose more benefits from being located 2 miles rather than ¼ mile from a metrorail transit stop (*distance to transit stop*) than do other respondents. This is intuitive. Perhaps a more interesting difference between the two sub-samples is that respondents who are "very willing" to walk or bike more also appear less against relying on a shared zipcar. To be sure, the coefficient of the *private transportation* attribute remains negative—indicating a preference for a free parking space rather than a shared zipcar—but its magnitude (0.67) is much less than the attribute's coefficient in the subsample of respondents who are not "very willing" to walk or bike more (1.12). This is a significant difference at the 0.01 level. Our result is intuitive—everything else being equal, those willing to bike or walk more would have weaker preferences for having a parking space for a private car—and it suggests that there are more opportunities for developing a shared car approach among such individuals.

5. Summary and Future Directions

Carbon emission reduction has captured the attention and imagination of thousands of city planners, environmental advocates, individual citizens, and businesses in the U.S. and elsewhere around the world. Even in already-built -out urban agglomerations, an array of local stakeholders appear interested in transforming the urban environment in climate friendly directions. Many of these efforts are consistent with other objectives in urban development and benefit from being paired with them. For example, the interventions that we explore in our survey—higher residential densities, more mass transit, greater energy efficiency, alternative options to private cars, and more mixed use—all have major implications for reducing carbon emissions and, with the possible exception of energy, all also are central tenets of the broader smart growth movement.

Subject to our caveat about the representativeness of our respondents, our survey shows generally broad and statistically significant support for several carbon reducing approaches in our sample. Although respondents prefer parking spaces for their individual cars rather than a subsidised zipcar, they also appear to favorably view mixed land use that combines grocery, retail, and restaurant uses with residential ones more than mixed office-residential environments. Being closer to a transit stop also appears preferred. Both of these attributes have large and positive coefficients relative to the negative coefficient for higher residential density, suggesting that they could offset the relatively small discount that respondents place on higher densities (*i.e.*, taller residential buildings). Energy expenses are viewed almost dollar-for-dollar equivalently to other costs (*i.e.*, a coefficient near 1.0 in our basic model). Since the energy attribute is expressed in units of $1,000/year, those attributes with magnitudes less than the energy coefficient (*number of floors, ground floor use,* and *private transportation)* can be expressed as imposing costs under $1,000/year, while those greater than 1.0

(*distance to transit stop*) yield benefits exceeding $1,000/year.

Splitting our sample into sub-samples based on transportation practices and attitudes yields similar findings as the whole sample. Coefficients generally remain significant for the different sub-samples of respondents, with the same signs. For those respondents very willing to walk or bike more to reduce their impact on climate change, the costs imposed by foregoing a parking space in favor of a shared zipcar are significantly less than for other respondents. This suggests that greater subsidisation of a shared car—or pairing this subsidisation with other benefits such as a grocery or retail establishment on the ground floor—could make some respondents willing to relinquish a parking space and their car. For those respondents who indicate that their dominant form of transport currently is metrorail or metrobus, the benefits from living ¼ mile rather than 2 miles from a transit stop are significantly higher than for other respondents.

Future research plans include developing a larger and more representative cross section of the WBNC Metro environment respondents in our sampling frame. This would allow a richer analysis of the influence of respondent characteristics (income, age, current housing situation, and attitudes toward climate change, for example) on attribute preferences. More delineated locational info on respondents—postal code and neighborhood location—also would allow a more complete examination of how variables reflecting the form (*e.g.,* street and building density) and socio-economic characteristics (age of housing stock) of the respondents' neighborhoods shape preferences. Both of these efforts would facilitate targeting of carbon-calming transportation and design options to subpopulations most likely to respond favorably. In addition, including information on the actual effect on carbon emissions of the different options and examining how preferences might shift with this information would greatly enhance our analysis.

Finally, future work should include additional attributes. The combinatorial logic of the choice experimental design limits the number of variables possible in such an analysis but larger samples and/or elimination of less interesting attributes can accommodate this. Possible additional variables to include entail several transportation options—car free zones, bus rapid transit, and reduction of parking requirements, for example—and built form features such as reduced setbacks and higher FARs. Understanding public preferences for these and other features that operate at the intersection of urban form, design, transportation, and energy is a valuable precursor to developing a robust, integrated strategy to make large-scale progress toward reducing the carbon footprint of metropolitan environments.

(1) attribute	(2) mode	(3) Coeff.	(4) t-statistic	(5) p value
number of floors	car	-0.0674	-3.49	0.000
number of floors	metro-user	-0.0145	-0.48	0.631
ground floor use	car	0.9233	7.90	0.000
ground floor use	metro-user	0.9055	5.05	0.000
annual energy costs	car	-0.9514	-6.79	0.000
annual energy costs	metro-user	-1.5081	-7.02	0.000
private transportation	car	-1.0876	-9.95	0.000
private transportation	metro-user	-0.8512	-4.95	0.000
distance to transit stop	car	-1.2123	-9.46	0.000
distance to transit stop	metro-user	-1.96	-8.74	0.000
intercept	car	-0.0768	-0.98	0.329
intercept	metro-user	-0.0498	-0.42	0.676

Table 4: Transportation Mode Model: Car vs. Metro User (Regression 2)

car respondents: n=914 observations, pseudo-R^2 = 0.25

metro-user respondents: n=455 observations, pseudo-R^2 = 0.30

(1) attribute	(2) mode	(3) Coeff.	(4) t-statistic	(5) p value
number of floors	somewhat/not willing	-0.0535	-2.53	0.011
number of floors	very willing	-0.0544	-2.53	0.011
ground floor use	somewhat/not willing	0.7125	5.46	0.000
ground floor use	very willing	1.1681	8.90	0.000
annual energy costs	somewhat/not willing	-0.9970	-6.46	0.000
annual energy costs	very willing	-1.2638	-8.06	0.000
private transportation	somewhat/not willing	-1.1184	-9.27	0.000
private transportation	very willing	-0.6749	-5.54	0.000
distance to transit stop	somewhat/not willing	-1.2320	-8.46	0.000
distance to transit stop	very willing	-1.6244	-10.78	0.000
intercept	somewhat/not willing	-0.0064	0.07	0.942
intercept	very willing	-0.0862	-1.01	0.312

Table 5: Willingness to Walk or Bike More (Regression 3)

car respondents: n=733 observations, pseudo-R^2 = 0.21

metro-user respondents: n=807 observations, pseudo-R^2 = 0.25

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Author details:

Kris Wernstedt
Urban Affairs and Planning
Virginia Tech University
1021 Prince Street, Suite 200
Alexandria, Virginia 22314 USA
00+1+301-785-6725 (cell), 00+1+703-518-8009 (fax), krisw@vt.edu

Greening the World's Airports

David C. Prosperi

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Introduction

The purpose of this paper is to review, assess, and identify research areas regarding the greening of airports. The paper necessarily includes air travel *per se*, but the major focus here is on airports in particular, although it necessarily involves attributes "in and around" airports. Although there are a few references to the general topic of air travel and sustainability (Longhurst et al., 1996; Gillingwater, 2003), the topic of greening airports is virtually ignored in the professional and academic literatures.

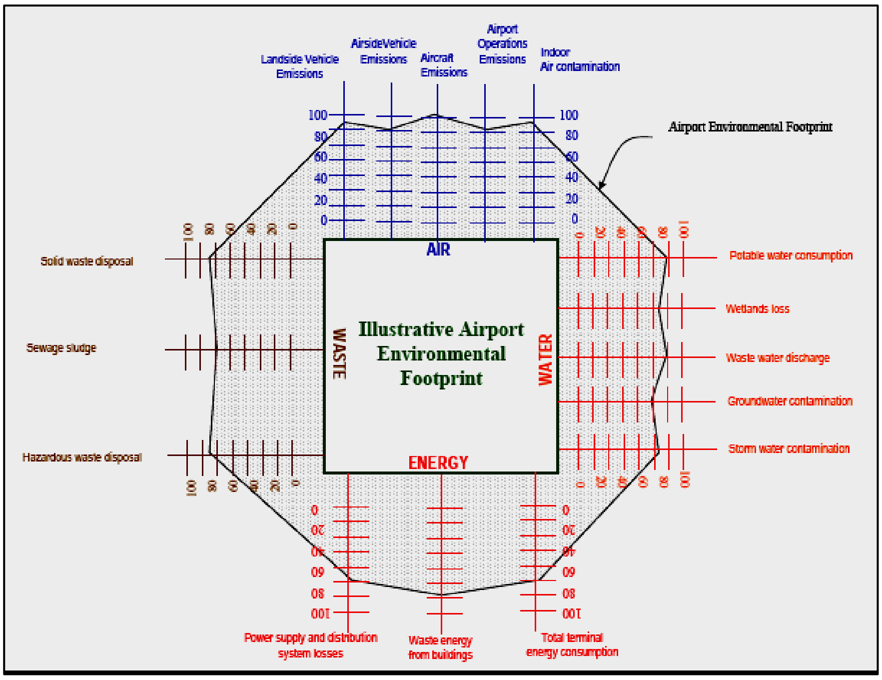

Figure 1: Theoretical Environmental Footprint of Airport

The Green movement is loosely organised around two high profile descriptors: climate change and sustainability. The major culprit in climate change is carbon dioxide, CO_2, which due to its high radiative forcing properties is deemed most responsible for global warming. The "triple E" of sustainability is more inclusive, including emphasis on preservation of non-renewable resources, green economics, social and intergenerational equity, and so on. To set the stage, it is useful to reproduce a figure developed by the Clean Airport Partnership that outlines the elements of an airport's environmental footprint (see Figure 1).

A major contention of this paper is that air travel and airports are relatively ignored within the mainstream urban and regional planning literatures, beyond the banal statements of climate change and sustainability and consumer-oriented "pay for your sins" approaches. The intent here is to frame the dialogue about the green efforts of/at airports. The paper is organised as follows. The next section provides an overview of how green (i.e., climate/sustainability) issues are framed for airports. The specific research is an internet search focused on the topic of green airports. Two major results are presented: several best practices, and a description of what appears to be the governance (loosely defined) terrain for this discussion. The final part of the paper presents conclusions and suggestions for future study.

FRAMING THE "GREEN" ISSUE FOR AIRPORTS

The literature review is organised around three themes. The first is to characterize the "green" values and issues. The second is to identify a typology and range of current and possible solutions and/or ameliorations. The final part sets the stage for a specification of the governance or institutional milieu in which greening efforts can and will take place.

Elements and Attributes

While it is always possible to list a larger set of variables, the major resource issues are, in keeping with the footprint model above, air, energy, water, and waste systems. Variations in responses of these systems arise from both point (local, the airport) and mobile (airspace) uses. The intensity and occurrence of "bad" values for these variables are directly tied to the operational mix of the overall [air] transport system. Operational mix means the various combinations of things such as type of aircraft, the composition of terminals, users, manufacturers, control systems, and society at large.

Air. Four sources (emitters) of air pollutants exist in and around airports. The most significant portion is due to aircraft operations. Pollutants are produced during taxiing, at take-off, at landing, and at rest. Surface vehicles, associated with ground services (crews, baggage) are a second source of pollutants. The third source is the generation of power to produce electricity and heat. The final source is the collection of landside commuter traffic generated by passengers, employees, and businesses. Pollutants include CO, CO_2, Nitric Oxide, Super Dioxide, unburned hydrocarbons and soot as well as typical vehicular emissions such as benzene, toluene and xylene. While the US National Research Council has concluded that the greatest source of air pollution is from mobile sources (cars, for sure, but also aircraft), within the realm of air travel and airport operations the major culprit is *CO_2 emissions* from both aircraft and land side vehicles, including those used for both passengers and landside operations. For example, the Clean Airport Partnership's study of DFW concluded that 65% of total emissions were from aircraft, 17% were from ground support equipment, 13% were from landside vehicles, and 5% from other power requirements (http://www.cleanairports.com/reports/gai_dfwforweb.pdf).

Energy. The requirements for energy stem from the need for electricity, heating, warm water, and air-conditioning in all airport buildings as well as aircraft. Energy consumption is determined by multiple factors, some quite specific to the function of the buildings. Beyond buildings are the energy requirements for, among other things, runway and approach lighting systems and/or for parked aircraft. The Clean Air Partnership's "10 Airport Survey" (2003, http://www.cleanairports.com/reports/cap10airportsurvey.pdf) included eight major findings: (1) airports represent huge opportunities for energy efficiency; (2) there is little guidance at all levels of government for airports seeking to improve efficiency through either renovation or new construction; (3) energy efficiency is a low priority within the air industry; (4) there are opportunities for energy service companies to get involved; (5) investments in building efficiency can yield significant rewards; (6) metering and control of temperatures can be improved; (7) there is some evidence that newer terminals are not more energy efficient than older terminals; and (8) there is wide variation in electrical costs. While tentative in their results, the overall picture is one of benign neglect, wide variation, an under-incentivized institutional framework, and several good and bad examples.

Waste management and water. Commercial waste from terminals, cargo facilities, and office buildings are the major source of food scraps, paper, packaging materials, plastics, wood, glass, etc. that are accumulated as part of normal operations. Of perhaps greater significance are hazardous wastes including oil, oil-soiled materials, anti-freeze, paints, fluorescent tubes and batteries, etc. Finally, there are water quality parameters that result from normal and storm water waste management (cf. Kaszewski & Sheate, 2004).

Possibilities of Response

Responses to these challenges in environmental systems are basically technological, economic, or ecological in nature. *Technological responses* are exactly that: the use of technology to improve values of certain parameters. Within the realm of air transport, the two technological fixes that have gathered the most attention appear to be bio-fuels and green buildings. In the former, for example, the recent Virgin Air experiment with bio-fuels (coconut, babussa) is illustrative and AFVs (alternative fuel vehicles) are in use for some ground operations. On the building side, many airports are now using LEED (Leadership in Energy and Environmental Design) or LEED-inspired policies to make projects "sustainable."

There are two types of *economic responses.* The most obvious and well-publicised response is the "green economics" response, which argues that those who consume "un-priced" goods should pay a compensation fee. The second is the desire and ability to make green products, and/or to recycle waste into profitable enterprises. In the realm of air transport, the dominant discourse is the compensation strategy, in which either NGO's or the airlines themselves seek a voluntary contribution from passengers to offset the environmental costs of travel. The argument has twin conceptual foundations: frightening statistics and the suggestion that monies collected are invested in green projects.

Finally, *ecological responses* include conservation and/or other environmental programs that use natural systems to ameliorate human consumption. Beyond the banal "plant a tree" suggestion, these are the least well understood and least implementable within the realm of air transport. The approach of wide-scale "adaptation" is virtually ignored in favor of specific, small scale, improvements.

The Governance Milieu

The function, size, and impact of airports within metropolitan areas are only recently becoming better understood (cf. Prosperi, 2007). Aside from sheer size (e.g., DFW is larger in land area than Manhattan), these places compete with both traditional downtowns and/or other established suburban business districts for employment, position within the metropolitan hierarchy, and as meeting places.

The final section conceptual issue to be identified is "who" is or should be involved in the overall movement towards greener airports. It is perhaps too trite to characterize the structural members of this stakeholder circle as "government", "the civil society", and the "producers/airline industry." Planners know little of the "airline industry" and the "civil society" includes both quasi-governmental and NGOs as well as the consumers broadly defined to include travelers, freight shippers, and mail services, but also community members living in and around airports.

RESULTS

Two impulses guided the formulation of the research problem. The first is that traditional planners and academics have ignored airports and airport related developments. The second is that is clear that "sustainability" goes beyond "compensation for [air] travel." To address these issues, an internet search was performed to identify best practices and actors in the governance milieu. While there are many "best practices" (e.g., see, http://www.enviro.aero/Airports.aspx for a list), we choose to highlight here four of them, focusing on: assessment, planning, building, and energy.

Results: Best Practices

Example 1: Assessment. As a way of bring home the issue of green airports, we review the status of conceptualization and planning at two US airports (examples from non-US airports are contained below). The US Clean Air Partnership's GAI program (described more fully below) was "run" for the FLL airport. The focus was on four elements: water; energy supply, distribution, and conservation; solid waste, both hazardous and non-hazardous; and air quality, including discussion of aircraft operations, ground service equipment and landside vehicles. The approach of Salt Lake City is much more comprehensive. The Salt Lake City Department of Airport's sustainability program assessment is based on five sustainability practice areas. The total of 150 sustainable elements, comprising businesses practices, policies, and specific programs managed holistically, include 42 elements that support environmental management, 52 elements that support facility systems management, 56 elements that support airport operations and management, and 4 elements "holistically" managed.

Example 2: Building the First Carbon-Negative Airport. The Port Authority of New York and New Jersey is planning a carbon-negative airport at its recent acquisition at Stewart International Airport, some 60 miles north of Manhattan in the Hudson River Valley. This bold promise, if realized, would actually cause a net reduction in the amount of greenhouse gases. While there is no specific plan yet, the multi-faceted possibilities include: (1) latest energy-efficient and environmentally sensitive design in all new buildings; (2) on-site power generation from solar and wind; (3) connection to Manhattan via mass transit; (4) linking the nearby City of Newburgh to help in revitalization efforts. The Port Authority is exploring green-technology opportunities with nearby Rensselaer Polytechnic Institute and is exploring partnerships with Virgin Atlantic whose recent experiments with bio-fuels and new engines could cut emissions per flight by 30%. Richard Branson of Virgin Atlantic has also suggested the creation of energy-efficient airports which include use of clean-fueled tugs to tow aircraft, which are themselves powered off prior to takeoff and after landing.

It is clear that the "carbon-negativity" in the promo is a dream. It is unlikely that the reductions in aircraft emissions will be sufficient to reach this goal alone. Planning comes in here. The PA could work with local land conservation organizations to preserve open space in the Hudson Valley area to sequester carbon in forested lands. It could promote smart growth to arrest – or even reverse – the sprawling residential and big-box retail development that increases auto emissions around the airport. The key is to direct new development into nearby city centres – such as downtown Newburgh – and around transit hubs. The Port Authority could consider locating its regional office in Newburgh.

Example 3: Terminal A at Logan Becomes World's First LEED-Certified Airport Facility. Designed by HOK (Hellmuth, Obata + Kassabaum), Terminal A is the first air terminal to earn LEED certification from the US Green Building council. Guided by Massport's 2001 guidelines for sustainable construction at the airport, the partners – HOK, Delta and Massport – Terminal A is comprised of two structures: a 362,000 sq. ft. main terminal and a 284,000 sq ft. satellite concourse, connected by an underground pedestrian moving walkway. The building process and the building accomplish a number of objectives. First, 10% of all materials on the job came from recycled sources, and 75% of construction waste was re-used, recycled or otherwise diverted from area landfills. Second, the project combats the accelerated heat island effect and storm water runoff issues typically caused by impervious surfaces on runways, parking lots, and large roof areas. Its roofing membrane and paving designed to reflect heat from the building and special storm water filtration devices to remove suspended solids and total phosphorous. Other features include: water-efficient plumbing and irrigation; extensive day lighting and high-insulation glass; energy-efficient electric lighting; construction waste recycling; and the use of recycled, local materials. Regarding human use and environmental friendliness, Terminal A pays particular attention to indoor environmental quality. Daylight is a primary focus of the terminal's design, striking a careful balance between the benefits of exterior light and undesirable glare. Special measures were taken to control construction contaminants from adversely affecting the indoor environment. Adhesive, sealants, paints and carpets were specified to have very limited or no volatile organic compounds.

Figure 2: Interior of Terminal A, Boston

Example 4: Geothermal Heating at Orly. Orly Airport has recently announced that it plans to provide more than a third of its heating needs via geothermal energy. Slated to begin construction in 2009 and to be completed in 2011, the $17 million dollar project will cut annual CO_2 emissions by 7,000 tons from the current level of 20,000 tons. As France's second busiest airport, Orly aims to be its greenest by launching a vast program intended to increase its energy efficiency by 20% by 2020 and 40% by 2040. While geothermal heating systems normally use heat pumps to regulate heating and cooling via the earth's fairly constant temperature, Orly's plan differs insofar as it will take advantage of a large cache of hot water directly underneath the airport, eliminating the need for a heat pump. The geothermal system will drill two 1,700 meter deep shafts at the perimeter of the airport. Water heated by the earth's core will be drawn upward via natural pressure, reach the surface with a temperature of 74 C (165F). From there is will enter the airport's heating system and then be cycled back into the earth through the second shaft. The system stands to cycle 250 cubic meters of water per hour, providing for 35% of the airport's heating needs.

Results: Governance

There appear to be five different types of organizations that constitute the institutional milieu in which any progress towards the greening of airports will occur. These are: trade organizations, NGOs/advocacy groups; engineering and technically oriented professional associations; academic and research societies; and the range of governments at multiple scales. Lastly, but not to be forgotten, are the individual airports themselves.

Trade Organisations. There are two major **trade organisations**. While there are perhaps many more, the International Air Transport Association (IATA, http://www.iata.org/index.htm) and the Airports Council International (ACI, best accessed via http://www.aci-na.org) seem to be the major players. **IATA** is a trade body that represents 240 airlines and 94% of scheduled international air traffic. According to its website, IATA's industry priorities for 2008 include safety, environment (reduce by 6M tons CO_2 emissions from operations and infrastructures, develop standards and guidelines for an industry carbon offset program and pilot it with at least 6 airlines in four different regions), simplifying business, and finances. Of particular significance here is the very recent (April 22, 2008) Global Declaration on Aviation and Climate Change, signed at the 3rd Aviation and Environmental Summit in Geneva, Switzerland. Based on a four-pillar strategy – investment in new technologies, effective flight operations, efficient infrastructure, and positive economic instruments – the commitment is to a 25% fuel efficiency improvement target and a vision of a carbon neutral growth leading to a carbon emission free industry. *So, growth will be carbon neutral.* As a good trade body, they note that government and industry help is mandatory, for example in implementing the next generation traffic management systems. They estimate that "a single European sky" could save 12M tons of CO_2 at a stroke. **ACI** is the self proclaimed "voice of the world's airports." Its Website opens to a plethora of useful information. For example, on its environmental page, are descriptions of its initiatives/positions/resources in the areas of (1) climate change; (2) noise; (3) local air and water quality; (4) sustainable development; (5) recycling programs, and (6) community campaigns. Each is "clickable" – for example, climate change issues are discussed at http://www.aci.aero/cda/aci_common/display/main/aci_content07_c.jsp?zn=aci&cp=1-4612-4615^14056_666_2__). There are two useful links on the North American group's Website (http://www.aci-na.org). The first is an overview of sustainable initiatives containing a number of links to projects, as well as to other organizations that provide guidance for things such as green building (http://www.sustainableaviation.org/pdfs/ACI%20Weblinks%20031406.pdf). Perhaps even more interesting is the formulation of a sustainability index for airports, available at http://www.sustainableaviation.org/pdfs/ACI%20Index%20031506.pdf that contains multiple criteria in ten areas of sustainable practice.

Of the NGOs/Advocacy Groups that have visibility, two of the best known are the Clean Airport Partnership (http://www.cleanairports.com) and Green Seats. The not-for-profit **Clean Airport Partnership** (CAP) was established in 1998 and is devoted exclusively to improving environmental quality and energy efficiency at airports. CAP believes that efficient airport operations and sound environment management go hand in hand. This approach can reduce costs and uncertainty of environmental compliance and facilitate growth, while setting a visible leadership example for communities and the nation. For example, CAP has established implementation of the Green Airport Initiative (GAI), which is a comprehensive streamlined approach for helping airports shrink their environmental footprint while creating a blueprint for sustainable development. The GAI was designed, tested, and made available for user implementation with financial support from the Rockefeller Foundation, US Department of Energy, the US Environmental Protection Agency, and the US Congress. Steps of the Initiative include: (1) documenting environmental achievements, (2) identifying new opportunities, (3) securing financial support, (4) managing strategy implementation, (5) monitoring progress, and (6) making continuous improvements. To keep its costs low and provide the best possible value, CAP has assembled a team of nationally recognised experts that include companies and individuals with special expertise in facilitation and conflict resolution, land use and noise mitigation, air quality, water quality, building efficiency, aircraft operations, ground transportation, and sustainable development. CAP has issued a number of reports over the past decade (http://www.cleanairports.com/reports.htm) covering various aspects of their work.

Green Seats

http://www.greenset.com/us/boekmod-pag1_dotnet.asp focuses its energy on both emission reduction through projects on both renewable energy and energy savings as well as on sustainable forest projects.

The third group includes engineering and technical professional organisations associated with associated with green buildings (www.usgbc.org) and/or biofuels (for example, ANSI in the US, http://www.ansi.org/standards_activities/standards_boards_panels/bsp/overview.aspx?menuid=3 or UFOP in Germany, http://www.ufop.de/english_news.php). The fourth group consists mostly of academics and research societies. On the academic side, we found focused research groups such as the Air Transport Research Society (http://www.atrsworld.org). Finally, several journals such as *Journal of Air Transportation and the Journal of Air Transport Management* provide focused studies and research agendas. There does not appear a single clearinghouse that catalogues for air transport articles. Finally, there are government and various governmental agencies. Perhaps more germane to the field of planning (which obviously exists in such governmental contexts), these include at the transnational scale the United Nations, OECD, UNESCO, and the European Union. In the US and in most of Western Europe, virtually every branch of federal government is involved. Most recently, several states including Florida have begun making climate change and the role of airports items of interest and programmatic response. The emerging situation in China is worth watching, as over the next five years, there are plans to spend almost 18B on airports, raising the number of such facilities by over 50%. The Chinese appear to have put sustainable airport design on their national infrastructure planning agenda

(http://enr.construction.com/news/transportation/archives/070517a.asp)

Finally, the airports themselves. The greening of airports is becoming big business, perhaps evidenced by the plethora of conferences and business meetings evidenced on the internet. We found several exemplars in a variety of environmental problem areas. For example, noise is a major concern in Hamburg – the Flughafen Hamburg GmbH (FHG) issues regular reports on its environmental mission and progress;

(http://www.airport.de/en/downloads/UE_e_screen.pdf).

We found increasing evidence of formal organisational structure to include environmental responsibility. But, we also found evidence that a number of airports do not take the issue as seriously.

One of the speakers at an industry-sponsored conference in June, 2008 had the title: Vice President for Public Information and the Environment. Clearly, there is wide variation and work to be done.

CONCLUSIONS/SPECULATIONS

The intent of this paper was to perform an internet research experience on the topic of GREEN AIRPORTS. Inasmuch as air travel and airports are virtually ignored in the generic land use planning literatures and that sustainability/climate change argument is mostly focused on automobiles, we have attempted to fill in a gap in both understanding and identification of possibilities of response. Much of this discussion remains outside traditional planning concerns. Perhaps it should not remain there!

Whatever one may think of the "big business" of air travel and airports, the players (industry, airport operators) are in the game. There is evidence among both airlines and airports of concern with environmental issues. Expectedly, the concern is both for "cleaning up" and for "growth that is carbon neutral." And, while they have all appeared to issue their "statements of concern and intent" the emphasis is clearly on the ability to grow. Nevertheless, either due to genuine concern or public pressure, there are numerous examples of technological and ecological fixes. These are well beyond the highly visible "compensation" strategy. Some are truly impressive. What is amazing is that most of these are "out of the public eye."

There appear to be THREE prongs to the GREEN AIRPORT effort. The first is green building, including the use of greener power facilities. Involving both new construction (e.g., Boston Terminal A) or retrofitting (Orly geothermal endeavor, other solar power installations), the push is clearly on. The second prong is technology. Clearly, the industry is concerned with more efficient and cleaner engines. But, they are also the leaders in funding bio-fuel research. Babassu nuts! Worldwide, the Air Transport Association reported that the aviation industry used approximately 7.06 billion gallons of kerosene based Jet-A1 fuel last in 2008. According to industry reports cited in articles by USA Today and Aviation.com, the target for 2030 is to replace up to 30% of Jet-A1 kerosene fuel with bio-fuels and other alternatives. Determining exact percentages for bio-fuels and other-fuels is problematic, because a percentage of that 30% goal includes a Gas-to-Liquid (GTL) fuel produced via the Fischer-Tropsch method. Assuming a very optimistic 95% bio-fuel share and a 5% GTL share, bio-fuels would account for approximately 2 billion gallons of the current 7.06 billion gallon aviation fuel demand. Gazzard (2008) reports that, according to the UK-based Aviation Environment Federation, it would take 1.4 billion hectares of land to replace the current aviation fuel supply with bio-fuels. Further, following the assumption of a 95/5 share for bio-fuels versus GTL, it would take approximately 400 million hectares of land to sustain the 30% goal set forth, an area just shy of half that of the Continental United States.

The third prong is the effort of airport operators. The effort and activities of trade organisations are important things for the general public and planners to keep abreast of. What appears to be missing is a meaningful role, beyond babble, of planning and government.

Aside from the aerotropolis folks, there is a paucity of professional and/or academic planning literature on airports. How do we work the “airport” issue into existing planning processes – such as MPO planning in the US or spatial planning in Europe? The Europeans, in particular, are especially vulnerable as they are still developing their airport systems. Much of the current effort appear to be of the signature airports icons (see Barajas in Madrid) or in creating aerotropolis nodes (see Vienna)! But, perhaps the focus should be on more simple things, like easy train connections (see Hamburg!).

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Author details

David C. Prosperi
Professor, Department of Urban and Regional Planning
Florida Atlantic University
Fort Lauderdale, FL 33301
prosperi@fau.edu

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