The Concept of the Urban Metabolism (UM)

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Sustainable Development and the road towards a dynamic equilibrium

Since to 1950's the subject of sustainability and the need to reduce global ecological overshoot has been at the center of debate on all fronts: social, economic and environmental. Defined as a process or transition strategy rather than an end in itself, sustainability has not yet been identified with a unified theory or approach.

It is important to link sustainability aiming urban solutions, that address to continuing transformation, economic-technical innovation and changing tasks in the public sector, to the use(rs) with optional help of technology and design.

Sustainable development is a moving target: knowledge, technologies, and skills are still being developed every day. In fact, sustainability often relies in the management of transitions—a shift to doing things differently—that tends to be specific to each site, rather than a constant recipe or 'one size fits all' type solution. This is why it is necessary to bring the knowledge and innovations of environmental technology and design and especially the role adaptation to change and complexity related to this. For sustainable (urban) development is mainly depending on people's mind.

One of the big debates in environmental urban development and design today concerns policy and strategic responses. Both public and private sectors look for operational strategies that can be implemented in the development and retrofit of sustainable urban areas. As a result, powerful market players working together with governments are emerging as the new leaders in this debate.

The different approaches can be classified according to the actors involved by the motivations and incentives, and the various implementation scales from regional and urban plans to building sites *(Timmeren & Röling, 2007)*. One way of addressing the complexity of the task at hand, often used these days, is through certification standards. Certification programs can cover most of the aspects of urban (property-) development, including setting targets for site decontamination, use of recycled materials, brownfield redevelopment, provision of public transport, options to discourage fossil transport use, energy consumption and efficiency in buildings, water recycling and waste management. There is however a certain risk attached to this development. Urban sustainability should be more: plans will have to be tied together in an integrated approach with surrounding projects as a total concept within a structure supporting flexible and continuous processes of change.

Social (economical) aspects in relation to Sustainable Urban Planning

The 'make-ability' of our environment is limited and we have to develop new patterns of interaction with the environment including inevitable adaptations of our way of living, working and recreation. Even to those who are thoroughly inured to warnings of impending catastrophe, the World Bank's recent report on climate change, *Turn Down the Heat (PICIRCA, 2012)*, made for alarming reading. Looking at the consequences of four degrees of global warming, a likely outcome under current trajectories, the Bank concludes that the full scope of damage is almost impossible to project. Even so, it states: 'The projected impacts on water availability, ecosystems, agriculture, and human health could lead to large-scale displacement of populations and have adverse consequences for human security and economic and trade systems.'

Simultaneously, one of the biggest technological transformations ever is taking place, viz., the fusion of the various geographical markets in the world into one dynamic, complex organism. In this, roughly forty "global cities" are taking up a key position within the global economy. They can be called the "hubs" of modern global economy, characterized by "denationalization" *(Sassen, 1991)*. Urban areas thus become the milieu for the world's economic engines, control centers and workforces.

After over a century of ignoring cities, the economics profession is beginning to come around; today, *Urban Economics* is now seen more often a growth discipline. Most of today's urban economic theorizing aims to explain the productivity advantages of large cities, taking inspiration from Alfred Marshall's observations of external economies of scale *(Marshall, 1920)*. But today's dominant theories in Urban Economics have a distinctly single-E focus, downplaying issues of social equity and the natural environment. According to *Glaeser (2011)* cities can be defined as "the absence of physical space between people and companies." It is important to realize that besides this single-E focus, to understand cities fully, the other two E's –Equity and the Environment– must be addressed. Modern studies of interest group politics *(e.g. Bartels, 2002)* demonstrate that socioeconomic inequality tends to bring about unequal access to the channels of policymaking. Glaeser however tends towards the view that urban poverty is a temporary condition through which destitute rural migrants pass on their way to wellbeing. This goes of course in particular for growing cities in developing countries.

The new Urban Economics focus of today identifies urban environments as "greener" than suburban or rural areas; city dwellers use fewer physical resources and emit fewer greenhouse gases per capita than their suburban or rural counterparts. But in terms of human well-being, the quality of the urban environment matters as much as cities' overall environmental footprint *(Timmeren, 2012; Enelow, 2012)*. Protection from air pollution and issues like lead poisoning, access to parkland and healthy food are rarely equitably distributed within cities, with poor people shortchanged on all counts. Environmental injustice hurts everyone; more equitable distributions of environmental benefits are good for all residents of urban areas, not just the disadvantaged *(Ash et al., 2010)*.

While it not being immediately apparent to the average citizen of the west, a tectonic technological shift is causing a sea change as markets around the globe that were once isolated by geography are beginning to fuse into a complex socio-technical-economic organism. The modern globalized economy is defined by roughly forty 'global cities' that have undergone a 'denationalization' *(Sassen, 1991)*, whose 'urban ingenuity' (i.e. Infrastructure, services, economy and social values) is more alike than when compared to other cities and towns found within national boundaries. Thus, urban areas have become the milieu of our global economy, its control centers and its workforce. Consequently, the typical global city is much more complex and chaotic as a growing number of spatial and virtual connections extend across traditional political boundaries. Harmful environmental development schemes are exacerbated by our chaotic, disruptive and aggressive spatial changes and will undoubtedly continue to intensify in the coming next decades if we maintain our current business-as-usual path. On closer examination, however, the global economy itself might be characterized as a system of structural exploitation that creates hidden dependencies on other parts of the world, forcing people to give up their rights to their own resources. The counter reaction to this, which I support, is called 'localization'. It is sometimes feared that this counter reaction, so-called 'localization', will lead to all kinds of negative aspects, such as repression, dependence and intolerance. On closer examination, however, it is clear that the opposite is true: the global economy is itself might be characterized as a system of structural exploitation that creates hidden dependencies on other parts of the world, and forces people to give up their rights to their own resources.

Towards an Urban Metabolism: Localization and Short Circuit Economies

The urban environment's capacity to generate ecosystem services has been largely overlooked. This will have to become an important starting point for the development of changed focus in Urban Planning. This 'response' to aforementioned processes of globalization, localization, is not about isolating communities from other cultures, but about creating a new, sustainable and equitable basis on which they can interact. In this context, short circuit economies can be developed when community initiatives are taken to release the imagination of those involved and enable them to take further steps towards economic revitalization, stronger and healthier communities.
The transition from unsustainable cities to more sustainable and resilient cities must gradually develop in an evolutionary way where today's open and global systems for energy and materials will be complemented by what has been referred to as more local and regional 'short circuit economies' that facilitate local social cohesion as well.
The development of short circuit economies has a potential to raise awareness and creativity on a local level so that adaptive governance will be an important force in the transition to sustainable pathways in cities. The aim of economic localization is not to establish complete self-sufficiency at the village level. In fact, localization does not mean everything being produced locally, nor does it mean an end to trade.

It simply means creating a better balance between local, regional, national and international markets. It also means that large corporations/ governments should cede more power to and communities, giving them more control over what is produced, where, when and how, and that trading should be fair and to the benefit of both parties. A very important result of more short circuit economies is that the use of resources together with the problems arising from our life styles and consumption patterns will be more transparent to people. Hence, the distance between awareness and action can be decreased.

Building the urban-focused economy of the future based upon inclusion of social equity, environmental justice and urban ecosystem services are as important as the main questions stated in this research: the inclusion of prosperity and innovation based upon interconnecting eMobility and energy generation and exchange based on renewables. This requires looking at, not overall national trends, but the sub-national performance of cities and metropolitan areas.
Today, cities in the advanced economies of North America and Western Europe may dominate the various surveys that measure urban productivity *(Colford, 2013)* and cultural magnetism, but, tomorrow, about 400 fast-growing cities in the developing world will reshape the economic landscape. As the long-established but slower-growing cities in developed nations, like for instance in the Netherlands, see their relative influence wane, the surging cities of the developing world will be increasingly ambitious competitors. The interesting thing however is that the vitality of metropolitan regions is upending traditional national power structures: Mayors and city planners often wield authority more effectively than gridlocked federal governments *(Brooks, 2013).* Or as *Katz and Bradley (2013)* state: "There really isn't a 'national economy. There's a network of metropolitan economies" where countries' talent, creativity and industry are concentrated. *Holland (2012)* calls this an evolutionary transformation in citizenship that is now underway.

For large urban developments it is important to be aware of this, and to try to focus its development on this principle, advancing a conception of sustainable urban districts (Eco Districts) as a microcosm of society.
Well-known initiatives to improve their competitiveness in this respect are the World Bank's 'City-by-City help for (eco)development'. Analyzing urbanization through the competitiveness lens is indispensable in designing effective pro-growth strategies. In the accelerating global economy, building on the creativity that's concentrated within competitive cities, creating green urban environments based on the before mentioned triple E approach, offers the best chance of delivering transformative solutions *(Colford, 2013).*

The concept and context of an Urban Metabolism (UM) approach

The metaphor of a city, or living environment, as a living organism with a collective urban metabolism[1] can be traced back for more than 150 years. More recently, the concept of urban metabolism has been used as an analytical tool to understand energetic and material exchanges 'between cities and the rest of the world' *(Fischer-Kowalski, 2002)*. It is tangential to concepts of 'regenerative design' *(among others: Tillman-Lyle, 1994)*, 'cradle to cradle' *(Braungart & McDonough, 2002)* and the emerging academic fields of industrial ecology *(among others: Goklany, 2003; Bai, 2007)* and biomimicry *(Benyus, 1997)*. Basis is that ecology needs to be the paradigm for technological advancement if global ecosystem health is to be restored. Metabolism is a precondition of life, along with homeostasis (regulation of the internal environment), structural organization, growth, adaptation, response to stimuli, and reproduction[2].

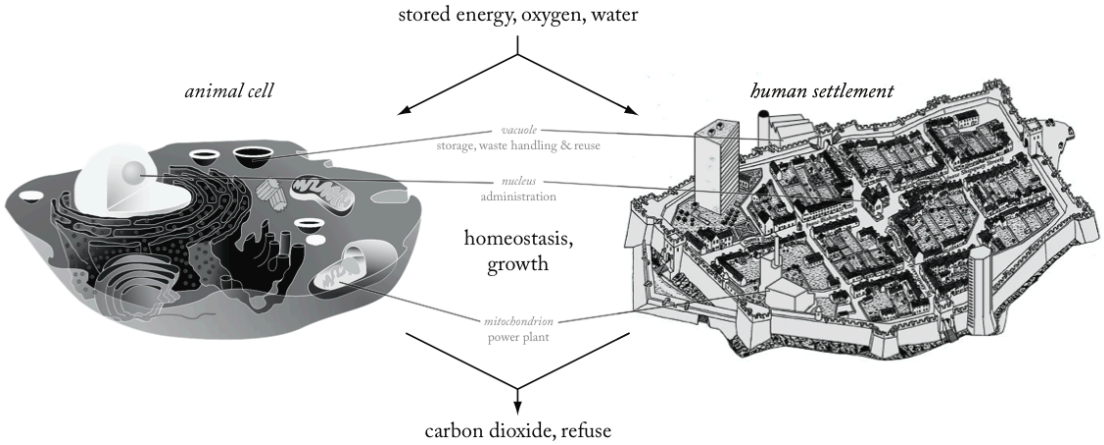

Figure 1 Metabolism comparison between an animal cell and a human settlement.

Though metabolism was at first used to describe living organisms, pioneering ecologist *Arthur Tansley* expanded the term in *1935* to encompass the material and energetic streams from the inorganic construction of settlements. Urban metabolism here is a framework for modeling complex urban systems' material and energy streams as if the city were an ecosystem. This approach allows the dynamics of cities (beyond 'traditional' mobility and the relationship between built/(un)cultivated environments) to be studied in relation to scarcity, carrying capacity and conservation of mass and energy *(Newman et al., 2009)*. From this perspective, buildings, districts and entire regions as not only consumers but also potentially significant contributors to essential energy and resource streams.

[1] In Biology, metabolism is the totality of biochemical reactions in a living thing. Metabolism is differentiated into consumption of energy by breaking down sources into smaller units to release energy (catabolism) and synthesis of complex molecules from smaller units by using energy (anabolism).

[2] When applied to more that one organism, the biological object is an ecosystem in which different actors (i.e. plants, animals, bacteria, fungi) interact to form a collective metabolism; thus assuming that a community of organisms are systematically integrated in the same way as an individual organism.

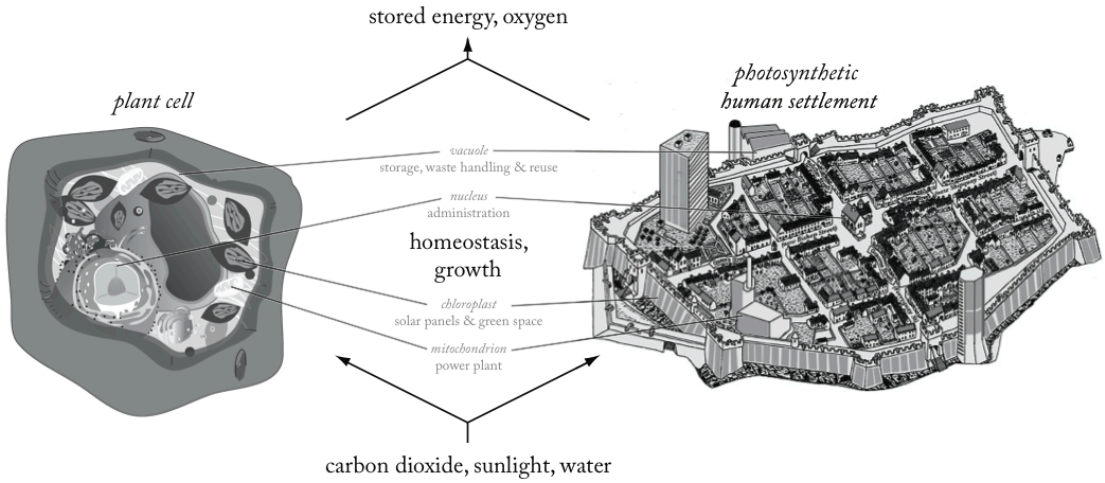

Figure 2 Metabolism comparison between a plant cell and a photosynthetic human settlement.

However, there is also a counter side to this approach: urban metabolism in a way is opposed to traditional urban planning, in which social, cultural, political and technical dimensions dominate over the biophysical dimension: hence, it synthesized environmental and biological science into the urban planning discipline[3]. Mo re recently, many interpretations followed concerning the industrial ecology and urban metabolism approach. *Abel Woman*, a sanitary engineer, originated the model in his *1965* paper, *The metabolism of cities*, which he defined as, "all the materials and commodities needed to sustain a city's inhabitants at home, at work, and at play." The three problems he identified are water supply, water pollution, and air pollution. 45 years later, more problems are relevant, including energy supply and nutrients. Important to mention is "The changing metabolism of cities" *(Kennedy et al., 2007)*, which updated the definition of urban metabolism to 'the sum total of the technical and socio-economical processes that occur in cities, resulting in growth, production of energy, and elimination of waste'. It introduces the essential component of integration of both technical as well as social perspective.

A society based on the principles of urban metabolism is predicated on the symbiosis of tradition and renewal. The architects, urban planners and engineers have a very important role toward the realization of a sustainable urban metabolism within our towns and cities. Oftentimes those in the field usually come up with solutions for singular problems with static forces. Let it be known that this epoch is now defunct. The importance of community building and 'self organization' will be paramount to creating a more self-reliant society that thinks globally but acts locally. Apart from our buildings and infrastructure, resilience, adaptability and transformability need to be incorporated into the modern idiom.

[3] For example, Karl Marx used metabolism to describe the material and energy exchange between nature and society as a critique of industrialization (1883): he advocated that urban metabolism becomes a power in itself (like capitalism), and will control society unless society is able to control it *(Nelson, 2010).*

Urban metabolism, however, is not without its critics. It has been challenged by certain social scientists because it neglects the sociological fact that humans are malleable and conditioned by their social environment *(Mc.Donald et al., 2007)*, not the natural environment. Human behavior is primarily influenced by societal norms rather than immutable natural laws. From this perspective, planning cities as a metaphor for a large biological entity is naïve because human relationships with the environment and other humans are more complicated.

Though sociological studies of urban metabolism have shown the irrationality of societies in regards to essential streams (water, nutrients, etc.), there is one, thankfully positive observation: human settlements are able to adapt to environmental conditions. Unlike all other organisms humans are self aware of their actions and can adjust behaviors accordingly. 'Reflexibility', or the use of critical intelligence and commitment in an envirotechnical, aesthetic or sociopolitical way for the design of environmental-technical and spatial processes, can be achieved in society through the participation of users in the design, construction and management of the environment.

Urban life has disassociated modern man from the nature. The western model of society is based on a number of immutable dictums that are rarely thought about in day to day activities: (1) there will always be an abundance of and access to food (and choices there of); (2) water always comes out of the faucet; (3) the infrastructures that provide us the goods and services (and the energy that they run on) we need will always be there. As it has been clearly illustrated time and time again, these assumptions cannot be guaranteed ad infinitum. Forced, top-down social control in the form of an environmental technocracy/dictatorship is not a desirable path for most. Instead, normal routines will have to change in order to create a post-scarcity society. Personal responsibility, environmental awareness, critical thinking, co-creation and communal well-being will be integral to the participation of users in this process of development.

Within the research tradition of environmental technology, the attention for water and energy saving has always been obvious, because of reduction in demand, enhancement of efficiency and renewable sources since the second energy crisis (in 1973) *(cf SUET main text Timmeren, A. van (2013a). "Sustainable Development; a Retrospective").* Meanwhile, there is a strong segregation between the various participants, as there is between the various disciplines, concerning solutions for matters including generation of renewable energy (wind versus sun), 'sustainable water management' and the development of the necessary water concepts and waste/material management. In the first few years after the energy crisis, the energy policy is also strongly characterized by institutional fragmentation. Until now, most research projects on environment related flows of energy, water, waste, nutrients and materials do not make any attempt to rise above the compartmentalized policy domains. Many well-meant initiatives stick in thematic and effect-oriented solutions without reaching a certain degree of integration or added value of environmental measures.

The corresponding infrastructure is often restricted to transport infrastructure with its own status, dominant parties involved and path-dependent policy. The relevant types of physical infrastructure (present in the Netherlands) which are considered in regard to the concept of Urban Metabolism, are as follows:

- Water supply; water extraction and purification, drinking water supply network;
- Wastewater treatment; sewer, wastewater treatment plants, recovery installations;
- Solid waste management; solid waste collection, separation facilities, transportation infrastructure, landfills, incineration facilities;
- Energy supply; electricity generators, electricity grid, heat network, pipelines for liquid or gaseous energy carriers;
- Food supply; farms, nutrient supply, storage facilities;
- Transportation; roads, bicycle infrastructure, pedestrian infrastructure, canals, public transportation.

The morphology of infrastructure is directly linked to the quality of urban metabolism. The infrastructure present in the city will have significant repercussions on the ecological footprint of the inhabitants, without any change in behavior. For example, electricity consumed in the Netherlands is predominately from fossil fuel while electricity consumed in Norway is predominately hydroelectric. Therefore, the Ecological Footprint and similar Environmental Assessment qualities are determined by the infrastructure providers, not by the consumers *(Nelson, 2010)*. The shape of the infrastructure changes the behavior of citizens, improving the quality of urban metabolism. The density of cities has a relationship to the type of transportation that is used. The location of the food supply, be it on another continent or in the city, influences the metabolism of energy in transportation.

Implementation of the Urban Metabolism (UM) approach

Few people in society deny the necessity to preserve or enhance the environment or our living surroundings, to distribute wealth and welfare, to offer all people scope to develop themselves and more awareness (the “equity” principle within Sustainable Development). However, the emphasis on the restriction of the environmental load will soon lead to resistance. Public support is lacking at times when this has consequences that cannot immediately be capitalized within the current economic models. “Most people like progress, fewer like changes” *Boisseleau* stated *(2004).* Therefore, the emphasis should be on conducting a transformation process, and perhaps on expanding environmental space *(Kristinsson et al., 1997).*
Critical to the implementation of this option of expanding the environmental space, or better: of integrated resource management in the urban living environment from the perspective of UM, is knowledge dissemination of low exergy solutions including strong feedback systems –constructive feedback loops– *(Folke et al., 2004)* between the different physical scales (site, neighbourhood, city-region, et cetera).
The basis of my view to take the updated UM perspective as a guiding principle lies in the interaction between integrated ecosystems and ecosystems in which the

created technical system performs (cf scheme by Kristinsson in Figure 13 of the SUET text "Sustainable Development; a Retrospective"): A sustainable built environment will not be completely reached until the flows of materials can be closed and the cycle can be managed and sustained without too many manoeuvres and losses of energy and other materials[4]. At all times alternatives should be offered (so-called fallback scenarios; especially important from the perspective of Resilience). Also, there is a theoretical challenge to understand existing frameworks on essential flows[5] from the perspective of emerging theories of complexity and to come up with a set of abstract dynamic models.

Meanwhile, "reflexibility" (which I define as "the use of the users' critical intelligence and commitment in an environmental-technical, aesthetic and political or socio-political way for the design of environmental-technical and spatial processes") can be achieved through the participation of users in the design, the construction and even the management of the built environment or parts of it.
For this purpose it is of importance to be aware that experimentation, learning knowledge generation, creativity and responsibility are common characteristics of all lifestyles *(Ryan et al., 2009; Florida, 2002).* And as community wellbeing is linked to participation in the process of development and in community activities, experimental setups (preferably within so-called 'protected environments') should be a first step.
The aforementioned issue of participation goes beyond just social control[6]. It could be seen as an attempt to hold users and occupants responsible for themselves, to ask them to think for themselves. As the notion of social structures is rather vague and does not allow for specifying groups or individuals, the term 'communities' most of the times is used[7]. The other, often dominant parties involved should realize that the involvement of users and communities goes further than just the change itself (design, construction/realization).
This alternative approach of "place-making" *(Healey, 1997)* is a balanced concept which is interconnected with surrounding projects, in a structure that supports flexible and continuous change processes, is open, and is continuously capable of absorbing corrections through permanent reflection (and learning).

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[4] The urban environment is a high activity, densely populated area. These areas inevitable require low-entropy concentrated energy supply.

[5] Like REAP ("Rotterdam Energy Approach & Planning"; *Tillie et al., 2009),* EPM ("Energy Potential Mapping"; *Dobbelsteen et al., 2011),* Ecopolis strategy & S2N ("Strategie van de twee netwerken"; *Tjallingii, 1996),* DPL ("Duurzaamheids Profiel van een Locatie"; *IVAM, sd),* Triple P ("People, Planet, Profit" /prosperity), etcetera. But also new developed and operationalized political decision making approaches like TEEB ("The Economics of Ecosystems and Biodiversity"; *UN, 2008),* and for instance in the Netherlands MKBA ("Maatschappelijke Kosten-Baten Analyse"; *NICIS Instituut, sd),* "Kader Afweging Duurzame Ontwikkeling" (KADO) and 'Provinciale Structuur visies" (PSV) attached to possibilities within the WRo (Dutch law on Spatial planning).

[6] In the field of sociology, described as "the way people have learned to control each other and themselves" *(Goudsblom, 1974).*

[7] Communities are the social and institutional components of the city. They include the formal and informal, stable and ad hoc human associations that operate in an urban area: neighbourhoods, agencies, organizations, enterprises, task forces, and the like. In sum, the communities act as the brain of the city, directing its activities, responding to its needs, and learning from its experience." *(Godschalk 2002).*

Within this approach the urban development of an area had better not follow the ready-made plan, but should be embedded into a structure of flexible and continuous processes of change *(Timmeren, 1999).* It should be open to corrections and capable of continuously absorbing changes. Starting from the ambition of sustainable development on the basis of UM, an integrated development of areas assumes a simultaneous change in the material/physical, social and symbolic domains. In this, the building and perseverance of relationships based on mutual trust between the participants is considered the social capital in the area. Empowerment, co-creation and placemaking than are important concepts to include (or at least consider).

Conditional concepts for the UM approach: Empowerment and Placemaking

Many of the large challenges we face can be categorized as wicked problems, i.e. problems for which there is no common notion of what the problem is, and so there is neither common understanding on the path towards a solution nor on what would count as a solution. Moreover, it is also clear that the problems cannot be solved by optimization of existing systems or 'add on' type of solutions. Wicked problems in cities require transitions of urban systems (as a whole) that will in general not 'solve' the problem but make it irrelevant as the transition leads to completely new modes to fulfill existing functions. Transition theory has been emerging in the last decade and is still a 'work in progress'. Historic studies of transitions show that imbalances are an important factor in triggering transition processes. These can be caused by external developments (tension), internal developments (stresses by gradual changes within systems" elements) or by newly emerging technologies that create competing options to fulfill the function of the system (pressure) *(Haan, 2010).* These system conditions might create a 'sense of urgency', which will accelerate the transition and lead to more daring transition attempts.

Although most cities pride on their public life, one could state that they inhabit a public realm that still pales beside what it could become. Many neighborhood streets and most major avenues still can be considered hostile settings for pedestrians; too many plazas outside major buildings are lifeless and cold; smaller parks, plazas, and squares are poorly maintained; and local institutions such as schools and libraries seldom enjoy the strong public presence they deserve. In this respect often the quote *"We shape our buildings, thereafter they shape us"*, (Winston Churchill[8]) has been brought up. The built environment and its design (both on the scale of building and outside environment) can be seen as a carrier of culture and a creator of

[8] Winston Churchill's speech in House of Commons on October 28, 1944 is often referred to as the origin of this quote, but in the original version it goes: "We shape our dwellings, and afterwards our dwellings shape us. However the first printed version is found in a *Time* Magazine article from 1960 which provide the slightly different version "We shape our buildings; thereafter they shape us.

meaning, which establishes norms and behaviour in our society *(Weisman, 2000)*. This way of thinking of society requires that one sees the world and values hierarchies within it, not as neutral or objective, but as social constructions that are based on certain interests. Through this perspective, spatial design, be it at the scale of a building or an urban environment is never constant but is constantly re-produced through certain means based on certain values and ideas. So one can speak of "performativity" in architecture and spatial organisation of functions. What architecture is *doing* rather than just *being*, using the term performativity in this context as discussed by *Judith Butler (1990)*. Creating green urban environments based on the UM and engaging citizens in more sustainable lifestyles is one of the biggest challenges. In this, policies should address to people as citizens rather than as consumers. It implies a new understanding of built environment that focuses also on the immaterial aspects of design (the so-called lateral Fundamental Needs; cf. Figure 16 in SUET text "Sustainable Development; a Retrospective), through its relation to urban and *social* life, besides of that of the actual shapes: How temporal aspects play a role in the experience of the city, as well as how activities including the human body can change the meaning of spaces *(Petescu, 2007)*.
The challenge for architects and urban designers is to create infrastructures and services that can become part of the fabric of city life. This will not be achieved simply by applying concepts such as citizen-centric principles to the design of smart city services. The more important question is who has the ability to apply such approaches on behalf of all of the people within a city? The answer lies in communities *(Robinson, 2012; Dorst, 2005)*. It is only by enabling the *"co-creation"* of new services by all of the stakeholders within city communities that a citizen-centric approach can be systematically and universally enabled.

The policy than for an area development based on UM should try to find a balance between government, business, communities and individuals that will deliver the reform, fairness and change the built environment needs. The policy agenda than should be based upon the following:

- Giving communities more powers (localism and devolution); to encourage a more 'organic' agency response by encouraging higher levels of social learning between individuals within their communities, to encourage a more collective response to energy and climate issues.
- Encouraging people to take an active role in their communities; empowering through a greater sense of ownership, e.g. by encouraging more decentralized energy generation, which could be owned and run by communities themselves.
- Transfer of power from central government to local government; addressing issues of 'trust' in relation to the role of government and business. By a continued devolvement of responsibility down to the local level might encourage 'grass-roots' politics around energy and climate issues *(Fudge and Peters, 2013)*.
- Supporting co-ops, mutual, charities and social enterprises (individual and community entrepreneurship); support by governments of these groups in realizing greater involvement in the running of public services.

- Communicate real-time data (including use(r) feedback, government data); open (transparent) data will help to empower individuals and communities and to respond more specific to changes in circumstances, leading to a more custom-made and effective approach.

Together with this focus of empowerment placemaking is a relevant tendency. Placemaking is a multi-faceted approach to the planning, design and management of public spaces. Placemaking capitalizes on a local community's assets, inspiration, and potential, ultimately creating good public spaces that promote people's health, happiness, and well-being. It is both a process and a philosophy *(Alexander, 1977),* but should also be seen as an overarching idea and a hands-on tool for improving neighbourhood(s) (or even the city or region). The last few years there were worldwide a variety of pushes for placemaking related to greyfields, docklands and waterfronts (see for instance: http://www.pps.org), which built upon existing energies while honing new techniques.

Resilience thinking and incorporating change in urban metabolisms

To work towards a sustainable future, a multitude of approaches are preached and practiced. A resilience approach deals with sustainability in a non-direct way. From a resilience perspective, spreading risk enhances a system's resilience. This was concluded before as necessary, with respect to the Urban Metabolism approach. These risks include not only the risk of depletion, but also of contaminating one's own living environment. Here a resilience approach achieves the goals of sustainable development via another route on a systemic level.
Facing the fact that the current way of dealing with our environment and resources is not sustainable, from a resilience perspective this means that it now shows that current human activities are not resilient to changes in its patterns of resource consumption: we seem not to be able to cope with a lack of our primary resources. Urban environments are currently highly dependent upon the built and natural environments in their hinterlands, depending on networks of infrastructures for people, information, water, materials, energy, and waste. The growth and densification of these networks lead to a greater interdependency between them, which increases their vulnerability due to potentially uncontrollable cascading effects *(Cohen and Havlin 2010)*. Within this context resilience and the previous concepts of localization, short circuit economies, place making and empowerment are important starting points. Resilience is a rich and complex concept. It has roots in systems theory, and it has a variety of interpretations and applications including for ecosystems management, disaster preparedness, and even community planning *(Medd and Marvin 2005).* Resilience is defined as "a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" *(Holling, 1973)*. This definition originates from ecology and indicates that change and disturbances is not countered, but instead is

utilised to alter the system in such a way that the system can cope next time similar changes or disturbances occur, without losing its identity.

Resilience has three defining characteristics:

- The amount of change the system can undergo and still retain the same controls on function and structure.
- The degree to which the system is capable of self-organization.
- The ability to build and increase the capacity for learning and adaptation.

The city's innovative capacity is important for its ability to adapt and renew itself in response to new future challenges. However, the resilience of a city not just depends on its capacity to produce innovations. A city's ability to respond to new challenges requires the ability to adapt itself, which does not necessarily require the implementation of innovation. Adaptive capacity is in part determined by the physical boundaries of the system. However, systems are in general more able to respond to new conditions if the system's components are more varied and the control of the system is executed at the lowest level *(Berkes et al., 2002)*. This implies that resilient cities should have:

- Innovative capacity;
- A dense and varied social fabric;
- Decentralized control, and
- Physical infrastructures that allow future adaptations.

Urban environments will never be finalized. As a complex self-organizing system the city will always be changing. Within this on-going change one can identify long periods of steady state during which the city is subject to small-scale disturbances and short chaotic periods during which the city is subject to strong fluctuations; often, the sequential accumulation of soft, hardly observed, urban perturbations lead to dramatic effects. In the language of the complexity theory of *Haken's (1983) Synergetics*, such an accumulating effect is termed 'control parameter'. From this perspective a distinction can be made between "soft" urban disturbances that typify cities during their steady state periods versus "hard" urban disturbances that typify (and are often the cause of) the city in its chaotic periods.

Resilience thinking is starting to shape how urban planners in cities think about updating antiquated infrastructure, much of which is robust in the face of normal threats like equipment failures but — as was demonstrated in the New York region after the most recent so-called 'super storms', hurricane Sandy and Philippines typhoon Haiyan— fragile in the face of unanticipated shocks like flooding, pandemics, terrorism or energy shortages. Combating those kinds of disruptions isn't just about hard engineering, or building higher dikes, it's about accommodating the waves. A resilient system withstands change up until a certain point after which it will adapt to the disturbance in such a way that it suffers the least damage as possible while preventing future damage from the same disturbance. Such a 'dynamic equilibrium'

allows for flexibility and for uncertainty. Within the resilience adaptive capacity is a key attribute of any system. It partly determines the ability of a system to cope with disturbances.

But at the same time resilience from the perspective of UM and regenerative systems involves other aspects as we'll also need to use nature itself as a form of backstop, or "soft" infrastructure.
And finally another issue plays a role: psychologists, sociologists and neuroscientists are uncovering a wide array of factors that make you more or less resilient than the person next to you: the reach of your social networks, the quality of your close relationships, your access to resources, your genes and health, your beliefs and habits of mind. These tools will have to find their way into wider circulation, as we better prepare populations for the mental, and not just physical, dimensions of disruption. Here, again community building will be of importance.

The scale(s) of Urban Metabolism

Regarding resilience and the ability of cities (and its buildings and infrastructures) to adapt to change *Downton (2009)* distinguishes a number of propositions: first of all, cultural change can be catalyzed by the creation of 'cultural fractals' that display essential characteristics of the preferred cultural condition. Second, an 'urban fractal' is a network that contains the essential characteristics of the larger network of the city. Each fractal will possess nodes, or centers, and patterns of connectivity that define its structure and organisation, and it will exhibit characteristics of community associated with living processes. It is a particular type of cultural fractal. In this, and with respect to the in the previous section concluded need for placemaking, empowerment of citizens and inclusion and creation of communities, important goal can be phrased as weaving characteristic and distinctive elements together in a pattern that we recognize as a particular culture.
In this, culture is defined as a living system of human relationships that expresses itself in language, arts, tool-making and social organisation, including politics and economics. According to *Downton (2009)*, if there is an identifiable smaller pattern that displays the essential characteristics of the larger culture – if it is self-similar to the cultural whole – it can be considered a 'cultural fractal', while the most complete fractal representation of a civilization is urban.
An urban fractal is any part of the urban system that contains sufficient characteristics of that system to represent the essence of that system in microcosm. It is a conceptual tool that has scope and potential as both an analytical device for understanding exactly what is the essence of sustainable cities and societies, and as a synthesizing device for creating replicable models of the Urban Metabolism approach. The urban fractal approach, in relation to UM, is also closely related to the work of Richard Register concerning "integral neighborhoods" and "ecological demonstration projects" *(Register, 2006)*. The urban fractal concept fits well with ideas of the "distributed city", for instance, where power, water and resource

management systems are less centralized, with the technologies under more local control. This implies also the inclusion of elements that at the moment are not generally considered as part of the urban system, including nature, ecosystem services, and urban agriculture.
A consequence is a necessary minimum size of the development area *(Timmeren, 2006)*, to be able to achieve such a 'complete' urban fractal. However, it is rare for even the largest of conventional developments to contain sufficient characteristics and services for it to function as a neighbourhood. Therefore integration with or into existing and/or surrounding urban environments is such an important prerequisite.

Within the concept of UM for 'urban fractals' or 'integral neighborhoods', as explained before, it is important to be aware that for its resilience it should be elaborated further into smaller pieces of urban development. In this the concept of 'pocket neighborhoods' by *Chapin (2011)* is relevant to include. Chapin regards to essentially a few dwellings, typically 6 to 20, that are gathered around a commons. He claims that with this simple concept he is giving name to a pattern innate to human nature. Considering that every dwelling in a pocket neighbourhood looks onto the green heart of a central commons of social and green space, it is easy to see how this can be extrapolated to the larger scale of the neighbourhood, and how that neighbourhood subsequently can constitute an urban fractal. The analogy with a metabolism appears *(Timmeren, 2013a):* systems are similar to those in a human body, where some processes are inherently centralized, while others are inherently diffuse. In this way an approach to the urban morphology with characteristics similar to that of ecosystems can be constituted. Although these characteristics could not all be displayed completely (e.g. resource flows might only be circular for some materials, not all) this parallels local ecosystem behaviour in that although all resources are metabolized in ecosystems when viewed globally, the process is only partial when viewed locally.
Innovative capacity and adaptive governance are not just transitional prerequisites for UM, but basic characteristics of a resilient city (possibly consisting of various UMs). Adaptive governance is reflexive in the sense that it recognizes that every policy objective is a temporary one and that policies need continuous adaptation.
A sustainable and resilient future for a city based on one or more (interconnected) Urban Metabolisms is not the result of a single explorative journey but involves the continuous ability to innovate and maintain the capacity for adaptive governance processes to both 'hard' and 'soft' urban disturbances, and to do so by a continuous change of its urban fractals and within these, its smaller components.

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