URBAN SYMBIOSIS, A NEW PARADIGM IN THE SHIFT TOWARDS POST-CARBON CITIES

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Abstract

The metabolic flows of cities have to be reduced. Efforts have been directed to provide the city with renewable resources, diminish resource consumption, and/or reuse the wastes and emissions.

The dense fabric of urban infrastructures does not only provide a high level of services. By the proximity of infrastructures symbiosis might be created between them. This Urban Symbiosis might lead to a considerable reduction of resource consumption and/or carbon- and other emissions of all systems involved. However, developing symbiosis between urban infrastructures implies that the owners/operators of the infrastructures are able to align their interests too. This might be problematic as infrastructure operators developed a culture of autonomy. Moreover, they are nowadays owned by various public and private entities that pursue different agendas.

The top down planning model of infrastructures appears to be at the end of its life cycle; citizens, businesses and NGO's request participation. Early participation, using future methods and workshops might contribute to align actors for promising urban symbiosis measures.

The paper analyses barriers in developing urban symbiosis and sketches strategies how to deal with them. It uses the example of urban waste water systems to sketch strategies to develop symbiosis between urban infrastructures.

1 Introduction

Cities have been transformed in various phases in recent history; industrialisation led to large scale urbanisation and the creation of large belts of relatively poor housing. More recently, new transport systems, and especially the car and freeways fuelled suburbanisation. It created another belt of commuter towns and urban sprawl. With the advent of ICT's a confluence of urban and rural development was foreseen, as a lot of jobs would no longer be tied up with urban areas. The dichotomy between urban and rural areas was supposed to fade away (Muhammad et al., 2008). That did not happen, on the contrary. ICTs did not stop urbanisation but even fuelled it, as teleworking only marginally substituted the traditional character of office work. Urban areas became economically and culturally even more attractive as they became the centres of the new ICT industry.

Hence, it seems likely that urbanisation will continue in the next decades, in the developing world as well as in the industrialized world.

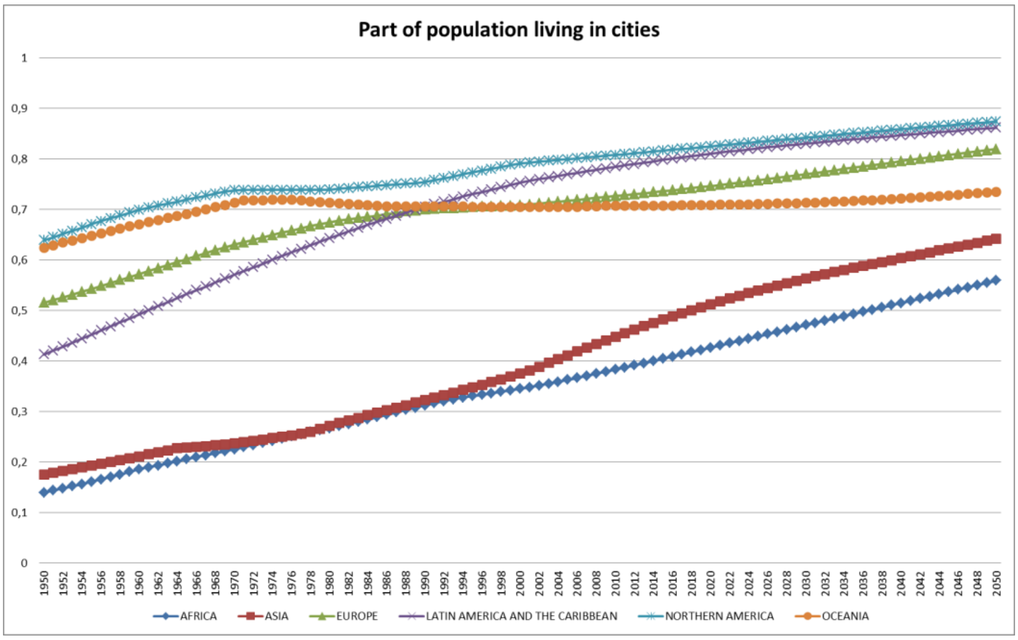

Figure 1 Based on data of (UN Department of Economic and Social Affairs, 2014)

1.1 Urban Symbiosis

City dwellers consume more resources than inhabitants of rural areas. Hence, reducing the footprint of the urban dweller is of utmost importance. Moreover, the world's giant cities are depending on a world-wide supply of resources, which makes them vulnerable to military conflict and natural catastrophes. Interruptions in crucial supply systems might create a series of subsequent catastrophes. Hence, urban resilience is of great importance (Ahern, 2011)

Cities have scope to improve. For example, current urban systems are generally quite inefficient. Moreover, the growth of cities creates scope for renewal, as technological innovation in urban systems can be far better achieved in new (Greenfield) urban districts. Moreover, cities are nodes in the societal innovation system as research and development and higher education institutes are usually concentrated in cities (Hekkert et al., 2007).

Besides improving separate urban systems, improvements might be achieved by analysing/managing the urban metabolism at a higher level. Innovation sometimes takes place between systems as they might aim at gaining from each other's proximity (Mulder and Kaijser, 2014). The concept 'Urban symbiosis' has been introduced by several authors to denote innovations creating symbiosis between urban systems (Mulder, 2015; Van Berkel et al., 2009). The concept was the equivalent of the concept of Industrial Symbiosis: *"Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity".* (Chertow, 2000)

Cities are an important scale in innovation (Raven et al., 2012). As cities are organisational as well as infrastructural nodes, developing symbiosis between urban systems could be an important goal for innovation. This has been earmarked as urban symbiosis (Mulder, 2015; Van Berkel et al., 2009; Vernay, 2013). However, urban symbiosis as a praxis is much older and its' best known example is probably the combined generation of power and heat, which boosts the overall efficiency of heat and power generation (Mulder, 2015).

1.2 Barriers for urban symbiosis

Urban symbiosis is not an easy fix, or a low hanging fruit. There are several barriers which could be categorized as:

- Technological. By-products of one system might not comply with the input requirements of the other, or the production of by-products does not match the demand for them in time (waste heat in summer, heat demand in winter). Storage, transport and distribution systems might be required. These technological barriers might be solved but at a considerable cost. Storage and/or transport require space and money and might lead to a lower quality resource.
- Institutional. Infrastructural systems are run by organisations that generally develop a culture of autonomy. Autonomy provides them with most opportunities to cope with any barriers (or reverse salients in Tom Hughes work on technological systems development (Hughes, 1985)) that develop during the life time of systems. This implies that urban symbiosis might be applied as long as it does not affect the system's autonomy, i.e. it might be terminated without interrupting the system's operations. Long term contracts and larger investments in urban symbiosis, however, curb the autonomy of the participants and are therefore generally avoided[1].
- Technology history. Infrastructures are in general extremely 'locked in' (Arthur, 1989). The lock in results from the long term character of the investments: Drinking water pipes from the 19th century are sometimes still in use, sewage pipes might last for 80 years, a road might last for 30 years with only marginal maintenance costs. Moreover, a lot of know how exists regarding the system as it is; alternatives require new know how, and the unknown might bring risks. Hence, every idea for encompassing symbiosis between infra systems might be objected by the risk that a large amount of assets might be lost if symbiosis is no longer needed.
  It is not just the loss of assets by a transition. A better system might be known, but there might be no feasible pathway to reach that ideal starting from the current system (e.g. it is almost impossible to switch from right- to left-side driving, or to switch from railway gauge)(Puffert, 2002). This strong lock-in creates a strong preference for add on innovation, contributing in fact to the build-up of additional lock in for the pre-existing infrastructure.(Frantzeskaki and Loorbach, 2010).

2 Strategies for change, the example of the sewage system

Given the strong technological and institutional barriers and the strong lock in, it is by no means clear which strategies are able to create urban symbiosis innovations (Pandis Iveroth et al., 2013). In the remainder of this paragraph I will sketch some options for urban symbiosis type innovations in the urban waste water system, and strategies to achieve these innovations.

2.1 Introduction: the waste water system

The urban waste water system is an interesting system as it has options for developing symbiotic relations with various other systems:

- Gas, a waste water treatment plant might produce biogas (methane), which might be treated to be injected into the gas grid (Vernay, 2013)
- Heating; sewage is warm, the heat might be recovered for heating purposes. Effluent of the sewage treatment might also be used for heating purposes.(Tassou, 1988)
- Electricity; biogas could be used in a combined heat/power installation to produce process heat for the sewage treatment and electricity for the pumps and to supply to the grid (Björklund et al., 2001).
- Agriculture; the residue from the sewage treatment process might be used to fertilise agricultural land. However, pollution should be prevented.
- Resource supply. Various resources, like struvite and metals might be recovered from the sewage (Uysal et al., 2010).
- Surface water quality. Waste water systems often also deal with storm water. During downpours, raw sewage might be emitted to open water, which might be devastating for water quality. Effluent emissions might also create 'thermal pollution, especially in winter.
- Drinking water; in regions with water scarcity, effluent of the waste water treatment plant might be upgraded to drinking water quality. This is generally far cheaper than seawater desalination.

[1] During a symposium in Delft, March 19th 2010, Chris Jordan, manager at the Rotterdam industrial network association Deltalinqs made a similar observation for industrial symbiosis in Rotterdam.

However, there are strong objections against drinking water that originated from sewage. Small residues of pharmaceuticals might still be present, like they are present in much drinking water (Benotti et al., 2008),

Some of the barriers to urban symbiosis might be an issue of developing improved technology, some might be an issue of removing institutional barriers, and some might be an issue of a long term strategy in order to cope with lock in. However, it is not always a priori clear what the nature of a barrier is:

- If a new improved technology might be developed, other solutions are not required. This is generally the 'easy way out'. However, not all problems are technologically solvable.
- Innovating institutions might be another option to create change
- The last strategy might be to introduce new systems for new urban areas and gradually substitute the old ones, once they are due to be replaced

For all these strategies, one needs foresight: it is not so important what prices, technology or regulation might do today; it is important to recognise what might happen, or probably not happen in the future and how a system might deal with change.

2.2 Visioning

Crucial for working on encompassing change in urban systems is not to start from the locked in systems but from needs to be fulfilled and the basic conditions to be met. Options for technologies could be scanned that comprise a promise to fulfil (part of) these needs. This could lead to a future vision developed in an interactive process with stakeholders. It is important to start visioning in needs to fulfil and not in technologies to be adapted: visioning allows 'wild ideas', while technological improvement only allows a better version of 'what is' (Mulder et al., 2012). In practice, visioning hardly occurs in sectors that are heavily locked in.

A long term vision that is widely supported by main stakeholders creates a framework that can act as a guidepost for innovation: what innovation do we need to move into the right direction, what organisational change and policy change might be required, and what innovations might be regarded as 'dead end streets'. Translating future visions into concrete strategy is called backcasting.(Holmberg and Robèrt, 2000; Quist, 2013; Robinson, 1988).

A future vision for a wastewater system will define key elements like: individual or collective, if collective its optimum scale, substances to be handled by the system (and substances that should be prevented to enter the system), the way how to treat the waste water, and what substances and forms of energy to recover.

2.3 Technological Change Strategies

The vision might define technologies to be changed (in general one aims for 'improvement' i.e. higher efficiencies, but adaptation to new conditions, or adaptations to deal with side effects might also be important). Technological change might be sought by:

- Stimulating relevant research & development
- stimulating experiments with alternative technologies, and protecting them (Kemp et al., 1998),
- Creating new demands that technologies are required to fulfil. Clearest example is 'technology forcing' i.e. announcing years in advance what will be the environmental standards for specific products, in order to force producers to innovate (Gerard and Lave, 2005).
- network management, i.e. change the set of actors that determine the course of research and development, create bridging events between various stakeholders to facilitate learning (Parandian, 2012).
- Specifically for innovation in large scale locked in systems, the technological designers are generally just focussing on innovating single artefacts. Systems analysis could make them more aware of the impact of their work on other parts of a system.

2.4 Institutional Change Strategies

From game theory, it is well known that monopolists have problems reaching reasonable agreements for both parties. Such a situation often occurs at city level. Hence, it is important that there actors that might act as intermediary or mediator. Such a mediating role is not a neutral role: a mediator is needed who has a strong interest in achieving environmental results, i.e. realise symbiosis. However, urban authorities cannot fulfil this role: they are too much involved in various interactions with the actors to be trusted as an intermediary (Vernay and Mulder, accepted for publication). Citizen's organisations/NGOs might perhaps also play such a role

Creating technological research and exchange platforms might also be important. Local infrastructure is generally defined by locally controlled engineering services. However, this leaves little scope for experiment and research, as the burden is too high for a single municipality. Platforms and (inter-)national support might foster bolder attempts for innovation(Cf. similar strategies in a dispersed industrial sector Moors et al., 1995).

2.5 Un-Lock-in Strategies

Locked in systems are so because of the huge investments in capital and knowledge that they represent. Both assets might lose considerable part of their value by a systems change. Moreover, capital and knowledge created a level of efficiency that cannot be matched easily by any incumbent technology as such technologies lack optimisation in practice. In general, only after such optimisation processes, incumbent technologies are able to match the performance of the established technologies.

This implies that incumbent technologies need protection against the competition of the established technologies, protection based on thrust in its potential which might be based on (technological) ideology (Schatzberg, 1994) or financial interests. Societal interests might urge governments to protect technologies that contribute to the environment, public health or safety.

3 Problem analysis sewage systems

In the 19th century there were various methods to deal with sanitation in cities: Cesspools and dumping excrements on the streets or in canals were no longer accepted for public health reasons and therefore various systems emerged: collection in barrels, pneumatic sewer systems (only for excrements) and a system that combined excrement removal with other waste- and storm water removal. This last system became 'the' standard sewage system around the turn of the 19th/20th century. (van Zon, 1986) It often combined the functions of preventing local flooding and a high water table, and sanitation.

In the course of time the sewage discharges in rivers and canals were no longer accepted as these discharged wiped out aquatic life. Sewage treatment plants were constructed. For these treatment plants, the large quantities of storm water that occurred at irregular intervals were a problem, which necessitated discharge of raw sewage. To prevent these discharges, storm water would have to be drained separately. In Europe, this separation is still far from completed, and so a considerable part of sewage is still discharged untreated.

In the treatment plants, more sophisticated forms of treatment were introduced, e.g. for energy efficiency, to generate biogas, and to recover resources. However, sewage contained more and more heavy metals and pharmaceuticals and therefore the sewage sludge could no longer be used in agriculture. From the end of the 1990s, sewage sludge was incinerated in the Netherlands. In fact this decision was reinforced by the subsequent decision to drain storm water that could be contaminated with higher levels of heavy metals, into the sewage system.

Besides the sewage system, a garbage collection system emerged from the traditional food scrap collection systems that existed in various cities. This system 'exploded' due to the 'explosion' of manufactured food and beverages after WW II. Various systems to stimulate recycling of materials and resource recovery were developed and food scrap is now generally composted (Block and Vandecasteele, 2011).

Clearly, the sewage system had problems adapting to new requirements by it's' inertia. Whether or not the system can be reordered, by developing symbiotic relations with the garbage system, agriculture and various energy systems is a question that is hardly addressed. It is my impression that 'lock in' is overwhelmingly present which prevents any serious ideas from popping up 'out of this lock'.

4 A process to open options for change?

In order to contribute to the challenge of climate neutral cities, urban infra-systems need to be torn out of their 'comfort zone', i.e. they need to step out of the options provided by the locked in technological system and the accompanying culture. Not just the individuals should adopt an open mind set; the organisation should also take measures to foster new ideas and protect their development. In fact the organisation should be aware that the standards and routines that it developed might be strong barriers to innovation.

Developing a future vision cannot be done without participation of the main stakeholders. Top down planning with its one dimensional optimisation goals and its technocratic rationality cannot bridge interests and perceptions of main stakeholder groups. Hence it is unable to provide viable options. The method that is proposed here is the participative double scenario method, that results in one or more stakeholder seminars (Mulder et al., 2012). These seminars might create foundations for a consensus on a long term vision regarding the fulfilment of the needs that the current system fulfils. Such a vision should be leading strategic and tactical plans for systems development.

Such an approach might trigger resistance based on the perception that it is impossible to change the systems' basic features. In part, such resistance should be acknowledged, as far as it concerns factors beyond the systems control: factors like magnitude of climate change, demographic change, cultural preferences, interest rates, unemployment rates and military conflict.

These ***external*** factors of relevance for the need to be fulfilled are gathered and analysed. They are used to create ***external scenarios***, i.e., scenarios that sketch the future environments in which a system might have to function. These scenarios are more or less setting the stage for the actions of the actors. Naturally, the external scenarios are focussed on future issues that are (potentially) of relevance for sanitation. Therefore, in making these scenarios, stakeholder interviews play an important role as they should provide information regarding the relevance of external developments for a sanitation system. In that respect, external scenarios are not neutral or objective: they focus on the external developments that trigger action in the perception of stakeholders.

External scenarios might be presented and discussed at a first stakeholder seminar. The aim of such a seminar is not to establish which external scenario is most likely, but to establish the reality of these scenarios, and the impacts that the futures that are sketched in the scenarios will have for sanitation.

Internal scenarios are based upon specific values or interests of stakeholders. They sketch a certain development of the sanitation system. Internal scenarios are based on future studies that identify 'forks' in systems development. The 'forks' that are major determinants of systems development should the starting point for creating 4 internal scenarios, that might be discussed in a second stakeholder seminar.

Such a structured scenario approach turned out to be productive in creating interaction among stakeholders. Its' success partly depends on the combination of a participation approach and a thorough qualitative analysis of future options for development (Mulder et al., 2012). By this combination, the approach might be an interesting tool to contribute to 'unlocking' heavily 'locked in' technologies. It might suggest new ideas for development but above all, it might render a longer term perspective to stakeholders.

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