Smart City Planning and Environmental Aspects?

Lessons from six cities

Tina Ringenson and Mattias Höjer
Division of Environmental Strategies Research (fms)
and
Centre for Sustainable Communications
KTH Royal Institute of Technology
Stockholm, Sweden
krin@kth.se; hojer@kth.se

***Abstract* — In this paper, we explore some promising Smart Sustainable City initiatives and solutions in Amsterdam, Barcelona, San Francisco, Seoul, Shanghai and Vienna, with a focus on environmental aspects. These initiatives and solutions include implementations of smart sustainable city technologies, and municipal support for such implementations. We analyse these initiatives and solutions with respect to their potential for replacing or intensifying products/spaces/travels/transports, leaning processes and activities, or informing city inhabitants or visitors of better choices from an environmental perspective, as well as their connection with a number of smart city challenges. We also discuss some of the problems we have found in these initiatives and solutions, especially regarding risks of rebound effects. Finally, we formulate three lessons for smart sustainable city implementation.**

***Index Terms*— Smart sustainable city, City Management, Smart city services, Sustainability, Environment.**

I. Introduction

Smart cities and sustainable cities are probably familiar terms for followers of the urban development field. However, opinions of what they mean differ, and their combination, the Smart Sustainable City (SSC), has been lesser explored [1]. But it has been proposed that ICT can be used to develop and manage cities more energy-efficiently [2, 3, 4] and sustainably [1], as well as to support a more sustainable urban lifestyle [2, 3]. However, a city with high ICT usage does not automatically have a small environmental footprint. It may just as well be the opposite, as suggested by growing problems with electronic waste [5, 6], resource depletion [7] and possible greenhouse gas emissions from electricity generation.

In recent years, cities are seeking to understand how to become “smarter” and use ICT solutions for energy use reduction and other environmental goals. For this, cities need to understand what types of ICT investments are most beneficial in the context of that particular city [2, 8]. It is also in the interest of telecommunications industries to understand what is most needed by current and prospective customers [2].

And already, all over the world, initiatives has launched that are of relevance for making the city - in a general meaning or with the focus on one particular city - smarter, more sustainable, or both in combination.

A. Aim

The aim of this paper is to explore some promising Smart Sustainable City initiatives and solutions, with a focus on environmental aspects. We identify resemblances and differences between cities’ approaches to Smart sustainable cities and comment upon possible consequences to this, drawing conclusions on what could improve cities’ SSC implementation and using these to formulate “lessons” for the future. The paper is based on the situation in six major digitalization-forward cities.

We have chosen to use the term “promising” as more or less synonymous with “having a positive potential”. As mentioned in section 2.1., the selection of initiatives and solutions is subjective since it is not easy to assess or define a positive potential. But the point here is to find illustrative examples rather than giving a comprehensive list.

B. Theoretical Background

The environmental perspective is not always strongly present in the smart city idea, although sometimes “smart” also includes environmental sustainability. One example is the definition by the Centre of Regional Science at Vienna University [9], where the smart city is characterized by 1) smart economy;2) smart people;3) smart governance; 4) smart mobility; 5) smart environment and 6) smart living. Two of these definitions involve sustainability goals – the definition of smart mobility includes “sustainable, innovative and safe transport systems” (p. 12) and smart environment encompasses “sustainable resource management” (p. 12).

However, a couple of attempts have also been made to pinpoint the combination of city smartness and sustainability into a clear definition of what a SSC is.

The ITU-T Focus Group for Smart Sustainable Cities [10] has defined the SSC as “an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects” (p. 13). Here, then, the definition includes innovation, and the ICTs are used together with other means primarily to improve social and economic factors, without negative impact on current or future generations

Höjer and Wangel [1] takes their starting point in sustainability rather than smartness, and defines the SSC as "a city that

- meets the needs of its present inhabitants
- without compromising the ability for other people or future generations to meet their needs, and thus, does not exceed local or planetary environmental limitations, and
- where this is supported by ICT."

(p. 342)

Here, "smartness" essentially means "ICT-supported", and seen as instrumental rather than normative - desirable only to the extent that it helps fulfilling desirable goals [1]. The sustainability aspect is more central than the ICT/smartness aspect. In this paper, we focus on ICT services that aim at creating benefits from an environmental sustainability perspective. Thus, the paper's aim is well in accordance with the definition by Höjer and Wangel.

We discuss the implementations' possible positive intended and unintended effects and negative unintended effects for the environment, where the latter include rebound effects, meaning that one responds to new technologies that increase the efficiency of resource use by increasing one's usage [11].

II. Methods

This paper is based mainly on literature and internet sources In the following section we describe our considerations when choosing cities and how we collected data. Then we describe how data was handled, and we end the section with a reflection on data collection and analysis.

A. Data Collection

The cities used as cases for our comparisons were selected by the authors in collaboration with an extended research team with participants from KTH as well as from other partners of the project (see acknowledgements). We decided that the outcomes should be internationally relevant and to focus on developed cities. All selected cities should be advanced in terms of digitalization usage. Moreover, we found it more interesting to look at already built cities in contrast to completely new building projects. We also wanted some global distribution among the cities.

The selection procedure took place at a point in time when the first European Union Horizon-lighthouse project, Grow Smarter, on smart cities was approved. The three leading cities in that project are Barcelona, Cologne and Stockholm. We decided to look at the first two, but not to bring in Stockholm in this paper in order for us as Swedes to keep some distance to the material. With those starting points, we held a number of workshops where cities were suggested. The method for finding the suggestions was mainly through snowballing, i.e. we used our professional networks and literature on SSC and then looked into the suggested cities. In the end, we selected the following cities, for the following reasons: Barcelona and Cologne as they are currently involved in the Grow Smarter project mentioned above; San Francisco and Amsterdam because they have well-known positive approaches to smart technology with relevance for environmental sustainability,; Shanghai as it has a strong focus on smart city development and exist in a political system very different from that of e.g. Amsterdam. Finally, we selected Seoul, because it is well known for its advanced technology and a fast-pace urban development with a growing interest in environmental issues. However, we encountered problems with using Cologne as an example city. While Cologne has interesting projects listed in for example the EU Smart city Mapping [12], the more extensive information we could find on the city's involvement in SSC project, such as from the Smart City Cologne website, was available in German only. As neither of us has a high enough German proficiency to understand it, we eventually excluded Cologne from the material.

Data collection was done mainly by collecting secondary data in the form of smart city-related conference presentations, peer-reviewed journals, and reports of academic, industrial or organizational nature. Each city's online public services were also assessed through their websites. The same was done for online applications and services for public use. In the case of Shanghai, we complimented our digital data collection with a personal interview with Yan Liu of the Department of Smart City Development Promotion at Shanghai Development Research Centre of Economy and Informatization. While the exact content of this interview is not in this paper, it helped provide a clearer picture of the Shanghai smart city project.

We have looked for the following:

- Implementations of SSC technology that
    - are ICT-based
    - aim at creating environmental benefits *or* have potential environmental benefits as according to the theoretical framework *and*
    - are supported by the municipality or city authorities
- Municipal support for above mentioned implementations, such as policies or city programs.

B. Data Analysis

The data on implementation was analysed using a typology by Höjer, Moberg & Henriksson [13] of replacing products/spaces/travels/transports; intensifying usage of products/spaces/travels/transports; leaning processes and activities; informing for changed consumption choices. The typology describes ways in which digitalisation can support a reduction of negative environmental effects and resource use, and was inspired by a typology developed by Mitchell [3] on how ICT solutions can support environmentally-sustainable development in cities. A fifth type would be broader societal transformation, induced by ICT. While this may usually not be applicable to separate SSC technology implementations, we have discussed it briefly for the supports.

We also used the challenges for SSC development as formulated by Höjer & Wangel [1]: strategic assessment of what to implement in the SSC; mitigating measures, to deal with counter-actions to that the environmental benefits of SSC solutions; top-down/bottom-up approaches to SSC development; competence within the municipality when it comes to digital solutions for the SSC and governance to coordinate SSC initiatives. Top-down/bottom-up approaches and governance are here jointly discussed. As the competence within the municipalities is hard to comment upon from the projects we have identified, we exclude this aspect in our discussions.

C. Methodological reflection

Just as the examples we have found of implementations cannot be seen as comprehensive for each city (see section 2.1), the choice of the cities was not intended to provide a full representation of how smart city development in the world looks today. While the selection aimed to be internationally relevant, we are aware that European cities are gravely over-represented in the selection, and "the global South" not included at all. We looked into cities in mainly Africa and South Asia, but saw that the challenges and opportunities in these cities were often very different.

Our data collection method accounted for a few problems. Deeper descriptions of projects were not always available, especially not in English. In the case of Shanghai we got some of our questions answered in an interview.

As previously mentioned, a full list of all applications available in each city has not been considered a realistic goal within the frameworks of this paper. The documentations we look at are dreams, seeds and plans. We have not controlled how they are going or analysed their actual effects, although we have discussed their possible effects. It should also be mentioned that it has often been hard to find reliable follow-up studies of projects' environmental effects.

Overall, it was far easier to find "surface" information – colourful, attractively designed presentations of SSC services – than to find more complex information, such as what political decisions that forwent implementations and formulated city policies. There could be several reasons why: that these are not available online, only available in the original country language and therefore hard for us to find, et cetera – or that the implementations in this case forego formalized policies.

III. Results

In the following section we briefly describe some of the promising SSC technology implementations we found, followed by a section on city support for these implementations.

A. Implementation in Cities

Smart work centres (SWC) are office centres in close proximity to residential areas, enabling working closer to home via telecommunication [14]. In Seoul, the Korean government has pushed forward an initiative for smart work since 2010 [14] and the Seoul Metropolitan Government has a project for employees to work from SWC [15]. In Amsterdam, SWCs have been facilitated in at least two ways. Firstly, there is the pilot project of SWCs by the company Cisco in collaboration with the cities of Amsterdam and Almere, which launched in 2008 [16]. We also found an undated project on the Amsterdam Smart City (ASC) website that referred to a smart work centre that the ASC reportedly works hard to realise [17]. Unfortunately, we were unable to find follow-up information. While the SWCs of Seoul municipality are intended for workers at the Seoul Metropolitan Government, the SWCs of Amsterdam do not require that the user belongs to a specific workplace.

As mentioned in section IIIB, the city of Seoul has decided to actively promote sharing [18]. Some governmental buildings have opened up to share some of their space with city residents, and what is shared between citizens include e.g. housing, children's clothes and parking spaces, with different amounts of involvement from the city [19]. Parking sharing is also available in Amsterdam with the privately developed, ASC-connected MobyPark application [20], which can also help the user quickly find a parking spot. San Francisco has a service that uses IoT technology for finding an available parking spot, organized by the San Francisco Municipal Transportation Agency [21, 22].

A smart grid is being tested in the New West in Amsterdam as a part of the European City-Zen project. The grid is equipped with computer and sensor technology to control energy flows and enables connected households with sun panels to feed spare electricity back to the grid [23, 24]. The project is described as preventing "large price increases for electricity transmission" [24].

San Francisco explicitly links their environmental goals to ICT solutions [25]. The solutions mainly consist of technically fairly simple online tools and guides to encourage and assist with environmental-friendly household activities like recycling, composting or saving energy. There is also a map tool that helps citizens plan for installing solar panels on their house by showing the potential for sun panels on their house, as well as a calculator for costs and savings for installing solar panels for a home or business [25, 26].

Almost all of the cities have some form of transport route planner, some made by independent developers and some municipal. One of the more advanced is Vienna's A nach B, which includes public transportation, bicycling, walking and driving and lets the user combine different means of transports. It compares travel times and CO2 emissions and updates to modify information and recommended routes every 7½ minutes using sensors and GPS vehicle data. It also includes points of interests such as car share or bicycle loan facilities [27]. The Smart City Vienna also lifts forth another mobility pilot, the Smile integrated mobility platform for finding, booking and paying for the various mobility services for a trip [28].

Similarly, many cities have some type of waste application or online service. One of the more interesting is the MA 48 Waste App of Vienna. This includes a city plan showing public facilities of the waste system, such as public recycling waste disposal sites but also e.g. public bathrooms. Among other things, it also includes a calendar with reminders for pickup dates for waste collection, information on waste separation, direct access to contacting the MA 48 and augmented reality presentations of the waste facilities [29].

In Seoul, the city environmental department has contracted the company Ecube Labs to install sensors at every trash can in the tourist-dense Bukcheon area. The sensors measure the amount of trash in the trashcan. The data is then used to automatically create an optimized collection route via a monitoring software platform [30].

Barcelona has a map over locations with connection to sustainability, from repair shops to food banks. The map is part of the international Green Map initiative, and has content created through workshops with citizens [31, 32].

The Seoul Eco-Mileage System program uses ICT to give incentives to member households and organizations who voluntarily cut back on monthly electricity, water or gas use by at least 10% compared to the monthly average of the previous two years. The content of the incentives are adjusted to encourage further more sustainability-oriented behaviour instead of using money saved for energy-intensive things, and can be public transportation card replenishment or gift-cards to be used in traditional markets, et cetera. The metering data is collected from the energy and gas providers [33].

B. Support and Implementation

The Amsterdam Smart City (ASC) platform is described as "a partnership between companies, governments, knowledge institutions such as universities, and citizens of Amsterdam" [34]. According to Lee and Hancock [35] the main amount of the smart city services offered in Amsterdam in 2012 were privately financed, but the ASC also includes private-public partnerships. This is similar to the project Smart city Barcelona, which Bakıcı et al. [36] describes as a collaborative movement among retail, academia, government authorities and Barcelona residents.

The municipality of Shanghai has a smart city action program that each stretches three years forward and is updated at the end of each such three-year period [37, 38]. Gil & Tian-Cheng [39] notes that the Shanghai Smart City plan is absent of clear environmental perspectives. However, it includes an aim to change the city's economy by shifting partially from retail industry to service-based economy. The city's development plan also includes environmental goals [40]. The government pushes toward a general transformation towards becoming a more ICT-connected city using clear goals of connectivity level for the many parts of the city. This approach to smart city transformation differs from what we have seen in Amsterdam. Zadek [41] proposes that the current economy in China is inefficient in terms of greenhouse gas emissions per GDP growth unit, and that changing the country's economy into one where ICT holds a bigger part could lead to significant decreases in carbon dioxide emissions per economic growth unit. He suggests that if the ICT development in cities is steered towards such a goal, it can contribute to a further reduced carbon footprint if the economy moves towards more innovation- and intellectually driven economic drivers [41].

Vienna's smart city initiative, called Smart City Wien, is described on its website as "a long-term initiative by the city of Vienna to improve the design, development and perception of the federal capital /…/ include[ing] everything from infrastructure, energy and mobility to all aspects of urban development" to "reduce energy consumption and emissions significantly without having to forego any aspects of consumption or mobility" [42].

In 2012, the Seoul Metropolitan Government promulgated an Ordinance on the Promotion of Sharing [43]. According to this Ordinance, the City should promote and support initiatives for sharing. Environmental goals are mentioned among the secondary goals as "promot[ing] sustainable consumption; reduce waste; address environmental issues" [43] (p.1). The government takes a very active part in the Sharing Seoul project. For instance, they support designated new non-profit and business sharing initiatives by administrative and financial support and permission to use the "Sharing City Seoul" brand license and logo [44]. "Organizations or businesses wishing to resolve social problems through sharing" [43] (p. 2) are eligible for designation as above. The Sharing City Seoul program also consists of several other forms of support, like adjustment of regulations, information to citizens et cetera [45].

In 2012, San Francisco mayor Edwin M. Lee announced the formation of a policy group on sharing economy [46]. The purpose was to find ways to simplify for sharing economy companies. The press-release explains sharing economy as "[using] technology and social media to promote the sharing and re-use of underutilized assets" [46], showing that ICT is central in their definition. Mayor Lee has a generally accommodating attitude towards technology-based sharing economy companies such as Airbnb [47].

IV. Analysis

In the following section, we analyse the results using the framework by Höjer et al. [13]. Thereafter we continue with a section analysing them from the perspective of the SSC challenges formulated by Höjer and Wangel [1].

A. Changing Consumption with ICT

We see little focus on reduction of consumption of things by *replacing* them with e.g. cloud-based or electronic services – Vienna even explicitly states no changes for mobility or consumption. But in Shanghai, we clearly see a striving for partially replacing physical goods with intellectual goods in the city's production. SWC's such as those of Seoul and Amsterdam have been identified as able to contribute to *replacing* travelling in the form of commuting to work [2]. However, the environmental effects of these SWC's would likely be affected by other things, like energy used for the user's normal mode of transportation and for heating/cooling of the SWC space as well as an eventual usual office space. If the SWC's use more energy for heating/cooling than they save by decreased travelling, this would be an unintended negative effect of the implementation of SWC's.

Some sharing initiatives might contribute to *intensifying* the usage of products/spaces/transports [13]. One could however speculate that this could result in rebound effects, if money saved on borrowing or renting an item is instead used on something else with negative effects for the environment. Or, to take it further – if e.g. the ability to rent out one's apartment while travelling finances one's plane tickets, or if cheaper apartment accommodations abroad increases travelling. There are also environmental complexities in sharing parking lots. On one hand, this intensifies the use of space and counteracts building more parking spaces. But it may also make travelling by car more convenient by simplifying finding a parking lot. This could lead to rebound effects of increased car travel. The same problem is apparent in the *informing* and *leaning* service of the parking spot finders of San Francisco and Amsterdam. While having the potential of lessening circling while looking for a parking spot, it also makes it easier to go by car.

This is also the case for many of the ICTs for *leaning*, such as, in many cases, smart grids. As an example, the smart grid of the Amsterdam test area encourages producing one's own electricity via solar cells, but is also described as preventing price increases for electricity transmission. Keeping electricity prices low may come with a *rebound effect* of using more electricity if it is cheap [11].

Overall, one of the more common uses for city ICT solutions seems to be informing to help users/citizens act more sustainably. This is apparent in the many city applications for sorting waste, route planning, solar power possibilities et cetera, as well as Barcelona's and other cities' mapping the locations of ecologically oriented services and businesses. These are also directly connected with analogue city services – there is little point to tell the citizens how to recycle without ensuring recycling infrastructure.

For *societal change*, some of the SSC support and programs we saw seemed to aim for this – although it differed how clearly. Shanghai formulates economic transformation as a goal, which could mean societal change. In Seoul, sharing solutions are expected to change consumption patterns as well as restoring a lost sense of community. In Vienna, on the other hand, the ambition is improving and modernizing the city, but with maintained consumption and mobility.

Implementation	**Function**				
	Replace-ing	***Intensify-ing***	***Lean-ing***	***Inform-ing***	***Social Change***
Amsterdam					
Smart Work Centre Pilot	x				
Smart Grid, Smart City Demo Aspern	x		x		
Barcelona					
Waste collection spot locating web service			x	x	
Sustainabler service map				x	
San Francisco					
Ridesharing match make service		x		x	
Parking sharing service		x	x	x	
Parking lot finder			x		
Waste sorting support online				x	
Solar map and calculator	x			x	
Seoul					
Smart work centres for municipal workers	x			x	
ShareHub		x		x	
IoT for more effective waste collection			x		
Eco-mileage system			x		
Shanghai					
-					
Vienna					
A nach B multi modal planner	x		x	x	
Smile			x		
MA48 waste app				x	
Support					
Amsterdam					
Amsterdam Smart City			x	x	?
Barcelona					
Smart city Barcelona			x	x	?
San Francisco					
Environmental goals connected with ICT services				x	
Sharing Economy policy effort		x			
Seoul					
Sharing City Seoul		x		x	x
Shanghai					
Smart City 4-year plans	(x)		x		x
Vienna					
Smart City Wien			x	x	

Table 1. List of implemented solutions and supports discussed in this paper and their potential contribution to reduced negative environmental impact.

B. Smart Sustainable City Challenges

For *strategic assessment*, the only city that we saw explicitly connected their environmental goals with ICT solutions was San Francisco, although it could be that some of the cities have clearer connections for this in internal documents. It should also be mentioned, as lifted by Höjer & Wangel [1], that having a freer approach to SSC development could have advantages like enabling more creativity in solutions. On the other hand, this may also lead to SSC technologies going in unintended directions, leading to unwanted second order effects, as suggested above.

For mitigating measures, many of the solutions seem to lack discussions and mitigations of possible negative effects. It could perhaps also be that such discussions existed internally but remained non-communicated. An exception was the Eco Mileage system in Seoul, where the participants' rewards for more sustainable living was further help to choose more sustainably.

For *governance* and *top-down/bottom-up*, it differs how closely independent projects connect with the city. The ASC project is described as an innovation platform, but since it is supported by the city government and bears the name of the city, even independent projects seem more closely associated with the "official". In many cities, there may very well be projects similar to those of Amsterdam, but without endorsement on a city webpage. In Amsterdam, this is made possible by the bottom-up approach that Amsterdam has chosen for its smart city project. However, it should be mentioned that "not government-based" does not automatically mean grassroots-based – it can also mean global companies.

In Seoul, we saw more active participation from the government in supporting sharing businesses as well as initiating sharing projects. In San Francisco, the sharing economy policy group focuses on how to formulate policies for a reality with sharing economy businesses, which do not always fit within older policy and legal frames. From an environmental perspective, this leads to different possibilities between the cities when it comes to mitigating the services and steer them towards environmental goals. On the other hand, we see no evidence that this would be central in either city's ambitions today.

V. Concluding Discussion and Lessons Learned

A. Lesson 1

In this paper, we have explored some promising Smart Sustainable Cities-initiatives and solutions when it comes to reducing negative environmental effects. A reflection after trolling the web for SSC initiatives is that there seems to be a multitude of solutions claiming to be SSC-oriented. The vast majority of them were excluded from this paper on the basis of its limitations (see section IIA) – many of them turned out to be either not ICT-based, or clearly lacking an explanation of their sustainability goal. Among the initiatives that were included, their sizes vary significantly – from large-scale smart grid trials to more specific solutions, such as applications.

Our approach lead us to a number of examples from major cities, but it is clear that it is not straightforward to quantify the actual environmental effects, or even to say if there is a positive or negative effect from them. In Amsterdam and San Francisco, for example, the parking finder service as described in section 3.1 has the potential to lessen emissions from circulating vehicles and prevent the building of new parking lots. On the other hand, the system risks leading to detrimental effects on car use, as it makes car use more convenient. The situation can be illustrated with a simple figure (see Figure 1), indicating that more or less any solution can end up as either positive or negative, even if the intended effect was positive.

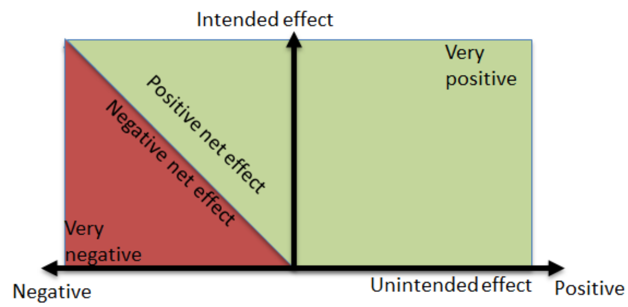

Fig. 1. Principle illustration of effects of SSC service. Here, the intentions of all services are positive, but there are also positive or negative unintended effects. If the unintended negative effects are greater than the intended effects, the total effect will be negative.

The net effect will be the sum of the intended and the unintended effects, so with a high negative unintended effect, the resulting net effect may be negative. Therefore, the solutions must not be evaluated only from what they are intended to achieve, but also from how they actually work in a real context.

Lesson 1: Net effects should be defined and evaluated, i.e. including indirect effects.

B. Lesson 2

Lesson 1 means that there are two ways to achieve positive net effects – to increase the intended effect and to reduce negative unintended effect. Both can be affected with policies. If a city has decided to support and facilitate ICT use for environmental-sustainability purposes, it should want to ensure to maximize positive environmental effect and minimize negative environmental effects and conflicts with other sustainability goals. To do this, the city can work with its support for SSC implementations and with regulations against negative countereffects. As part of its governance, the city can create a framework of incentives to drive the city service towards the upper-right corner and away from the lower-left corner in Figure 1.

The city can include high expected positive impact *and* low expected negative impact as criteria for choosing what services the municipality implements. Here, the San Francisco case of connecting environmental goals directly with ICT services is *promising*, although not quite what we suggest here. That is because it only focuses on what ICT services the city can make that directly serve their environmental goals, but no policies on how the city should connect its environmental goals with its work to be a smart city on a more general level. We have already seen that some cities are willing to formulate policies so that they fit sharing economy services, and presumably reduce resource use. This has been done for Seoul [45] and Amsterdam [48] and seems to be the point of the San Francisco sharing economy policy group, as described in section 3.2. The city should then ask that follow up evaluations show that the expectations are actually met. If not, they need to be adjusted accordingly. As an example, the previously mentioned Eco-Mileage system in Seoul counter rebound effects by giving "carrot" incentives for more sustainable consumption, in the form of coupons for things like public transport and local traditional markets. If no adjustment can be done to move the service out of the lower-left corner of figure 1, the city can choose not to support the implementation.

We have also seen that some of the more promising implementations of ICT involve less complex and new technology. While e.g. city sensors may perhaps come to have big impact in the future, one should not underestimate the strength of simpler mobile applications or webpages.

Lesson 2: When a city decides to work for becoming an SSC, they should ensure that the SSC services they support actually serve their purpose. Policies should be directed towards supporting intended effects AND counteracting negative effects.

C. Lesson 3

As previously mentioned, here we have not looked deeper into what political discussions that have foregone the cities' development plans. Therefore, many times we can only speculate in what has driven it. For example, as mentioned in the analysis we have not seen many initiatives to seriously decrease consumption of physical things by (partially) replacing them with digital solutions. We do not know why, but we imagine that the question of reduced consumption is politically complicated. Consumption of physical things is closely associated with perceived living standard [49] and may be an important part of the city's economy. At that, citizens' consumption of wares produced outside the city boundaries is not always included in the city's carbon emission calculations [2].

Furthermore, we have seen some signs of the cities possibly aiming towards bigger societal change, induced by ICT. We have however not seen e.g. plans for changed city structures because of decreased travelling due to telecommunications or reduced living spaces because the inhabitants needs less after having reduced their use of physical objects by replacing them with digital alternatives. The SSC definition we chose excludes many of the solutions cities define as part of their smart city development, e.g. efficient city planning but without any ICT connection. However, if cities plan for changing the physical structure of the city for real with respect to future structural changes due to ICT, that could be part of the smart sustainable city definition we use here.

Lesson 3: Further research and projects are needed on the relations between digitalized life, city planning and sustainability implications.

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