Smart City SRS

Summary of Phase 2 Findings and Results

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1. Executive Summary

The Smart City SRS integrated and analyzed data from city sectors, including energy, water, waste and transportation to provide realtime feedback to city planners, industries, organizations, and citizens, can generate new insights and support better decisions through awareness of their consequences. The project represented the joint collaboration effort of citizens, construction developers, waste, water, and energy utilities, as well as the city departments, to meet the vision of realtime feedback as outlined in the city's sustainability program for the Stockholm Royal Seaport.

Integrating Data Streams Towards Better Decisions

Vast amounts of data are already gathered throughout cities from sensors in buildings and roads to the city's utilities and departments. But the data is not used efficiently to support decisions that lead to sustainable development in the city. The Smart City SRS project aimed to bridge this gap by developing an open data integration platform coupled with realtime analytics and feedback processes. Towards this aim a prototype of an information platform was designed, developed, implemented, and validated.

The prototype can provide integrated feedback to questions like:

- Did our city reach our climate goals today? If not, why?
- How much better is my building portfolio performing compared to the others?
- It has been snowing this morning, what is the fastest way to get to work?

Sustainability Benefits

With a data infrastructure to coordinate city infrastructure and citizens, the district can use fewer resources to support its citizens. Businesses and citizens can move around more efficiently, and citizens can become empowered with relevant information to support their daily decisions. New insights can be derived from the causes and effects of everyday city dynamics, which in turn can lead to a more sustainable planning and development of the district.

Project Goals – Phase 3

The project is in its second phase where the aims is to prototype a solution and identify supporting business models. The third phase is aimed towards completion and commercialization, such as:

• Support the sustainable urban development process in the SRS

• Utilize realtime data from city sectors, including energy, water, waste, and transportation, to allow for smarter decisions and automation

• Provide feedback at the right time, at the right place for stakeholders and citizens, through visualization and augmented reality

• Continuous evaluation of city district goals stated in its sustainability program, ranging from fossil fuel free status to renewable energy share

• Develop new services and businesses that can support other cities

Realized R&D Outcomes in Current Phase (2 of 3)

Overall, the project has successfully reached its over-arching goals by designing, developing, and implementing a prototype, in participatory process with partners, residents, and end users, as well as identifying business model to support the platform:

• A smart city data platform capable of integrating heterogeneous data sources, analyze them, and feeding data back to stakeholders and citizens

• An integration of data streams on energy, transportation, waste, and water

• A calculation engine – the Smart Urban Metabolism Framework - that analyses the complex incoming data streams in realtime, and feed them back as key performance indicators such as ecological footprints, energy use intensities, and resource use. Based on the needs of the sustainability program and the project partners, four real-time KPIs were developed: CO2e/capita, kWh Primary Energy/capita, kWh/m2, and share of renewable energy.

• In-depth big data analytics on citywide waste and energy with substantial local policy implications towards sustainable urban development

• Feedback through dashboard visualization and smARt Viz - place-based augmented reality solutions

• The Smart City Marketplace – A new business model to support the data platform and future innovations

• Transportation simulation spin off to EIT ICT Labs funded technology development projects that will go into commercialization in 2015.

Other Outcomes

• Four awards

• 10 Peer-reviewed papers

• 1 KIC InnoEnergy European project course

• 1 PhD Dissertation

2. Project Summary

The work was distributed over eight work packages and is described in what follows.

WP 1 – The Business Development

The responsibility of this work package was to identify the new value chains the smart city creates in the actor network to subsequently develop business models that can support it. The work package was also responsible for identifying a Trusted Service Provider (TSP) that could own and operate the system.

Core Outputs:

- Concept and Market Analysis for Smart City Marketplace
- E3 Value Business Model Analysis Tool Predicting Probability of Business Profitability
- Criteria and Recommendations for Trusted Service Provider
- Scientific Publications

WP2 – System Integration

This work package identified the system requirements for the entire system. Then it developed a prototype that exposed the interface / API for data collection from energy, water and waste, and transportation systems. A large part of the development was agile with mockups along to allow project partners to influence the development during the project.

Core Outputs:

- Integration Platform
- External APIs
- Smart City SRS Dashboard[1]

WP 3 –Calculation Engine and Feedback Processes

This work package developed a model that gave a systems-based approach to compute flows in the district on the basis of urban data streams. These were transformed into key performance indicators (KPIs) for relevant feedback processes to stakeholders (users, developers, property owners, infrastructure companies, administrations, etc.). The indicators and metrics developed in communication with relevant partners and the city. The work package also developed a smart city dashboard and made an experiment with integrating social sustainability data into it. The work package also did a series of in-depth big data analytics on energy and waste to innovate for new local policies.

Core Outputs:

- Smart Urban Metabolism (SUM) Framework
- SUM Data Model
- SUM Algorithms and Key Performance Indicators
- SUM Big Data Analytics Waste Study and Energy Study
- Smart City SRS Dashboard
- Scientific Publications

WP 4-5 Energy, Water and Waste

These work packages consisted of so called “problem owners” (i.e. challenges related to their everyday businesses and infrastructure), and data owners. They contributed with the essential know-how and subject matter expertise to support strategy development on solutions that could aid their organization or society at large. They also provided technical assistance on providing data integrations to the integration platform.

Core Outputs:

- Sector-specific challenges and research questions
- Data mapping
- Data integrations and API-testing

WP 6 – Transportation

KTH CTS that conducts nationally leading research and development on transportation led this work package. They were both data “owners” in so far that they managed GPS data for thousands of Taxis in Stockholm, as well as recording massive amounts of publication transportation data from SL. Furthermore, they are a solution provider in terms of integrative transportation simulation for planning and design.

[1] http://www.srsdashboard.falcoprofil.com/SRSnewUI/

Core Outputs:

- Transportation data inventory
- SL transportation database
- Simulation demonstration for KTH Campus
- Advanced agent-based model that integrates several data sources and visualized in an interactive game engine for interactive planning, to be commercialized in 2015

WP 7 – Follow-up of Environmental Targets

Led by the Development Administration, this work package focused on connecting the KPIs and feedback to the sustainability targets of the Stockholm Royal Seaport, both with regards to the sustainability program, as well as with regards to the phase-based control plans.

Core Outputs:

- Sustainability target breakdowns
- Coordination towards sustainability plans
- Communication with other city departments and SRS Innovation

WP 8 – Visualization

The focus of this work pacakge was the visualization of sustainability data in public places using Augmented Reality. The aim is simplify decisions, raise awareness, and provide the ability to for comparisons with the collective by visualizing the smart city data in public places. The designs were developed in a participatory design process with partners and representatives of the residents, and based on this; the prototype was developed and implemented in a live environment.

Core Outputs:

- Prototype demonstration (in bad weather conditions) using real live data and 3D SLAM technology (Simultaneous localization and mapping)
- Development of Augmented Reality Concept App for Buildings in SRS

3. Test and Evaluation of Systems

To establish a path towards “realizing the vision of the sustainability program” a series of partner workshops and meetings were held to determine the key performance indicators (KPIs) that would be the initial focus of the study. These were:

1. CO2e/cap
2. kWh Primary Energy/cap
3. kWh/m2
4. % renewable energy

These are supported by roughly 25 heterogeneous real-time data sources. The prototype was tested and evaluated with a specific scope of the residential neighborhood called ”Garphyttan” in the Stockholm Royal Seaport. While some data sources are national, regional, and citywide, all the apartment and building level data all came Garphyttan. The neighborhood consists of 324 entries (an entry is defined as block, property, building, entrance,

apartment, etc.), which includes 287 apartments, containing 2,297 data feeds (meters). Of these, an agreement to stream live, anonymized data on apartment level data was reached for two buildings with 40 apartments. The KPIs were successfully implemented in the calculation engine and their outputs validated with spreadsheet calculations. Based on these KPIs, the smARt Viz solution was deployed in Garphyttan and successfully implemented with SLAM Augmented Reality SLAM technology.

Augmented Reality Testing

A workshop with end-users was held with the Hammarby Sjöstad community. The goal was to identify needs, motivations and incentives for sustainable practices. The workshop resulted in a list of insights that would later be used to guide the design of the concept services. Guiding insights included functionality, aesthetics and sender of the service to name a few. This resulted in a demonstration of the technology by connecting real time sensor data that interacted with AR content was carried out by Interactive Institute, Greenelizer, IBM and Metaio.

An early AR prototype demonstrated consumption of the garbage chutes found in SRS near Högviltsgatan (see appendix). For the proof-of-concept, a simulation database for waste handling was developed. In this demonstration the stability and readability of Augmented Reality was tested by using simple bar graphs representing the amount of waste recycled from the apartments. At the end of the project another AR demonstration illustrated energy consumption, production, waste generation, and greenhouse gas generation of the building at the same location in Garphyttan. This visualization included comparisons to the neighborhood average. The following steps were taken to conclude the prototype cycle, from idea to demo-product.

- Target group analysis
- Three target group scenarios
- Test evaluation of concept with a paper prototype in a workshop in Hammarby Sjöstad
- Proof of concept - demonstrating a rudimentary platform connecting dummy data with end user visualization. This demo was tested on waste .
- Prototype demonstration (also in bad weather conditions) using live real-time data and 3D SLAM technology (simultaneous localization and mapping)

Evaluated solutions/ products:

- AR technology - Creator Software from Metaio.
- 2D and 3D tracking solutions of objects
- (2d - Markers, 3d - Point cloud, SLAM & EDGE)
- AR content, video, graphics, 3d models

Business Models and Value Chains

The project started with step 1, scoping up, during which information from a wide selection of sources was collected. These sources were a literature review, interviews and workshops with project members, also international courses and workshops. During step 2, scoping down, the most important requirements, ideas and trends that corresponded to the purpose of the project were identified. During step 3, an analysis framework was created that was used in step 4 for detailing and analyzing. The results of step 3 are formalized as conference and journal papers. In Step 5 the trusted service provider problem in the light of all the gathered data. The data used for creating the business models comes from interviews, workshops, conference visits and smart city literature.

The Smart City Marketplace (SCM)

Of all the business models, the one that stood out was the Smart City Marketplace. An inefficient economic sector was identified that covers local, small transactions between citizen, companies and the public sector. Inefficiencies are due to excessive transaction costs in relation to the transaction size. A related problem is the need for an intermediary for risk reduction for these transactions and resource management. We see that the new technology can solve the problems in four ways:

(a) A considerable transaction cost can be attributed to geographical distance. Small transactions like renting or sharing would become too expensive if the buyer and seller are at a too great a distance from each other. The positioning services offered by smart phones make it possible to detect when buyers and sellers are geographically close to each other.

(b) The inconvenience that transferring small sums between potential buyers and sellers involves, creates transaction costs. This is especially true if the buyer and seller are strangers to each other. It is complicated to pay for a ride to work or for help of cleaning the driveway. Firstly, there's negotiation involved, secondly, who guarantees that the service is completed with sufficient quality, or the money is paid after the work has been completed, and thirdly one must have the exact amount of cash available. With modern technology, these obstacles can be dramatically reduced.

(c) It can be intimidating to do business with strangers. Many feel uncomfortable with sitting into a stranger's car, for example. With a feedback system, where buyers and sellers leave their experiences, trust can be established even between parties who didn't know each other previously. For example, eBay uses such a system to successfully create trust between buyers and sellers on different continents.

(d) The status of public resources that are available for entrepreneurs to digitally include in their services, needs to be managed centrally in real time. For example, if there were to be more than one company helping to provide a parking service in a city, then each of them would need to know and change the state of the parking place they are selling.

The conclusion of the studies is that the discussed new technology should be made available to all participants such as entrepreneurs as a platform of common services that addresses the aforementioned four problems. The reason to choose platform architecture is to have a balance between common services and flexible customization. A value network model of the Smart City Marketplace can be seen in the Appendix. The business evaluation of the Smart City Marketplace was that there is a relatively high probability of failure if deployment is only limited to Stockholm. However, if aimed at a global market, then 74.1 % of the revenues fall on the positive side in the E3 business modeling.

Transportation Data Evaluation and Testing – WP6

Within WP6, the ambition was to go beyond using data from one source, and instead work on a data fusion from multiple API's of transport operators. With this data, simulation models have been set up, as well as an automatically generated interactive environment in which both historic data and simulations for future scenarios can be visualized. By adding game-like interaction modes to this environment, it becomes possible for decision-makers to play with scenarios for the transportation options based upon large data sets. This has resulted in an interesting new set of technologies, and spun off in EIT ICT Labs funded technology development projects that will go into commercialization in 2015.

4. Identified Barriers and Opportunities for Wide-Spread Use

This chapter delineates the key challenges and solutions that were managed within the project, and then expands to general barriers that need to be resolved for a long-term successful deployment.

Key Challenges and Solutions that were Managed within the Project

In short, the project as a whole came across six key challenges and had to identify six innovative solutions to address them. Beyond that there were additional work package-specific challenges that are also described further below.

Challenge 1: [Our partners' business developing units are wondering:] What is our deal in this? What do we earn on integrating our data into a single system?

Solution 1: The Magic Hat
We made the following proposal that business developers could agree on: "During the project period, put all your data in our magic hat so we can do a hands-on evaluation to identify if there are good use cases and business models to base the concepts on. If there are, then you can do business development from that and leave your data there, and if not, you can take back your data your data after the R&D project. This is a paradigm shift in approach for many smart city solutions. As opposed to traditional work, many of the potential socio-economic benefits do not arise until the isolated, heterogeneous city sectors/verticals have been connected and integrated, after which new understandings of city dynamics can arise, and after which opportunities and predictions of new interventions and thereby business opportunities can arise.

Challenge 2: Our partners are about to connect their different (legacy systems) with very different data quality and connection methods, how can we intelligently integrate everybody into the same environment?

Solution 2: SRS Integration Platform
Built on open standards (SOAP, REST, FTP, ODBC) was designed and implemented. It is compatible with an industry-standard (fi2xml) and becomes more generic for each new integration.

Challenge 3: The data starts flowing to the integration platform, but how do to store / organize / and structure it?

Solution 3: Smart Urban Metabolism Data Model
There are some existing city related ontologies from e.g. Open Street Map and Lantmäteriet, but they were not sufficient for our purposes, therefore, a generic data model was developed, that is compatible with the existing ontologies, and at the same time allows for the complex KPI calculations that are needed. To do this, our data modeler spent substantial time and effort with a long list questions to the consortia to develop a robust data model that could hold for all the use cases the consortia had identified.

Challenge 4: As structured real-time data starts flowing, how is it transformed into the four KPIs (selected by the consortia to reflect the SRS sustainability program) in real time?

Solution 4: Smart Urban Metabolism Calculation Engine
A modular, flexible calculation engine that delivers the four KPIs, and comparative metrics in real-time from a scientific systems perspective that has been peer-reviewed by leading experts.

Challenge 5: None of the back-end, data modeling, and KPIs have any value unless it can be fed back and visualized to stakeholders in an intuitive way, how should we provide appropriate feedback from this? Furthermore, citizens of the SRS responded that they are not interested in the KPIs "on their walls" unless we integrate those KPIs into a greater context that relates to their daily lives.

Solution 5: smARt Viz, Building Follow-up App, and Smart City SRS Dashboard
The Interactive Institute and Greenelizer developed two augment reality solutions. One for household feedback on waste generation and one for building level feedback for construction professionals, architects, and city officials. KTH developed a simple app for monitoring target achievement of buildings for city officials. KTH and IBM developed a citizen dashboard that integrates 30 real-time data feeds to support citizens with daily decisions.

Challenge 6: There seems to be many socio-economic and sustainability benefits to these results, but what business models can support this infrastructure?
Solution 6: Smart City Marketplace and City Communication Platform. Many business opportunities were identified by WP1. The core business model that was identified, is a platform called the Smart City Marketplace that allows for the exchange of data and services, between stakeholders and citizens. The exchanges are either free, or enabled by ”hyper local” micro-transactions.

A parallel Vinnova project ”Sjöstaden i mobilen” also identified a different (and compatible) business model that covers all the basic information and communication needs of citizens, funded by local advertisement of local shops. Both these business strategies are considered for further development. Smart cities have been scrutinized for their top-down, industry-pushed, centralized approach, leading to polarized and socially exclusive communities. The prototypes and results from Smart City SRS could help steer smart cities in a more inclusive and substantiated direction.

Opportunity: Vision for the Environmental Sustainability the Stockholm Royal Seaport

Given the complexities associated with sustainable urban development, it is befitting to share a more tangible vision of the fruition of how the results from the Smart City SRS project could be further deployed in the SRS. The vision is that anyone in the city, based on the results framework, is able (and arguably has the right) to receive real-time feedback on the system consequences of his or her own decisions. These consequences include local and global environmental impacts, as well as economic and social consequences. This vision is hinting a data-driven and data-intensive sustainable urban development process. The benefits of such a process can be realized at all levels of society. Smart cities that are developed as citizen-centric (bottom-up smart cities, grass-root smart cities), put high hopes in how transparent data, and feedback can empower citizens to become more informed, aware, and influential in the sustainable urban development process.

Barrier: Data and Trust

The project has been able to deliver on most of its promises. Given this, what would be its barriers to widespread adaptation? Without knowing much about what the future will hold, what is certain is that the coming decade the pioneers that adapt similar methodologies require a significant coordinated effort by local triple helix partnerships that make an effort to collaborate in somewhat unorthodox ways. This is especially true for the data owners, whom are the key enabling stakeholders. Making business data available to joint R&D projects, no matter how strong agreements and security measures, requires a significant amount of trust among the consortia. The experience from this study is that this trust can be built by galvanizing partners towards a common vision and work with the partners to identify their roles towards meeting vision.

Barrier: Steep Learning Curves

A strong vision both helps build trust as well as overcoming the second barrier, which is the potentially steep learning curve that these might become for partners. Overcoming the learning curve is of importance for project members to communicate the needs to their organizations. It is one thing to believe in an idea, and another to understand its benefits and being able to make a case for them in the internal organization.

Barrier: Unclear Business Opportunities

The last barrier is that of market value. All business strategist and CEO’s have an obligation to their businesses to question how taking a risk (in time and effort) might affect the bottom line. This is both tricky and hard. The business potential is there, but it is not always clear how and when a profit can be made. Perhaps overly simplified, all of the sustainability benefits related to smart urban metabolism, can in one way described as

efficiencies (except the social sustainability benefits), by better and more informed decisions made by people or machines. Wherever there is an efficiency to be gained, a business model should be hiding nearby. For instance, if there is a water leakage which leads to € 1M losses a year, a sensor solution to identify where these leaks occurs and send notifications to fix them, is worth something and could be sold. In theory, that might make sense, but in practice, a working business model requires much more than efficiency to be gained, in particular for Smart Urban Metabolism, where the currency is data. In particular since the majority of the benefits, efficiencies, and insights will be developed in a more distant future. Therefore, the Smart City SRS invested substantial focus into understanding the value chains (Webb et al. 2011) and business models associated with these type of smart city solutions. A core business model, a Smart City Marketplace was designed, in which stakeholders could buy and sell, give and take, services and data on a platform, based on micro-transactions. That could, at least in theory, allow data owners to profit if their data is leading to socio-economic benefits in society. This will be evaluated in the years to come.

Barrier: Privacy

The massive amounts of data in the Smart Urban Metabolism framework triggers questions about privacy and personal integrity. This should however not discourage professionals and researchers to pursue it with the intention of achieving sustainability outcomes. Privacy and personal data integrity might be one of the largest challenges of the 21st century. Whether Smart Urban Metabolism and other "smart city" solutions are implemented or not, the concerns about privacy are just as real. Therefore, it is perhaps not a bad thing that sustainability professionals start managing sensitive data, as their presence might lead more of them to opt becoming a part of the solution as opposed to becoming a part of the problem. In short, the privacy challenge goes far beyond the scope of this study, but future smart urban metabolism projects should however actively seek to manage sensitive data with the latest best practices developed by privacy engineers.

Barrier: Transportation Data

With regards to the data owned by Trafikverket and Trafikstyrelsen, the project was met a positive attitude, especially from Trafikverket, Trafik Stockholm and Trafikförvaltningen of Stockholm Stad, who jointly operate one data storage structure. We now know exactly what data resides where and how we could use it. But getting access to it is a bit harder. There is a research agreement between KTH and Trafikverket through which a lot of data is pushed to KTH. But this data is of such low level of aggregation that it requires real-time massive processing capabilities to do something with it that is useful for apps or other services. This is where new technologies like Apache STORM and IBM's Infosphere come into play. Setting up such potential is feasible in projects of the order of magnitude of 10 – 20 the size of the current project.

Getting access to this data for an individual project or company does not seem possible, and Trafikverket has made it clear that they currently do not consider themselves as a data provider to companies directly. This hints at a new service layer that is needed here.

Barriers and Opportunities: Augmented Reality

One of the goals for the visualization of the information platform was to design an information environment that openly, and interactively can present this type of information, in a way that it awakens the users engagement. WP8 aimed to make the information as open to the public as possible. The logic was that if the public can visually connect to the ecological footprint caused by behaviors and lifestyle, it could lead to a deeper understanding of sustainability aspects, and at the same time benefit social sustainability and democracy. One challenge was to communicate this information without the need of expensive infrastructure, such as screens and infrastructure.

In order to distinguish what type of technologies that would be used for this, a series of workshops with citizens of Hammarby Sjöstad was held. This provided a deeper insight in daily routines and behavioral patterns that was needed in order to map possible solutions. One key finding was that mobile solutions were already an important aspect in lives of most people and currently 87% of the market have adapted smart phone. This led to the idea of combining new mobile technology with real time sustainability feedback, where the information can either be situated central or distributed over the city, using facades, parks and other outdoor areas, providing valuable feedback at the right location at the right time.

General strengths of Augmented Reality

The strength of AR is that it can display content in the right place at the right time. Content can be displayed on/over the objects it concerns. A good example is the AR version of a user manual. With the AR technology users can see animated maintenance instructions visualized on the product they are fixing. This intuitive connection between context and content offers added value to the user. Service content can now be presented in a way that is better for the user.

There are also possibilities within the technology to facilitate universal/inclusive design solutions. The way AR works by identifying and tracking objects means it needs less instruction from the users to provide desired information. Content can provide good user experience for a broader range of users. AR content can cover larger age groups, cognitive abilities, languages differences and difference in the users physical abilities. The reduced need for physical products is another aspect of AR that may contribute towards a more sustainable future. Any surface that show dynamic content like monitors or projections can in theory be replaced with AR.

Possible Threats

One concern with AR as it becomes mainstream is the question of platform and content ownership. What platform should developers focus on? Today Metaio Gmb is one of the world leading AR content providers but that may change over time, in particular as Google is a strong contender in AR.

An AR app demands a lot of smart phone resources, therefore the battery, as well as the processor chip is a crucial performance factor. Due to the chipset performance some platforms run unstable when tracking AR. Camera capacity can also effect tracking performance in poor lighting and bad weather conditions.

5. Deep Knowledge of End-users, Requirements, Customers, Markets

Similar National and International Initiatives

In the table that follows, the most promising identified projects and initiatives are presented. It should be mentioned that Grow Smarter is both National and International, as it is led by the City of Stockholm and has Årsta and Globen that constitute one node, complemented by nodes in Cologne and Barcelona. In addition to these, there is also a Strategic Innovation Agenda being developed by KTH and multiple other stakeholders for ”Smart Sustainable Cities”.

National	International
SRS – Urban Smart Grid http://stockholmroyalseaport.com/en/rd-projects/urban-smart-grid	**EU Horizon 2020 Lighthouse: Grow Smarter** http://www.stockholm.se/Fristaende-webbplatser/Fackforvaltningssajter/Fastighetskontoret/Hallbara-fastigheter/EU-projekt-GrowSmarter/
HS2020 – Att förnya en ny stad http://hs2020.se/	**Apern+ Viennas Urban Lakeside** http://www.aspern-seestadt.at/

Malmo Western Harbor	**Smart Glasgow**
http://www.fi-ware.org/2014/11/12/smart-cities-fiware-in-malmo-sweden/ http://malmo.se/Stadsplanering--trafik/Stadsplanering--visioner/Utbyggnadsomraden/Vastra-Hamnen-.html	http://www.ft.com/cms/s/0/d119ac06-e57e-11e3-a7f5-00144feabdc0.html#axzz3K9fsIpts

Understanding of End-Users

Smart City SRS is platform-based and has multiple providers of data and services, and multiple end-users. It can address issues of city infrastructure by enabling two-way streams of real-time data to infrastructure organizations such as the energy utiltiy, the waste utilities, the water utilities, and the road utilities. Multiple of benefits, efficiencies, and arguably business opportunities have been identified during the course of the project. In such a case, the city and publicly owned companies might be the end user to focus most on. Organizations and building owners all have a stake in reducing operational costs, and to the extent that Smart Urban Metabolism can identify inefficiencies and propose interventions, it arguably has a business opportunity.

During a workshop about what KPIs the partner would like to have, there were four KPIs that were in highest demand from the project partners. One of the KPIs that caused a bit more debate was that of Primary Energy, some partners were in favor of it since it favored their systems, and other partners were against it for the same reason. A key lesson from this was that the KPIs should be stakeholder specific while still remaining scientifically sound so that each partner can derive benefit, while also providing citizens with a dashboard that is intended more as a "public service", that aims to provide all the different angles so that citizens can make up their own mind.

The following table summarizes the current understanding of the three main end-users.

	Understood Interest in Sustainability Feedback by Dialogues with Partners and Citizens	**Barriers**	**Opportunity**
City	High – All cities have sustainability targets that have to be monitored and cities currently do not have strong data-driven tools to support local policies	1. **City-wide solutions for multiple departments** City responsibilities and budgets are siloed into different departments and despite strong leadership in Stockholm to overcome these barriers in SRS, this still poses a barrier for implementing solutions that span multiple departments. 2. **Learning curve and chains of command.** The solutions proposed are still quite new and are associated with a relatively steep learning curve. Getting consensus along the chains of command in cities can be challenging.	There are tremendous efficiencies to be gained in cities if the cities work intentively on smart city solutions towards sustainable urban development. In particular, the City of Stockholm has made significant organizational efforts within departments as well as citywide. One of the many outcomes of this has been the achievement of the Horizon 2020 Lighthouse "Grow Smarter" project.
Building owner	Medium – As long as it results in lowered	**Existing Market** There is already an existing market on	Individual housing cooperation's are generally

	operational costs or increases in property value.	intelligent building portfolio management, so where there is added value from this project, this could lead collaborations with the existing market.	left out of the existing markets for practical reasons and might be a good starting point for future business development.
Citizen	Low – Unless it is put in a larger context that creates a significant daily benefit. It should be pointed out that no in-depth behavioral study was conducted on this conclusion; this was feedback from workshops with residents in SRS. This statement may therefore not be generalizable.	Environmental scientists and professionals often talk about "sustainable behavior change" with a fairly narrow perspective. One key lesson from the project was that there needs to be a sense of humility and understanding that for most citizens, environmental issues may only account for a very small fraction of their every day consciousness. Citizens have many other concerns relating to family, health, work, economy to name a few, and therefore, if sustainability feedback is to be effective, it should preferably be set into a larger context, or at least be contextually appropriate.	While the citizens have expressed the lowest interest in the sustainability feedback, they constitute the largest opportunity for sustainable urban development. With this deeper understanding of the needs of citizens that came out of the project, there is a tremendous opportunity to empower citizens. The ideas generated from the Smart City Marketplace and the mobile platform "Sjöstaden i mobilen" embody those opportunities.

Citizen Feedback on Visualization

To gain knowledge about end-users a series of workshops were held with citizens from the Hammarby Sjöstad district as well as new residents in SRS. The workshops started with a presentation of three user journeys involving new concept services, which would contribute to a more sustainable area. Participants were then asked to reflect and give feedback. The key insights on the citizens desired characteristics in a sustainability promoting service are listed here:

- Comparability. Users should be able to compare themselves to neighbors and set goals
- Confirmation of impact. Users should be able to get feedback on the results of their changed patterns and behaviors.
- The graphs should have a desirable aesthetic design.
- Users should not be singled out and get negative attention.
- Economic feedback. Reducing energy bills was often mentioned as an incentive.
- Customized tips and recommendations for how to improve by reducing consumption.
- No big large tech-company to maintain their data and service, more trust was given to an environmental organization or the city.

Quotes from Workshops

- "It would be interesting with setting alternatives up against each other. Public transport, versus weather for instance. The economic incitement is indeed important. Connect benefits of energy saving to saved pennies."
- "Translate reduction in energy consumption into something tangible the user can understand."
- "You feel better if you know you can influence your own situation."
- "Changes in behavior to reduce energy consumption should manifest itself and confirm for the user that that they do really have had an impact."
- "Economy is a key area"

How would it make you feel to live in an interactive area where your buildings energy consumption would be available to everyone?

- "If it had good stats, it would make me proud, if not ashamed"
- "It is a big step forward"
- "Nobody wants to go first (in reference to visualizing energy consumption publicly)"

Business Requirements of the Smart City Marketplace
WP1 identified several needs, but most the important ones are listed below. We see the solution to those needs as a service built on top of the Smart City Marketplace platform.

1. Need to optimize office and living space usage and accommodation for visitors.
WP1 suggestion is a service like Airbnb, but for office and public places as well. The aim is to enable office and apartment owners to rent out their places when not used to others in need.

2. Need to optimize parking space usage.
WP1 suggestion is a service like a Streetline, a way to see in real time which parking places are in use and which are not. The city will get real time data and analytics for future decisions.

3. Need to optimize people's behavior towards environmental and social sustainability.
WP1 suggestion is a service like GymPact, but with a focus to CO2 usage. A service, where users can bet on their own behavior to change their consumption towards reducing their CO2 footprint. If they fulfill their goals, they earn money, if not, they lose money and that money is shared between those who were successful.

4. Need to meet the transportation needs of the growing population.
WP1 suggestion is to set up a local ridesharing service, like Carpooling.com or Lyft. The drivers that have free places in their car can cover their expenses, while sharing reduces the transportation needs of the population.

The list of possible service is by no means complete. There are other possibilities like sharing cars, sporting equipment, or reusing furniture and clothes. The role of the platform is to help to create such businesses, while an entrepreneur must come up with an idea and take the actual risk of starting the business.

6. Developed Utilization and Communication Plan

The project has been published in the City of Stockholm's SRS Innovation website[2] as well as in SRS Innovation brochures and events. The project has been showcased for a large number of international delegations, and presented in a multitude of international conferences and workshops. The project outcomes have identified new intervention measures and are being used to inform and support the development of new policies on waste and energy in the City of Stockholm and are being used in new R&D applications. The project is also being included Hammarby Sjöstad 2.0 Export Platform (also known as ElecTriCity). The prototype of the project will be used for evaluation and pilot testing in the Horizon 2020 Grow Smarter project in Årsta and Globen. The project has been used as a basis for 30 student projects and master theses.

Smart City SRS Societal Benefits and External Communication Plan:

- Identified interventions for Local Waste Policies
- Identifeid interventions for Local Energy Policies
- Integrated with EU H2020 Grow Smarter
- Recognitions, awards by thought leaders and scientific communities
- Scientific publications
- New national and international R&D projects based on findings
- Showcase for international delegations at SRS Innovation
- Showcase in Hammarby Sjötad 2.0 Export Platform

Mandatory Part of KIC InnoEnergy Smart Cities Master Program

[2] http://stockholmroyalseaport.com/en/rd-projects/smart-city-srs

Diffusion of Results and Scientific Outputs

Four awards

- HomeBit – Hackathon at Urban Prototyping Festival London 2013
- Best KIC InnoEnergy Master Thesis Award – Smart City Innovation – Smart City SRS Dashboard – Wim Ector
- Best KIC InnoEnergy Master Thesis Award – Scientific Contribution – Big Data Analytics toward a Retrofitting Plan for the City of Stockholm – Bram van der Heijde
- 1st Prize Vattenfall Thesis Award 2014 – KTH Energy Dialogue

Papers – WP3 – Smart Urban Metabolism Framework

Shahrokni, H; Brandt, N., 2013. Making Sense of Smart City Sensors, *Urban and Regional Data Management: UDMS Annual 2013, CRC Press, Taylor and Francis, Norwich, United Kingdom.*

Shahrokni, H; Lazarevic, D.; Brandt, N., 2014. Smart Urban Metabolism: Toward a Real-time Understanding of the Energy and Material Flows of City and its Citizens. *Submitted to the Journal of Urban Technology*., New London, NH, USA.

Shahrokni, H; Levihn, F.; Brandt, N., 2014. Big Meter Data Analysis of the Energy Efficiency Potential in Stockholm's Building Stock*, Journal of Energy and Buildings*

Shahrokni, H., Van der Heijde, B., Lazarevic, D., & Brandt, N. (2014). Big Data GIS Analytics Towards Efficient Waste Management in Stockholm. In Proceedings of the 2014 conference ICT for Sustainability (pp. 140-147).

Shahrokni, H; Årman, L; Lazarevic, D; Nilsson; A.; Brandt, N., 2014. Implementing Smart Urban Metabolism in Stockholm Royal Seaport – Smart City SRS. *Journal of Industrial Ecology*

Papers – WP1 – Smart City Marketplace

Johnson, P., Iacob, M. E., Välja, M., van Sinderen, M., Magnusson, C., & Ladhe, T. (2014). A method for predicting the probability of business network profitability. Information Systems and e-Business Management, 1-27.

Valja, M., Osterlind, M., Iacob, M. E., van Sinderen, M., & Johnson, P. (2013, September). Modeling and prediction of monetary and non-monetary business values. In Enterprise Distributed Object Computing Conference (EDOC), 2013 17th IEEE International (pp. 153-158). IEEE.

Osterlind, M., Johnson, P., Karnati, K., Lagerstrom, R., & Valja, M. (2013, September). Enterprise architecture evaluation using utility theory. In Enterprise Distributed Object Computing Conference Workshops (EDOCW), 2013 17th IEEE International (pp. 347-351). IEEE.

Johnson, P., Iacob, M. E., Välja, M., van Sinderen, M., Magnusson, C., & Ladhe, T. (2013). Business model risk analysis: predicting the probability of business network profitability. In Enterprise Interoperability (pp. 118-130). Springer Berlin Heidelberg.

Ullberg, J., Lagerström, R., van Sinderen, M., & Johnson, P. (2012). Architecture modeling for interoperability analysis on the future Internet. Enterprise Interoperability: I-ESA'12 Proceedings, 111-117.

• Course:

International course: Smart Cities and Climate Change MJ2685/MJ2686, 7.5 ECTS – Mandatory, project based course for all students accepted to the competitive KIC InnoEnergy Smart Cities program. The projects are based on needs arose by the consortia in the Smart City SRS project. The students have made significant contributions

• Dissertations:

Shahrokni. H, (Early 2015) Smart Urban Metabolism –Toward a New Understanding of Causalities in Smart Cities

7. Development and Changes in Project Consortium

The consortium was transformed in a few key aspects. The most significant partner that was not included was the building sensor company that NCC and HSB used, Infometric. For multiple reasons, accessing correct data from existing partners was not feasible. For instance, other buildings as well as the construction site, making it difficult to use for feedback, shared the district heating sensors that were available to the project. In this case, Infometric had sub-metered the buildings and were able to supply key data to the project. A number of other data or service providers, not initially anticipated, also joined the project under specific agreements. These include Trafikverket, Nordic Electricity Grid, Naturhistoriska Riksmuseet, and 46elks. Furthermore, due to a recommendation from the work package leaders, the scope was limited to the block of ”Garphyttan”. Therefore, partners not active in this block were less active in the project. However, in the case of Byggvesta, a separate trial on demand-response was run in another development project outside SRS. The project strongly relied on strong partnerships and relations in the consortia which one of the project’s success factors. At the same time, it made the project outcome dependent on the presence and empowerment of partner representatives. In this phase, the partners successfully developed a prototype, for the next phase, the consortia would need to shift to a stronger focus on development and implementation.

8. Lessons Learned and Experiences from Unfulfilled Goals

While much progress was made on understanding value chains and business models, it still continued to be one of the main barriers for progression. Another key project barrier was data access. Having high level partner agreements on data integration and a vision to along with that led the partners to a project, but actually getting data required substantial work and negotiation with business developers and IT-departments, as that had not been included in the project application. Furthermore, legal limitations on privacy and data management provided additional barriers that had not been planned for.

The project vision was ambitious and by necessity, included many partners. Therefor it took substantial work to get a project consensus on the shared vision, and even more time translate that into the roles and actions that aligned to the stakes of each partner.

Another problem was that IT-departments at each partner and software developers were far away from each other. Since many of the IT-departments had not been a part of the original application, they had other priorities and supported the projects in between other tasks related to their core business. This resulted into a delayed development process where each step in the development and data integration could take weeks, as most communication was done by email. As a response to this, a new work stream was included called “The Data Hunt” that actively pursued the data integrations, and key software developer days/weekends, where the software developers came together for concentrated work. The outputs of these sessions where all software developer gathered into the same for a day were very successful.

9. Measureable Results and Deliverables

The project was based on the following activities, these numbers were estimated ex post facto in dialogue with partners and based on project plans.

Input	*Process*	*Output*
25 000 hours of labor	*4 Large Partner meetings* *35 workshops* *10 hack days / half days* *10 international conferences* *Continuous project management and steering group meetings* *Continuous presentations to international delegations visiting SRS*	*Met all project deliverables in the project management system summary (PMSS) except the envisioned inclusion of transportation data (see project summary)* *Designed, developed, validated, and implemented prototypes* *3 international awards* *1 national award* *10 peer-reviewed papers* *Increased know-how, expertise, skills within consortia* *Strengthened abilities to work in triple helix constellations*

10. Appendices

Appendix 1 - Summarizing Article: Implementing Smart Urban Metabolism in the Stockholm Royal Seaport -Smart City SRS

Appendix 2 – Infographic – Smart Urban Metabolism Framework

Appendix 3 – System Integration and System Architecture

Appendix 4 – smARt Viz Including: Posters, Short Movies, and Workshop Summaries

Appendix 5 – Smart City Marketplace