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DEMONSTRATE · DISSEMINATE · REPLICATE

D6.2 Smart City Framework

WP6, Task 6.6

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IV. List of Abbreviations

API	Application Programming Interface
DSR	Demand Side Response
EIN	Eindhoven
EU	European Union
FC	Follower City
FCIS	Follower City Implementation Strategy
FCTM	Follower City Training Mission
Fhg	Fraunhofer Research Society
FOKUS	Institute for Open Communication Systems
GA	General Assembly
KPI	Key Performance Indicator
IAO	Institute for Industrial Engineering
IAT	Institute of Human Factors and Technology Management
ICT	Information and Communication Technology
IoT	Internet of Things
LC	Lighthouse City
MAN	Manchester
SCIS	Smart City Implementation Strategy
SCC1	Smart Cities and Communities lighthouse projects
SME	Small and Medium Enterprise
STA	Stavanger
WB	Webinar
WP	Work Package
WS	Workshop

0. Executive Summary

The current deliverable is called "D6.2 Smart City Framework" and is part of Work Package six (WP6) of the same name. It is the distinct outcome of Task 6.6 which summarizes the outcomes of Task 6.1 Adaptation of Approach and Methodology, Task 6.2 ICT Reference Architecture, Task 6.4 On-site assessment in Lighthouse Cities, Task 6.5 On-site assessment in Follower Cities, Task 6.8 Second on-site assessment in Lighthouse Cities and Task 6.9 Training mission to the Follower Cities. In addition it directly supports Task 6.7 Development of Follower City Implementation Plans by providing guidance and support to the Follower Cities through the framework. The tasks have been fulfilled in strong cooperation with WP2 to ensure consistency between monitoring and replication.

The goals of WP6 in Triangulum are to streamline ICT integration between all three Lighthouse Cities (LCs); to design a Replication Framework and a Smart City Decision making tool for Smart City Project development and implementation; and to apply parts of this framework for accelerating the replication of successful solutions within the Follower Cities (FCs) and beyond. By this, the aim is to speed up planning and implementation and optimise the design, transformation and monitoring of Smart City implementation projects. The methodology and approach applied here is consistent with the framework developed by Fraunhofer within the "Morgenstadt" project.

The framework consists of following building blocks:

- **Replication Approach:** It is structured two-ways. On the one hand, a process to structure the learnings within the LCs and provide it to entities that want to replicate, the so called "technology transfer approach" and in the other hand, the "customer centric approach", which supports the FCs in developing their own customized Implementation Strategies.
- **Use Cases as replication units:** A Use Case focusses on using a technology to reach specific goals in a defined context or setting. A particular Use Case would have various supporting factors which enabled its implementation in this specific setting. When replicating the Use Case, another city or organization could reproduce similar supporting factors for their local context or consider the different impacts that the replication would have in the absence of these factors.
- **Overview of Triangulum Use Cases:** The core outcome of the technology transfer approach are the actual replication relevant information gathered for each Triangulum Use Case. All together 57 Use Cases were financed by and are being implemented within the project Triangulum.
- **Smart City Decision making tool:** enables cities across Europe to find relevant, proven Smart City Use Cases, which fit their needs and provides the required information to replicate them. The tool is a public deliverable from WP6 (D6.3).
- **ICT Reference Architecture:** It facilitates a common understanding regarding the ICT related terminology in the city context and outlines the standard/common sources of data and the belonging data consumers. It also facilitates the interoperability among the identified components, modules, layers, and general artefacts within the reference model.
- **Impact Assessment:** It documents and analyses the impacts in the Triangulum project. Next to the actual build-up of the Cloud Data Hub, its specific monitoring related tasks are underpinned by a logic of developing the right indicators to assess the impact of the Triangulum modules and Use Cases. The methodology of creating and calculating this set of indicators is set out in so called monitoring protocols. The seven stage methodology adopted by WP2 for developing impact indictors and calculating impacts can be found in Deliverable 2.1 (the Common Monitoring and Impact Assessment Framework).
- **City analyses:** took place twice in each LC and focused on understanding the framework conditions behind a Smart City (political and management processes, business models and financing aspects, citizen participation processes, etc.). Also data on the Use Cases in the respective city was systematically collected, as well as the local context enabling such developments to be successful.

- **Follower City Training Mission (FCTM):** It was a 10-month program (February – November 2017) to transfer the learnings from the LCs (LCs) to the Follower Cities (FCs) and consisted of 3 different knowledge-transfer vehicles and 17 sessions (3 FC Days, 7 Workshops and 7 Webinars).
- **Smart City Implementation Strategies (SCIS):** The task and target of the FCs within Triangulum is to write an own SCIS – a document outlining the vision and committing to a list of concrete projects to be implemented within each FC.

Bringing about a successful transition towards FCs requires tackling problems from two perspectives: Developing and modifying Smart City Solutions according to a city's specific conditions (legal, structural, economic, environmental) and shaping the organisational, social and economic environment in order to provide the basis for a functioning Smart City system. The Smart City Framework will thus address both: the analysis of local framework conditions (regulation, planning, citizen integration, business models and stakeholders) and the interdependencies of technological systems.

The development and implementation of the Smart City Framework follows an inductive approach: based on the evaluation of existing projects in the LCs, we introduce the concept of Smart City Modules (1 Module consists of technology + interfaces + business case + stakeholder structure + policy) and later further develop it into the concept of Smart City Use Cases. Successful modules will serve for an optimised Smart City development and will thus be integrated into a project development tool. The advantage of this approach is to have a direct relation to implementation. Conceptual work is based on real-world projects. The challenge of this approach is to deal with ongoing processes of implementation and to take into consideration that real world problems occur (plans are modified, technologies need to be improved, policies are not working properly etc.). In order to deal with this challenge, we designed four integrative feedback loops that link WP6 with the implementation in the LCs and replication process in the FCs. These feedback loops follow the hermeneutic cycle of knowledge generation, leading to a deep understanding of the systems and structures at work.

Crucial success factors for the replication of the Smart City Modules are working business models and sound financing. Identification of gaps in existing standards and defining requirements for future standards based upon the implementation in Eindhoven, Manchester and Stavanger are additional important tasks that helped design a Smart City Framework. Information and data on business models, financing and standards were collected, reviewed and integrated into the Smart City Framework by business partners to understand and transfer the schemes and provide the FCs with direct added value.

Throughout the process there was a strong collaboration between the Fraunhofer team and the business partners with respect to analysis, data collection and formulating the framework and necessary tools for replication.

1 Introduction

Smart Cities have increasingly emerged as a social, academic and industrial topic and cover a large amount of solutions with the goal to improve the quality of life for citizens within an urban environment, especially given current predictions that in near future the majority of humans will be living in cities. Based on the specific needs of a city, the topics covered by these solutions are, amongst others, Energy, Transportation/Mobility, ICT, eHealth, Water, Building and Automation.

Nevertheless, Smart City Solutions are characterized through a range of factors that make it almost impossible to use conventional business models and well-tested technology approaches. Following current shortcomings of Smart City Solutions are only a few examples of factors that are still hindering integrated and smart solutions to take off.

Regarding the city administration, its structure and thinking is still in silos, and therefore it is difficult to push integrated projects, which need cross-coordination between departments. Also, many cities may not convey to Smart City development and sustainability since the leadership level has a different agenda and a political leadership is missing. Considering the companies, they often fail to address the real demand of cities, because they think in product categories, not in integrated solutions. But for Smart City Solutions Eco-systems of businesses, technologies and services become more and more important and this also implies that new forms of collaboration, open innovation and co-creation need to be learned by these companies. In economic terms the largest benefits of smart and sustainable urban technologies are achieved in reducing external effects. This leads to difficult cash-flow models and unsecure investments. In addition to calculating ROI companies and cities need to develop holistic Value Models that reflect the complex benefits of Smart City Solutions for environment, society, economy and a resilient city. Furthermore, the integration of innovative technologies has often not been tested and standards are missing. This lacking precedence means high risk for investment an unsecure ROI.

Through European Union (EU) funding a range of barriers have been overcome within the SCC1 project Triangulum, leading to a successful implementation of a broad range of Smart City Technologies in Manchester, Stavanger and Eindhoven (so-called LCs) in an integrated manner. This implementation process served to develop a modular framework that helps to systematize the solutions and the factors that lead to a successful design and implementation of smart districts and prove the distributed benefits of smart and sustainable technologies in cities. Furthermore, the project aims to replicate these solutions in so-called FCs, which are Prague, Leipzig and Sabadell.

Therefore, the following document describes the Smart City Framework and represents the main outcome regarding replication. It is structured as follows: Chapter 2 elaborates further on the purpose and target group of the framework presented in this document. Chapter 1 deals with the background and motivation for such a framework. Chapter 4 describes the methodology applied for developing two approaches when addressing replication: The technology transfer approach and the customer centric approach. These two approaches constitute the main part of this document and are described in the chapters 5 and 6, including a Smart City Decision making tool, an ICT Reference Architecture and a Follower City Training Mission (FCTM) for helping cities replicate Smart City Solutions. Chapter 7 gives an overview of how many Use Cases have been/are being replicated in the FCs and finally, Chapter 8 summarizes the main outcomes and describes next steps.

2 Purpose and target group

This deliverable develops a Smart City Framework that focuses on applicability, functionality and replicability to be transferred to the FCs or any other city towards becoming a Smart City. According to the task description, the framework contains:

- Smart City indicators, an ICT Reference Architecture, monitoring protocols and a data hub for Smart City impact assessment,
- checklists and design principles for Smart City development projects,
- a set of integrated Smart City Modules that serve as building blocks for future development projects
- a decision making tool that operationalizes the Smart City Framework into decision making processes and a guideline for using the tool.

The purpose of this deliverable is to transfer learnings from the replication process itself on the one hand and on the other hand, to transfer learnings from the implementation processes. The reader will learn, not only from the two replication approaches needed (customer centric and technology transfer approach) but also about important lessons learned for not making the same mistakes.

The document consequently can support several audiences within its different chapters being of special relevance for:

- **Cities planning their own Smart City Projects** will discover important learnings on the implementation of Smart City Solutions in chapter 5. Especially the section 5.6 gives an overview of the more than 50 Use Cases with relevant data collected and implemented in the LCs. The section 5.7 introduces the Decision making tool which guides those cities in replicating the Use Cases that are most interesting for them. Also, section 5.4 presents the ICT Reference Architecture as a reference model which captures the general structure of ICT solutions for a Smart City in an abstract manner.
- **Local government initiatives** can get an overview of possibilities and an insight into the development of their own Smart City Implementation Strategies (chapter 6). Also, they can use the Decision making tool for finding the right Use Cases based on their personal needs, i.e. benefits (section 5.7).
- **Company representatives** can learn about current developments and the process of implementation of Smart City Solutions. Especially they will learn about the problems cities are facing and how to tackle them. This includes not only understanding the different technologies, but also the processes accompanying them. The overview provided in the sections 5.6 and 5.7 gives an insight into interesting Use Cases currently being implemented in Smart Cities.
- **Consultants or people planning replication processes** should read chapter 4 and chapter 6. There they will learn how to design cross-city learning and which formats can be used to optimally address the training needs of a city.
- **Consortia planning new Smart City Projects** will get an overall insight of lessons learned of the Triangulum Project regarding replication and therefore they can optimize the implementation and replication processes and avoid the mistakes when doing so.

The groups mentioned above are only a selection of possible target groups and in fact any person or institution interested in implementation and replication of Smart City solutions in cities can use the findings of this report. Everyone interested in details on what are future-proof Smart City implementations and what needs to be considered not only when implementing, but also when replicating them in other cities, is invited to read these documents and gain new insights.

3 Background and motivation

This chapter provides the theoretical background of WP6 and the Deliverable 6.2 Replication Framework. It includes the “Holistic Smart City Value Model” and the “Morgenstadt Methodology”.

The Holistic Smart City Value Model aims to include not only financial factors but also social, environmental and organizational influences into the planning process of Smart City implementations. It was developed i´within the first year of the project by researchers from Fraunhofer IAO in order to provide a theoretical underlying to the practical approach towards replication. It is based on years of theoretical and applied research in more than 10 relevant Smart City projects.

The Morgenstadt Methodology is the city analysis framework that was developed by Fraunhofer IAO together with the Morgenstadt Innovation Network. It is a structured approach to gather information and develop actions helping a specific city to mitigate problems and become smarter by outlining a process towards implementations. It was used as a basis for the Triangulum replication process.

3.1 Holistic Smart City Value Model

Concepts and technologies for planning and realizing sustainable urban systems not only offer solutions to the many challenges of an urbanizing world, they also bear the potential to unlock significant future markets (see Corvellec et al. 2013; Balakrishna 2012; or also Weizsäcker 2009). Yet most cities are struggling with the process of transformation and businesses have so far not been able to harness the full potential of the sustainable city as a future market.

This is partly due to a range of new challenges that cities, citizens and companies face when trying to respond to the challenges of a Smart City. Along with the design of urban systems solutions, cities, citizens and companies need to find new ways of collaboration and mutual engagement. Cities increasingly have to deal with complex systems that are cross-sectoral and dynamic. They aim at meeting goals that cannot be directly tied to specific technologies, but are highly ambitious and require collaboration across all departments and sectors (e.g. achieving carbon neutrality, reduction of individual mobility, increasing resilience, etc.). (cf. e.g. Næss und Vogel 2012 or McCormick et al. 2013). Until now, no standard approach exists for companies to address cities as customers by tailoring their products to cities’ needs in an efficient way without encountering major risks. The result is a range of corporate sales strategies for single products that are unable to cover the complex demand a city faces when attempting to implement more sustainable approaches to development. However, Smart City Solutions are characterized through a range of factors that make it impossible to use conventional business models and well-tested technology approaches. Developing smart cities in fact means that local governments and city administrations need to become innovators, just like companies need to discover their corporate share in urban governance. The following list of challenges for developing, implementing and operating smart districts and smart cities is based on a range of surveys, personal interviews, group discussions and personal experiences as co-ordinator of large multi-stakeholder Smart City consortia (Braun und von Radecki 2012; Kalisch et al. 2013; Radecki et al. 2012; Segedi 2014). It is not deemed to be exhaustive but should give a good overview over the current state of Smart City challenges in cities and corporations across Europe. The main challenges are structured into three larger categories:

a) challenges through market barriers,
b) organizational challenges,
c) leadership challenges.

Challenges through market barriers:

- Integration of innovative technologies has often **not been tested** and standards are missing. This lacking precedence means high risk for investment and unsecure ROI, leading to a situation, where conventional investment schemes fail and risks are neither taken by investors nor by the city.
- **Cash-flow models are not clear yet** – especially in complex stakeholder constellations, which are characteristic for smart and distributed solutions. In addition, different national landscapes for incentivising technologies like renewable energies (feed in tariffs) or electric vehicles prevent consortia from developing one-size-fits-all solutions.
- **Business models fail** in the face of complex urban systems solutions. This is due to two main reasons: a) sustainable technologies often have their largest gains within external costs (reduction of emissions, pollutions, noise, resource consumption etc.). If they are not factored in to the business model e.g. via government incentives, pigouvian taxes or cap-and-trade systems, they are unable to compete against conventional solutions, unless the service model is strikingly better and the achieved benefits are noticeably higher. However b) as complexity of solutions rises, more stakeholders are needed to develop, implement, operate and maintain Smart City Solutions, which reduces the likelihood of an even distribution of benefits across all stakeholders, leading to unbalanced cost-benefit models and therefore to uneven investment incentives.
- **Standards** and **interoperability of systems** are lacking. There is little security of planning and transaction costs for Smart City consortia are high, since they are not able to refer to existing architectures, communication protocols and standards.
- Many companies have not realized that own Smart City products and business solutions need to be **embedded within larger systems**. New forms of collaboration, open innovation and co-creation need to be learned by these companies.

Organizational challenges

- Most companies still think in products not in holistic solutions to larger needs and problems. They have a classic sales perspective that is output driven not demand oriented. However, in order to address cities as customers, companies must re-invent their sales strategies. No single products but systems-solutions to existing problems and needs are what cities want. The better a company can prove how their solutions contribute to the goals of the city; the higher it will be ranked as development partner. This, however, requires a deeper understanding of the city and its aims and problems (which are often individual). Instead of focusing on selling ones product portfolio, business-to-city (B2C) business means to constantly realign and reinvent ones solutions portfolio with cities‘ needs and demands. **Eco-systems of businesses, technologies and services** become more important, but companies are hesitant to truly open up to new partners.
- Virtually no company sees itself as **systems-integrator** of Smart City Technologies and Services. Neither do city administrations, nor municipal service providers. Thus there is a vacuum when it comes to designing, coordinating and leading integrated Smart City Projects.
- Equally, most companies that aim to address the Smart City market are not prepared to become **systems operators**. Since the actual benefits of Smart City Solutions for users, local economies and the environment consist in increasing the share of using connected systems and lowering the share of owning individual products, the operational model (and with this also organizational structures like sales, marketing and corporate responsibility) change drastically. The operators of Smart City systems and the corresponding networks of companies and municipal representations have not yet been identified or developed.

- Far too often city administrations **still think and act in silos**. They are structured in silos and give actors a hard time who want to push for integrated projects and solutions since cross-coordination between departments often needs to be built from scratch. The **Smart City integrator** who is missing at corporate level is also missing within local governments.

What makes it even harder– there is no standard for organizing municipalities. This results in a broad variety of departments and offices across cities. Departments and offices are named differently and have different responsibilities in virtually every city. According to the administration's structure, the responsible managers for traffic, Smart City, urban development, economic development, sustainability etc. are found in different departments. This causes barriers, e.g. when industrial partners need not only identify these managers across the city administration, but also get in touch with a number of them to reach one goal. The organizational pathway to deliver smart cities at local government level, thus needs to consist in local organizational innovation and change management processes rather than being able to adopt a blueprint for Smart City organization.

Leading cities have developed a set of different strategies for dealing with complex cross-cutting issues and to escape the silo-dilemma. Some cities install cross-sectoral departments (New York City), some create special staff units (Ludwigsburg), others install rather informal inter-departmental work groups (Freiburg), and again others outsource the responsibility to semi-autonomous project companies (Vienna) etc. Iveroth impressively delineates the complex institutional interactions that are needed for developing a systems-integration approach in Stockholm (Pandis Iveroth et al. 2013). Depending on the city's approach to deal with cross-cutting issues, elements like smart districts, innovation leadership, sustainability, resilience etc. are emphasized and addressed differently. Creating a cross-sectoral structure that is able to bridge the silo-organization of city administrations is one of the most important success factors for pushing for the delivery of smart districts.

Leadership challenges

- **Political leadership is missing**. Building smart districts means long-term investment and it requires the will to test something new. Many city leaders today are afraid of overstraining their citizens with new and innovative approaches that actually cost money and have not been thoroughly tested somewhere else before – especially if this means to push for an organizational shift within municipalities or to bet on an unclear return on investment. We are therefore seeing multiple challenges at the political leadership level of cities that make it difficult to have mayors buy in to Smart City developments. Yet, if the top-level decision makers do not buy-in, there is little chance to push for a successful development of smart districts on the ground.
- Often no **real partnership** between cities and companies exist, since in some cases procurement regulations prevent close partnerships and in other cases the ways of thinking and acting are very different. When understanding a company and the city as part of a larger Value Model, city administrations and municipal stakeholders automatically start to become partners instead of customers. This shift in perception is of high importance since it means that urban solutions are co-created and fitted to the actual market, allowing for a rapid market uptake and providing support from the political and administrative realm. Full deployment of the triple helix model means that there is a continuum between politics, administration and private sector, linking these players as partners with equal importance but different roles within the Value Model of a city.
- Cities need support in **creating sustainable value**. But opposed to business understanding, value for cities is not confined to business value – it also refers to a sustainable development, a healthy environment, socially viable solutions and long-term stability of infrastructure and economy. In economic terms large parts of the benefits of smart and sustainable urban technologies are achieved by reducing external effects and by creating socio-technical capital. This leads to difficult cash-flow models and unsecure investments. To actually identify the value of smart solutions and smart districts, companies and cities

need to start thinking in **holistic Value Models** that reflect the complex benefits for environment, society, economy and a resilient city.

Companies and cities thus need to start thinking beyond business models and mere social welfare and understand themselves as part of a larger Value Model that delivers value added services to cities and citizens, creating value that reaches far beyond a monetary return on investment. In a second step Smart City Value Models need to be transferred into business cases for corporate players. Today, however, many corporate players fail to address the real value of smart cities, since they start with their business model right away.

3.1.1 The need for a Smart City Value Model

Many cities across Europe have started to implement first pilot projects for smart cities and smart districts within publicly funded projects as it can be seen e.g. on http://smartcities-infosystem.eu/. Wherever these projects do not rely on a well-established efficiency model or are supported by a strong regulatory framework or government incentives, the implemented solutions still fail to build on viable business models that would allow for an easy replication under market conditions.

Through EU funding a range of barriers have been overcome within the Smart Cities and Communities lighthouse projects (Triangulum, GrowSmarter, RemoUrban – cf. WelcomEurope 2015) leading to a successful implementation of a broad range of Smart City Technologies in these cities. In absence of a viable business model EU funding closes the investment gap. However, the funding is directed towards a technology-based and data-driven development of smart district demonstrators. Little emphasis is put on governance structures, processes, business model innovation and integrated action planning to support the actual delivery of results. It however neglects, that Smart Urban solutions represent a fundamentally new approach of developing, implementing and operating cities and thus also need a fundamental paradigm shift with regards to business model innovation in complex public-private stakeholder environments. Up until today we are basing our investments into clean technologies on two models – the efficiency model and the policy model:

The efficiency model is largely distributed and applied with clean technologies. The main innovation of the efficiency model lies within one single piece of technology or one clearly defined product. This makes market uptake rather easy (Weizsäcker 2009). In the case of the efficiency models the reduction of external effects goes in line with the increase of efficiency. This is also proven within this report by the high importance of the corresponding benefits displayed in Chapter 5.6.

Figure 1: Efficiency Model

As shown in Figure 1the **technological innovation** itself is able to reduce external costs and to increase the socially efficient allocation (Q1) through a free market allocation of money and technology (Q) at the same time. The gap between social costs and private costs of the solution (Figure 1 assumes a gap of 5m € for a conventional technology) is being strongly reduced through efficient and clean technologies.

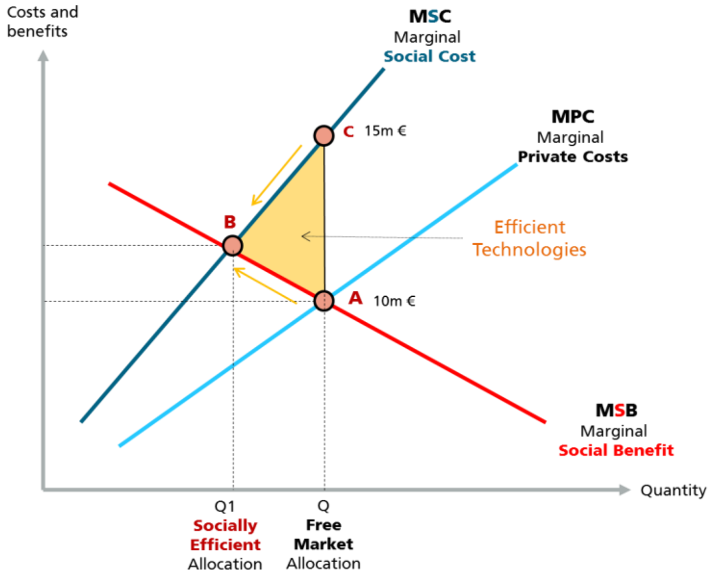


Figure 2: External cost model and the effect of efficient technologies[1]

The **policy model** is strongly used in creating renewable energies and energy markets, or for overcoming lock-in structures of established socio-technical systems. We encounter it wherever governments seek to support politically desired technologies and there is a financial gap between the efficiency model and a profitable business model (e.g. cf. Nijkamp und Perrels 1994; Evans 2005; Cumo et al. 2012). The investor then invests into the clean technology and receives an additional bonus (in terms of granted return on invest or investment support) that allows for a profitable return on invest. Examples for this are feed in tariffs for solar and wind energy, subsidies for electric vehicles or market regulations like **taxes**, **fees** (e.g. for polluting cars) **caps** (e.g. emissions trading schemes) or **bans** (e.g. for FCKW).

[1] This Model is based on the standard economic model of externalities as described by (Cornes und Sandler 1996).

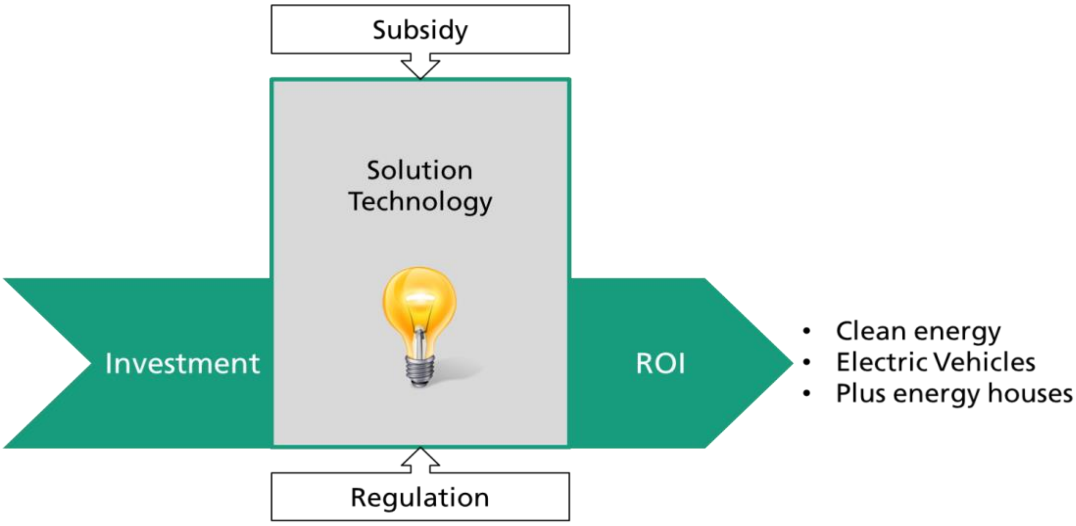


Figure 3: Policy Model

In the case of the policy model the technology itself is not able to achieve a profitable return on invest under given market conditions. Therefore the government closes the gap for the investor with a subsidy or adopts a regulation that makes investments into the desired technologies – or systems – more profitable than investing into conventional alternatives.

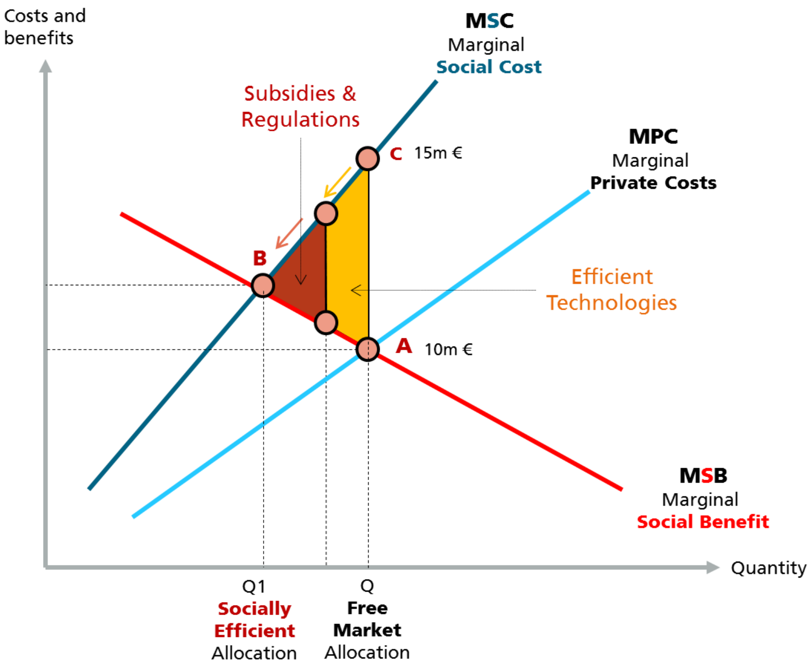


Figure 4: External costs and the effect of subsidies and regulations

Figure 4 shows how subsidies and regulations help move the marginal private costs more towards the marginal social costs and therefore increase the social benefit.

Up until now, these models, the **efficiency model** and the **policy model** are the only economic models for incentivizing investments into clean technologies and for developing the markets of clean tech. Smart City Solutions draw on both these models. However, Smart City Solutions are inherently different to the incumbent solutions, since they aim to link multiple technologies and multiple stakeholders from public and private by an ICT based connector. With digitalization and the Internet of Things (IoT) a new organizational and economic model for connected clean and efficient technologies needs to be developed and it will be substantially different from the two incumbent approaches towards financing clean technologies – the efficiency and the policy model.

Intelligent solutions that connect a range of technologies for a larger benefit not only have the potential to drastically increase efficiency, they also produce a range of **additional benefits** for many different actors. An **electric car-sharing** solution for example reduces noise in cities, frees up urban space, reduces emissions and increases personal mobility for everyone. A **hybrid district energy grid** reduces fossil fuel consumption, maximizes clean energy use, achieves cost effective production use and storage of energy through intelligent balancing schemes and increases the liveability for city dwellers that have electricity and heat at their demand at any time.

What is substantially different in this model is the interlinked and connected nature of the systems solutions that are able to achieve these effects. It is not one single technology, but rather a set of socio-technical systems that need to interact in an intelligent way, in order to deliver a broad set of benefits to an individual network of beneficiaries. The sustainability potential of these solutions cannot be harnessed through conventional business models and regulations or subsidies. New approaches are needed today to prove the potential of smart and connected solutions and to develop collective investment schemes that relate individual benefits with joint investments. The reason for this is the new interconnected nature of smart cities solutions. Multiple stakeholders from the public (municipalities, municipal enterprises, state-owned agencies etc.) and the private realm need to collaborate in a close way, sharing data, costs, benefits and responsibilities in a complex way. Neither of these organizations is set to do so in an easy manner.

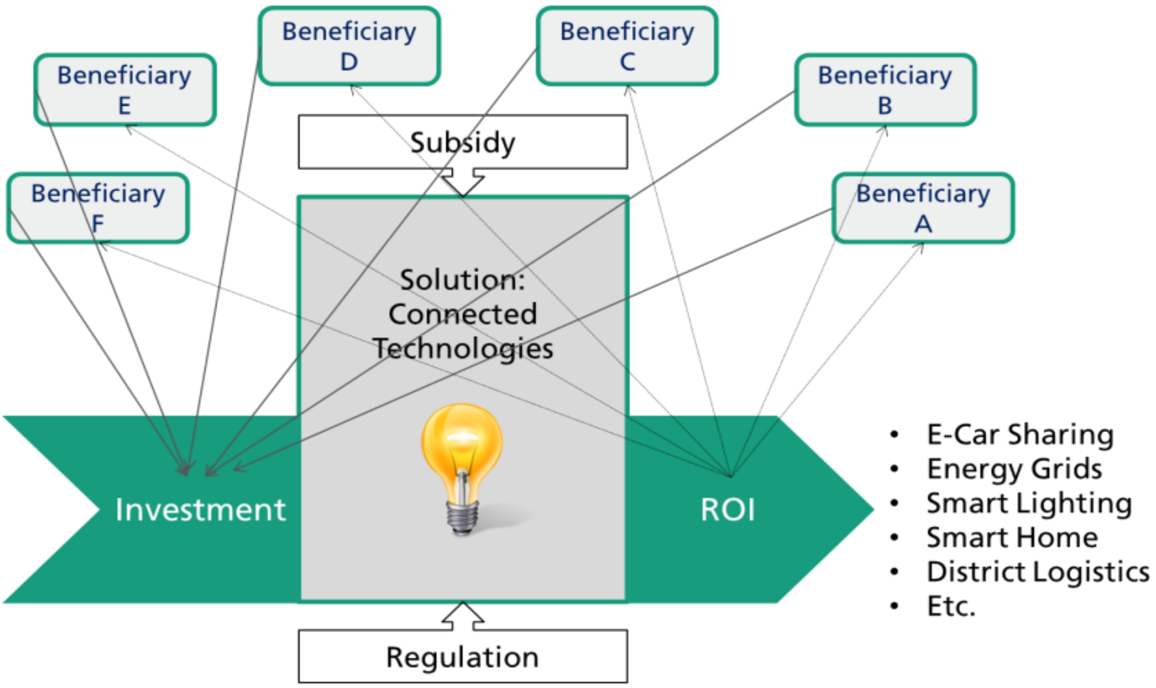


Figure 5: Smart City Value Model

Connected Smart City Solutions thus have the potential to not only reduce external costs of technology but on top of this, to maximize value creation and welfare in districts and cities. Through this, they theoretically eliminate the need for a range of state subsidies on clean technologies that are part of the systems solution, freeing public money for other purposes (e.g. infrastructure investment or social development programs). Through activating the additional benefits of a smart solution, an urban value can be created that combines high social benefits with low marginal social costs.

This potential, however, cannot be harnessed through conventional business models and regulations or subsidies. As subsidies and regulations were needed from the 1970's on to enforce market shifts toward clean technologies, new approaches are needed today to prove the potential of smart and connected solutions and to develop collective investment schemes that relate individual benefits with joint investments. Costs for smart solutions need to be shared by all stakeholders that receive a significant benefit from the solution. **Crowd-investment schemes with public and private stakeholders are thus the financial equivalent to socio-technical systems solutions for cities.** They, however, will only successfully occur, if the benefits of a specific solution and under specific circumstances can be proven to actually occur. In other words: **prospected benefits of Smart City Solutions need to be proven under reproducible circumstances in order to convince future beneficiaries to become Smart City investors!**

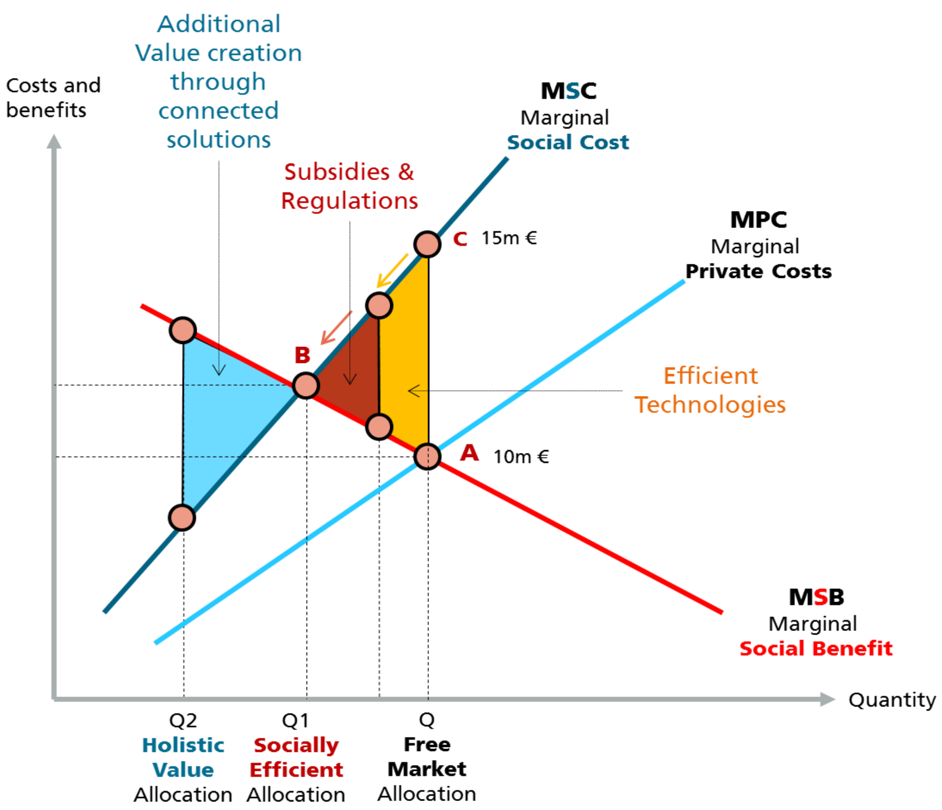


Figure 6: External costs and holistic value creation through connected solutions

Figure 6 shows how through a holistic value approach positive externalities derive from connected solutions in cities. Similar concepts have already been described by authors such as McEachern for the case of edcuation (McEachern 2012), Römer for the case of smart meters (Römer et al. 2012) or Krugman for the case of preserved farmland (Krugman und Wells 2013, S. 466) and technology spillovers (ibid, p468}).

The **Smart City Value Model** is thus a new economic approach to link the value creation of integrated socio-technical systems to a set of different beneficiaries and types of benefits, which builds on the conceptual work of positive externalities and external benefits.

3.1.2 Smart City Modules – the conceptual basis for a Holistic Smart City Value Model

The implementation process of the solutions in the EU-funded LCs is one of the few opportunities that allow learning from a large-scale implementation program and developing the business cases around a new and complex system of urban value creation, which is derived from the Smart City.

The lighthouse project Triangulum thus serves as test-case to develop a modular framework that helps to systematize the factors that lead to a successful design and implementation of smart districts and prove the distributed benefits of smart and sustainable technologies in cities. This framework shall consist of a range of "Smart City Modules" that can be described as systems solutions for smart cities. They represent core technologies that are organized around a business model and pursue a specific goal for cities and citizens. A set of Smart City indicators will help distinguish between individual local factors and generic Smart City success factors.

Connected solutions can be broken down into some core categories, leading to a finite number of connected solutions with specific characteristics. Thinking in Smart City Modules helps to systematize solutions and to operationalize them for an analysis, replication and further development. For Triangulum it was proposed to operationalize Smart City Modules according to Figure 7 and Figure 8.

- ➔ At the core of the Smart City Module are distinct **socio-technical units** that serve to **deliver a specific service** to citizens, the city administration and / or companies in one of the districts of Manchester, Eindhoven or Stavanger.
- ➔ To implement each socio-technical unit, a **set of actors** is needed that have a specific interest in the solution and want to **achieve a core goa**l and to produce a core output (*mostly gains in efficiency or return on invest*).
- ➔ Technology units and actors are linked through a **service and business model** which describes and specifies interactions, responsibilities and operation details of the unit.

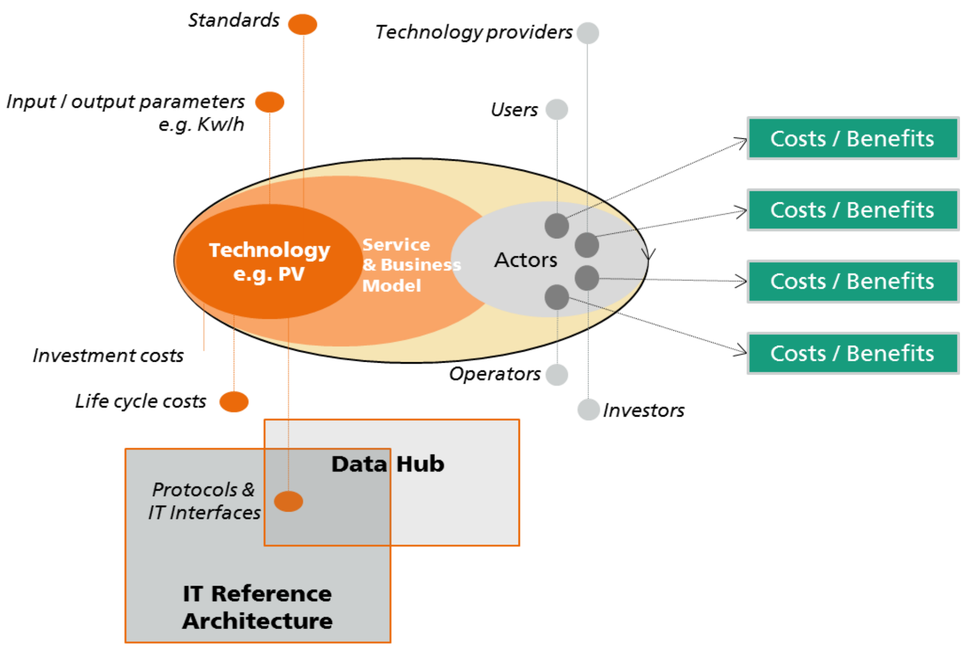


Figure 7: Components of the socio-technical unit

➔ Each socio-technical unit is linked to a set of other socio-technical units through digital interfaces and a larger operational model of the Smart City Module.

➔ The technologies within the technical system are linked to one another through **interfaces, protocols and communication**. At the same time the module itself is linked to its environment and other infrastructures through technical interfaces in order to function properly.

➔ Usually a **systems integrator** is responsible for coordinating the flow of data and information between the units and for delivering the operational value of the Smart City Module.

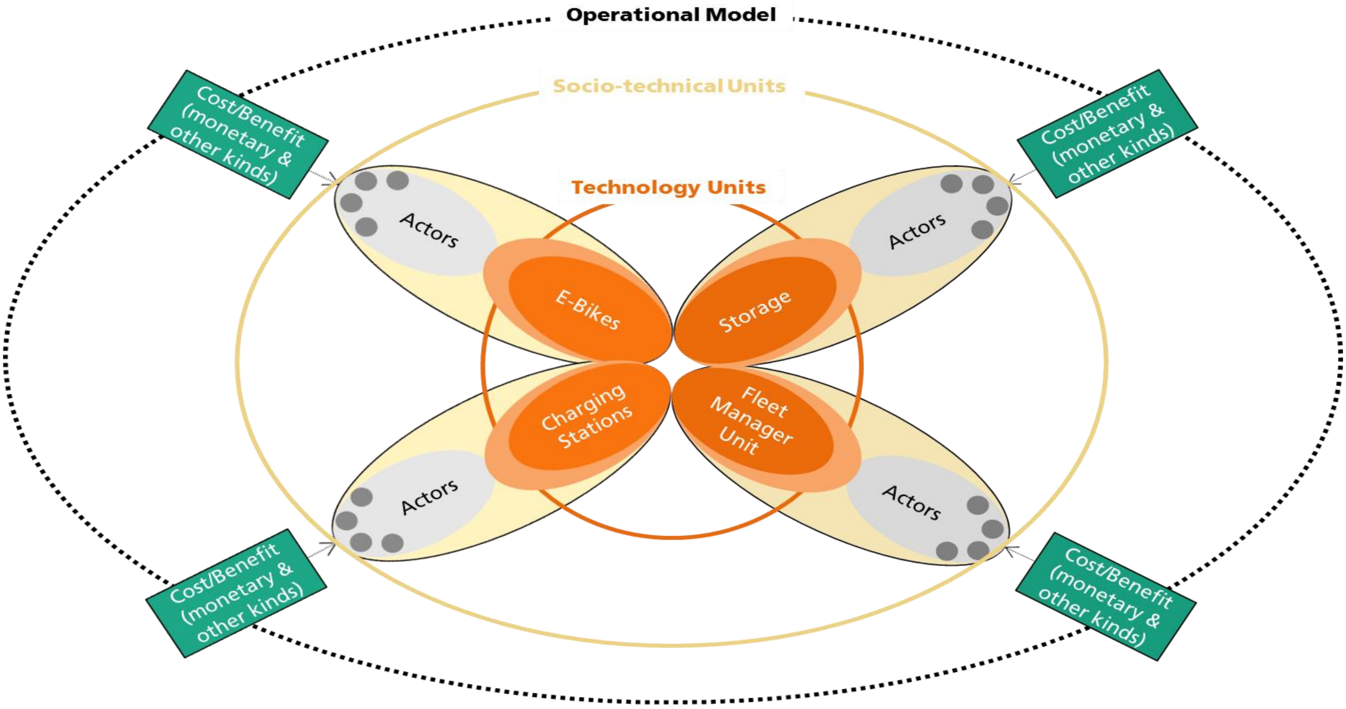


Figure 8: Modular concept for Smart City Solutions (example: E-bike distribution system)

➔ The technical system needs to be integrated into **existing infrastructures** – therefore the connection and linkage to wider technical systems needs to be assessed, as well as the **dimensions and economies of scale** under which circumstances the solution is successful.

➔ Some of the technologies and interfaces already obey to **existing standards**, some of them do not.

➔ **Regulations and incentives** that are in place in Manchester, Eindhoven and Stavanger are relevant frame conditions that maybe hinder or support the roll out and uptake of some of the Smart City Solutions.

➔ In addition, **individual factors** like geography (wind, sun), the governance structure, society and culture or the political power setting have an impact on the Smart City Modules that are being implemented in the 3 LCs.

➔ The **individual benefits** and **additional beneficiaries** of each Smart City Module need to be estimated and verified with local stakeholders and beneficiaries.

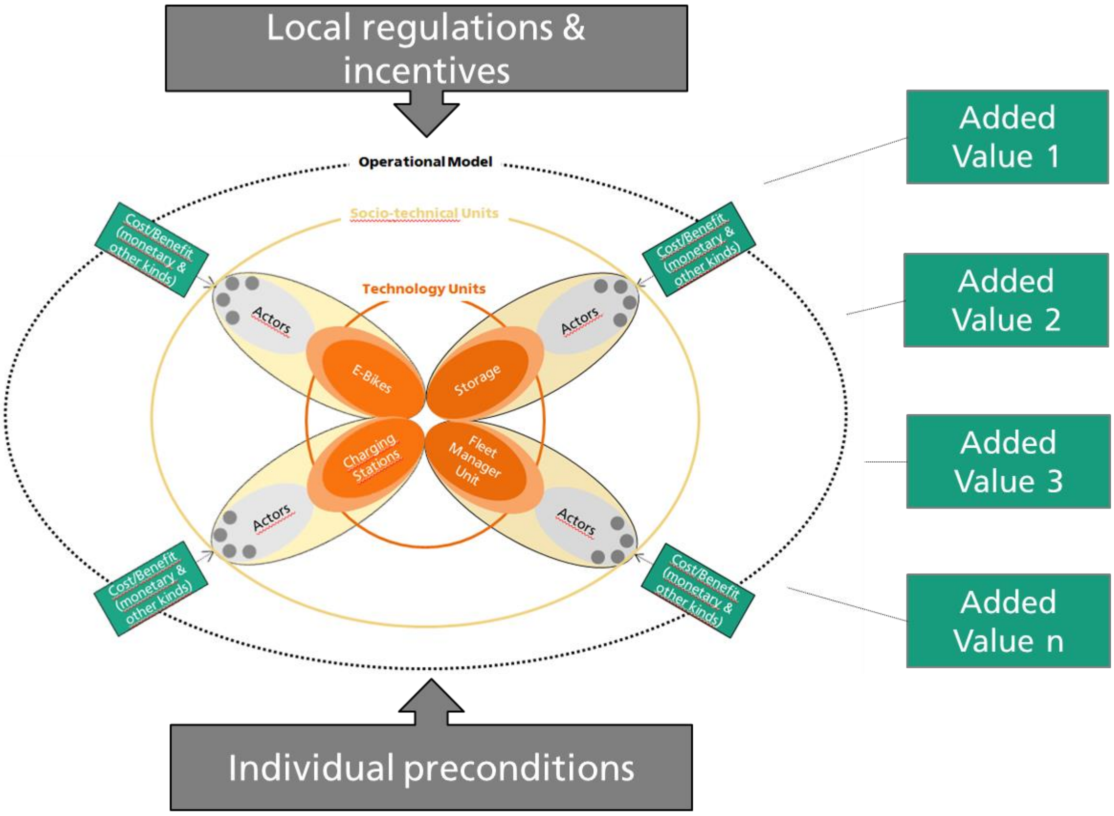


Figure 9: Operationalizing Smart City Modules for Triangulum

This setting allows for a clear structuring of the assessment of data and information within the LCs. The proposed steps to be undertaken for operationalization are described below.

The basic concept for leveraging the additional value of connected solutions lies within identification of the additional benefits that come on top of the conventional efficiency or policy model. Therefore all benefits that solutions like an e-car-sharing or smart lighting infrastructure are creating for a range of different stakeholders, need to be identified in a first step. In a next step the benefits are allocated to main beneficiaries and underpinned with an estimation of the positive economic effect that the beneficiary will experience:

Table 1 - Example for an external benefits table used in the assessment of smart solutions

Benefit	**Beneficiary**	**Economic effect**	**Time to impact**
Less emissions	Climate -> Co2 certificates	1500 t CO2e / year x 6,50€ per certificate	After implementation
Increased Security	Police / Prisons	5 less prisons /year x costs for 1 prisoner	2 years after implementation
Biodiversity / provision of ecosystem services	Utilities company -> less water purification needed	3 Mio l less to purify / year	2 years after implementation

Time savings	Commuters in district A	10 min. per commuter per day	After implementation
Increased live quality	Local dwellers	7,5% rise in real estate prices	2 years after implementation
More Public space	Local cafés have space on sidewalk	15% increase in turnover for 5 cafés	1 year after implementation

Having proven the impacts and the de-facto creation of benefits the model foresees that the identified beneficiaries invest own money (or use corresponding investment schemes like Smart City Bonds) into the solution proportionate to the benefits that they achieve.

Usually a large part of the required ROI will already be generated through the efficiency model: smart lighting will pay almost off through efficient LED lightbulbs alone. Therefore it is estimated that the identified beneficiaries will only need to invest a smaller share of their own estimated benefits (10% - 30%), making the solution highly attractive to a range of beneficiaries. The cumulated investments will easily bridge the investment gap of the efficiency and the policy model, however they need to be proven, organized and the return must actually occur.

The main problem with distributed benefits and shared investments is the risk that is connected to achieving the benefits. If it has not been proven that e.g. an e-car-sharing solution frees up public space in a certain district by a certain amount of m² or that a smart refurbishment programme actually increases real estate value by a certain percentage, investments will not happen. In other words: **prospected benefits of Smart City Solutions need to be proven under reproducible circumstances in order to convince future beneficiaries to become Smart City investors!**

This is the reason, why the HORIZON 2020 Smart Cities and Communities lighthouse projects represent such an important test-bed for the development of holistic value in cities and allocation to selected beneficiaries. In these projects public investments into innovative and smart solutions bridge the gap that prevents potential beneficiaries from investing, thereby creating a large number of use-cases and precedence for smart solutions and their benefits.

3.2 Morgenstadt City Lab Methodology

The joint research project »Morgenstadt: City Insights« is an alliance of high-ranking partners from a range of industry sectors, leading-edge sustainable cities, and key Fraunhofer research institutes. Using innovation management methodologies and a range of tools and measures (international city surveys, “City Labs“, analytical tools, online assessment instruments etc.), »Morgenstadt: City Insights« aims at developing and implementing socio-technical innovations and lighthouse projects to provide answers to the challenges of the cities of tomorrow.

The alliance focuses on the interplay of technologies, business models, and governance approaches for sustainable urban development. The fundamental goal of the network is to accelerate development that helps reduce energy and resource consumption while also enhancing the liveability and prosperity of a city. Fraunhofer, together with numerous industry and city partners in the Innovation Network »Morgenstadt: City Insights« has developed an action-oriented model for accelerating and strengthening the sustainable development of cities.

It is based on six deep-dive analyses and hundreds of case studies to enable other cities to improve their sustainability credentials. Based on an integrated indicator framework and the assessment of over 80 action fields, Morgenstadt experts derive individual city profiles that serve to design and implement individual strategies for city transformation. A team of 3-4 Fraunhofer researchers supported by Morgenstadt Experts from industry and cities and a local counterpart team from the cities assess a broad range of information and data on the cities and – building on the Morgenstadt Framework– develop integrated measures and projects that help the cities boost their development. Core of the analysis is a 2-3 weeks on-site assessment in the cities where a large amount of interviews is conducted and solutions and existing projects are evaluated in-situ. Based on this analysis a range of innovative socio-technical interventions are developed and integrated in a strategic roadmap that helps Morgenstadt Cities develop in an economically strong and socially and environmentally sustainable and resilient way.

The City Lab approach or Morgenstadt Framework has been applied and tested in more than 10 cities world-wide and functions as the basis for practical experience that has been gathered by the responsible researchers of WP6. The approach has been used in an unmodified format within the first year of the Triangulum project. Using the learning and deviations arising through the replication oriented approach, this framework has been adjusted in Task 6.1 and validated in Tasks 6.7, 6.8 and 6.9. The underlying tools, logic and approaches however form the strong basis of the Triangulum replication approach. Therefore the goals and research design of the City Labs are described in detail in the following chapters. The adopted version that has been developed within Triangulum, on the basis of the City Lab approach, is described in Chapters4, 5 and 6 and evaluated in Chapter 7.

3.2.1 City Lab Goals

The complexity inherent within the requirements for sustainable city development lead to a future in which individual technologies must be integrated ever more within systems solutions. The development, evaluation, and implementation of socio-technical system solutions for cities can be more effectively implemented through a collaborative network of research, industry and city administration than through a limited number of individual service providers alone.

The Fraunhofer innovation network “Morgenstadt: City Insights” (“m:ci”) is working towards the vision of a City of the Future. This City of the Future is one that is CO2 neutral, resource efficient, clean and resilient, while simultaneously providing its population with a high degree of health, happiness and economic prosperity. The members of the network have made it their goal to illustrate future-compatible progress for cities, to promote system innovations and to accompany cities in the transformation processes they must necessarily undergo.

One of the areas of focus in doing so is the creation of City Labs. This involves the development of strategic roadmaps for selected cities, which based on a holistic system analysis will initiate and accelerate the sustainable development of these cities through a variety of innovative projects. In order to accomplish this, strategic partnerships with cities in Germany, Europe and international foreign countries will be created. Labs serve to anchor technological, structural, social and economic innovations within a holistic city context, thereby creating international lighthouses for future-oriented urban development.

In close cooperation with the individual cities, local stakeholders, involved businesses and Fraunhofer institutes, strategic solutions within the context of the city-wide system are developed and then implemented in operative projects. At the core of the City Lab is an analytical framework created by the Morgenstadt Initiative, which allows the involved actors to move forward with goal-oriented project development.

3.2.2 City Lab Research Design

3.2.2.1 Understanding cities as complex and adaptive systems

For the purposes of the City Labs, cities are understood as complex adaptive systems (CAS): open and evolutionary systems which consist of a multitude of interacting sub-systems. According to the general definition, CAS consist of many adaptive agents, the interaction of which result in complex, non-linear and dynamic developments.[2] Parallelism of events (incl. positive and negative feedback loops), conditionality and modularity as well as adaptation and evolution are elementary features of complex adaptive systems.[3] The development of a city, which occurs in parallel on many levels (technological, political, economic, societal), is thus understood more as an emergent system phenomenon than as a planned and controlled process.

"As coevolving human-environment systems, cities are spatially heterogeneous, complex adaptive systems. As such, the dynamic trajectory of cities can never be fully predicted or controlled, but can and should be influenced or guided in more desirable directions through planning and design activities that are based on urban ecological knowledge and sustainability principles".[4]

The consequences of this definition of cities as CAS is visible in the approach and the research process. The City Lab approach shares Holland's opinion that an understanding of the system is not possible with conventional research methods which traditionally rest on the division of complex questions into individual pieces which are then analysed separately and in detail. CAS lose the majority of their characteristics when individual aspects are analysed in isolation.[5] A system as a whole cannot be recognized and understood via detailed information about individual sub-systems, but rather must be identified through the detection of patterns and the correct description of relationships between the various elements of the system. "Thus, two elements are essential for recognizing patterns: reduction of data to only the key components and the linkage of these components.[6] A central aspect of the Morgenstadt City Lab therefore comprises the identification of technology- and action-fields, as well as key drivers, which are relevant for sustainable urban development and to then locate these with respect to their relationship to the system as a whole.

3.2.2.2 Sustainability as a principle for urban development

A multitude of global indicators indicate that a speedy transformation of cities worldwide to CO2-neutral, resource efficient, intelligent systems is the only way to reduce the negative developments occurring in global ecosystems. Thus, this is the only way to at least minimize the serious effects these developments will have on the lives of many people. In the new „Climate Economy Report" cities, thus, play an especially significant role:

„Cities are engines of economic growth. They generate around 80% of global economic output, and around 70% of global energy use and energy-related GHG emissions. How the world's largest and fastest growing cities develop will be critical to the future path of the global economy and climate. But much urban growth today is unplanned and unstructured, with significant economic, social and environmental costs. As pioneering cities across the world are demonstrating, more compact and connected urban development, built around mass public transport, can create cities that are economically dynamic and healthier, and that have lower emissions. Such an

[2] Brownlee 2007.

[3] Holland 2006.

[4] Wu 2014.

[5] Holland 2002.

[6] Vergl. Vester 2003, S. 55.

approach to urbanisation could reduce urban infrastructure capital requirements by more than US$3 trillion over the next 15 years."[7]

Sustainability, as a principle of urban development, is based on the definition of sustainable development from the Brundtland Report as well as the UNCSD (1992).[8] In addition, the "m:ci" defined several key aspects of sustainable urban development in the "m:ci framework".[9]

In summary, the City Labs address the question of how cities, complex adaptive systems made up of multiple socio-technical sub-systems and actors, can be moved towards sustainable development, which will finally allow for long-term system existence within ecological limits and taking into consideration important human needs (supply, prosperity, work, leisure, self-realization, mobility, etc.).

3.2.2.3 Systemic analysis of cities

Starting with an analysis of the identified technology- and action-fields in the city, an understanding of the systematic drivers[10] that may promote, hinder or accelerate a sustainable type of development will be gained. Based on this information (analysis of action-fields and drivers), the goal is to individually identify the most important parameters for sustainable urban development and to demonstrate the interlinked nature of technologies, business models, use processes, actor networks as well as regulatory and governance approaches. A subsequent step is designed to use the insights thus gained in order to create a strategic roadmap which will include concrete projects and measures for future development. Since this process is inherently trans-disciplinary and systemic, a suitable approach must be applied which will enable the systemic analysis of a city (City Lab) within an interdisciplinary team of experts.

3.2.2.4 Theoretical basis

The basis for the City Lab approach is Systems Theory, which is a collective term for a multitude of theoretical building blocks from various academic disciplines. Instead of searching for linear causal explanations and isolated objects, these are replaced by circular explanations and relationships between objects.[11] „Systems thinking" is the discipline which serves to describe and identify systems, system elements and their interactions.[12]

We base our definition of cities as complex adaptive systems on authors such as Sanders, Nikolic, Miller and others.[13] Urban systems are made up of a large number of technical, social, economic, political, etc. elements, which, independent of one another, function according to their rules, which also, however, stand in relationship

[7] Oppenheim et. al. 2014, S. 8.

[8] „Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987).

[9] All Fraunhofer institutes involved in the project were included in creating the "m:ci" definition of "sustainability". An iterative process led to the collaborative formulation presented here.

[10] The term „driver" is used throughout this document. The following definition is useful: a driver is a factor of influence, which has either a positive or negative, direct or indirect effect on the best practices identified. These could include: regulations, laws, actors, business models, socio-cultural factors, values, norms or events. One should differentiate between drivers and framework conditions, which also have either a positive or negative, direct or indirect effect on the best practices, which, however, represent global or geographical factors which cannot be altered on the local level. These could include: location and climate of the city, available resources, global economic crises, etc.

[11] For comparison, see {Simon 2007 #249, S.13}

[12] For systems thinking see: Senge 2011; Meadows und Wright 2008.

[13] Compare with Sanders 2008; Nikolic 2010; Miller und Page 2007; further information about complex adaptive systems can be found in e.g. Brownlee 2007, Holland 2002, Holland 2006 oder Manesh und Tadi 2011

to one another.[14] Changing one element or sub-system often results in not completely predictable adaptations within the urban system.

One central insight of complexity theory is that no one has the ability to completely understand or master a complex adaptive system in its entirety. No single individual can comprehensively shape a complex adaptive system.[15] For this reason, the interdisciplinary analysis of system elements, as well as the system as a whole, by a team of experts from different disciplines and sectors represents a central element of the City Labs. In doing so, both the expert understanding of individual sub-systems that contribute to sustainable urban development (e.g. local heating, public transit, integrated planning concepts, electro mobility, renewable energies etc.) as well as the interaction between the researchers themselves, is of central interest in the research, with the aim of achieving a holistic systems understanding of sustainable urban development.

The starting point for this methodology is that both, a detailed observation of individual sectors and their best practices as well as a systematic analysis of the city as a whole, are necessary in order to identify technology- and action-fields as well as drivers of sustainable urban systems. To achieve this, a general division into two levels of analysis has been made:

- Level 1: Urban System

- Level 2: Technology- and action-fields

An analysis of the two levels must be based on data, or information, originating from many different sources and a large variety of data types. In order to structure and later analyse the data, a second division – into quantitative and qualitative data – has been planned. Figure 2 shows the classification of data according to level of analysis as well as the corresponding designation of sources used for data collection.

[14] Although the here presented understanding of urban systems is not based on Niklas Luhmanns theory, it does adhere to several aspects of Luhmann's definition of systems, e.g.: self-referentiality, autopoiesis, binary codes and environmental communication. Compare with Luhmann 1987.

[15] Compare with Johnson 2009.

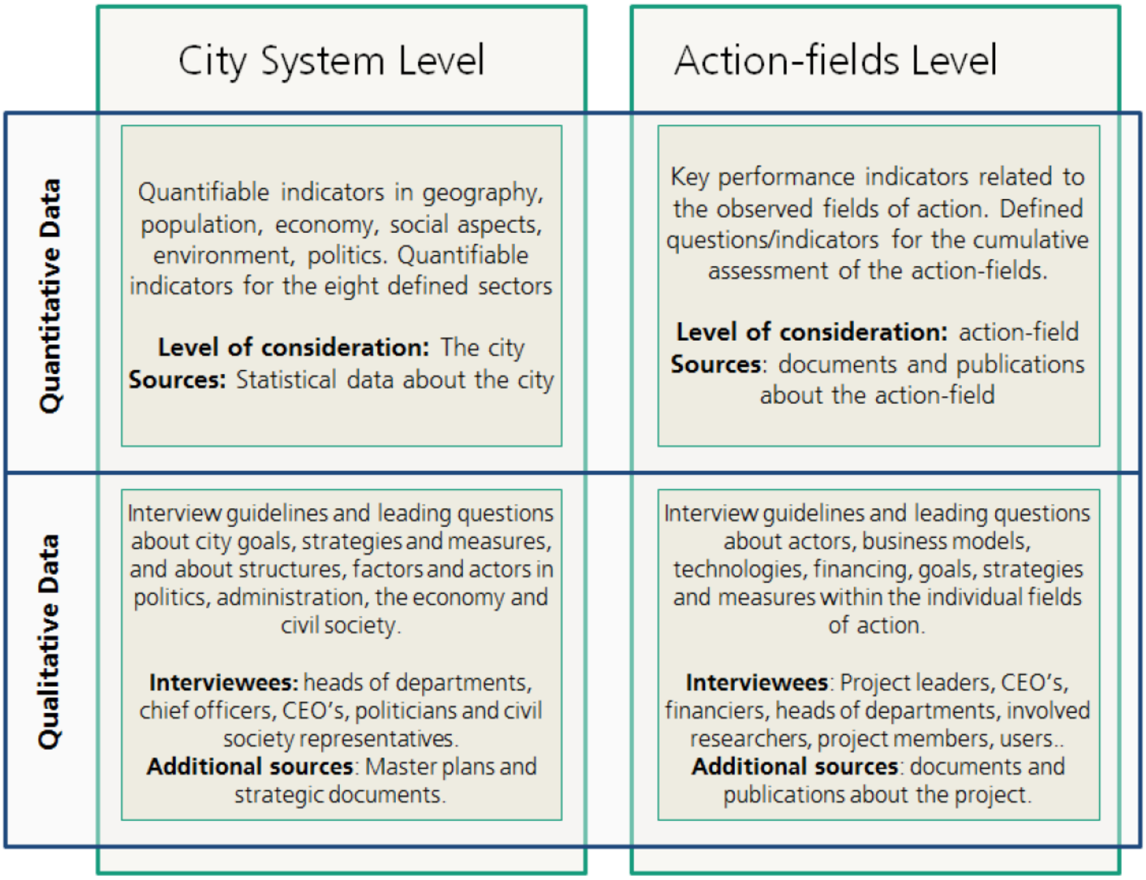


Figure 10: Classification of the basis for data collection on both levels of analysis

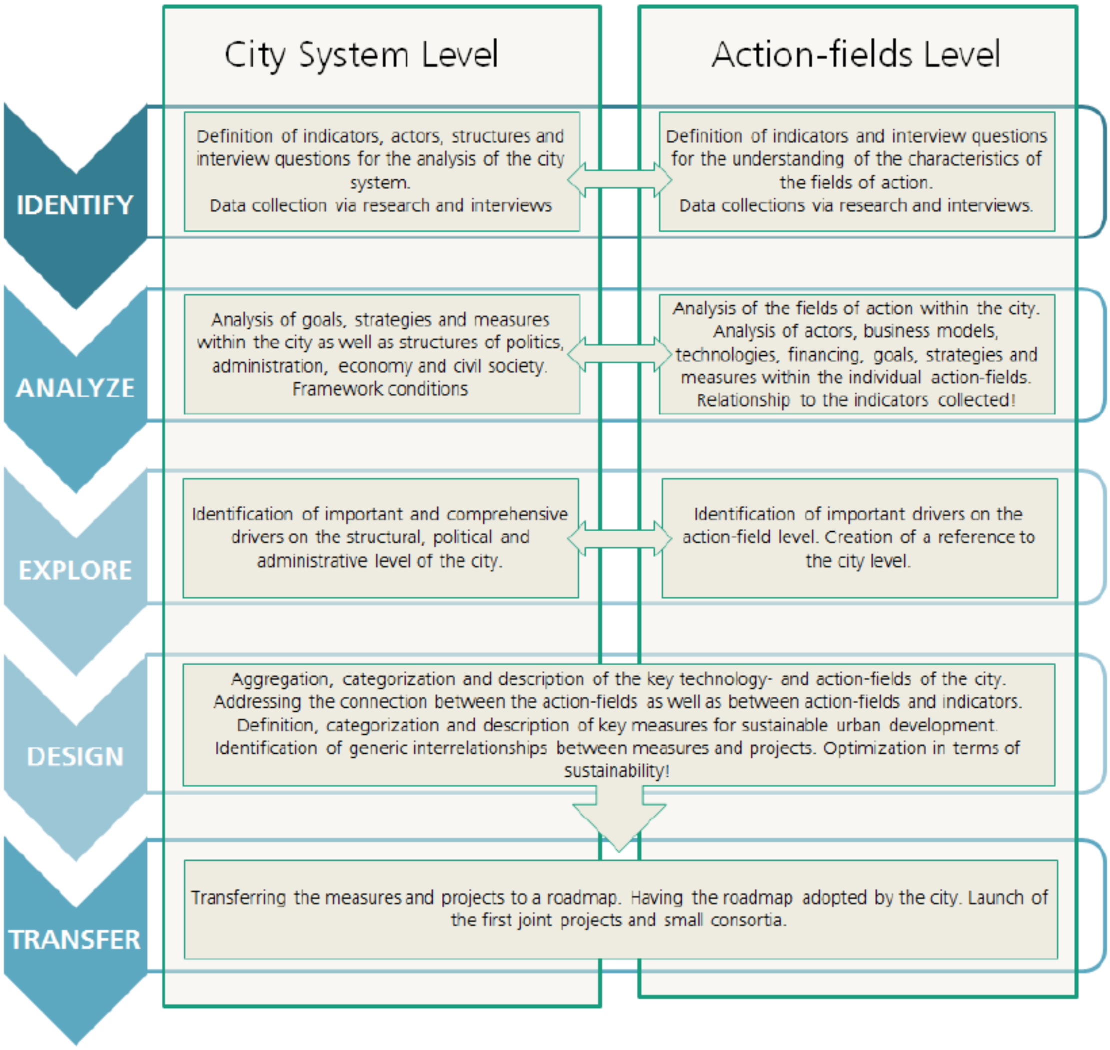
A separate template, which defines the data and information to be collected and simultaneously acts as the place in which to enter this data into a central database – in which all quantitative and qualitative data about the cities of interest is gathered –, is created for each quadrant in Figure 8. Thus, the following documents are available as tools to the research team before data collection begins:

1. A list of the indicators to be analysed on the city level.
2. A template for the collection of indicators and success criteria for the 83 defined fields of action.
3. An interview guideline for the city system level, with questions for heads of departments, politicians, chief officers and civil society representatives.
4. An interview guideline for the technology- and action-field level, with questions for project leaders, CEO's, financiers as well as others involved in the project and users.

In order to horizontally link the quantitative data and the qualitative information, which were generated on different levels of analysis, the continual comparison of the collected data as well as the continual analysis of the overall city system – and the relationships and interconnectivity of individual components within it – is necessary.

Based on the foundation of system and sensitivity analysis[16], as well as on hypothesis-based structured group discussion[17], an appropriate procedure was developed, based on the following two key components:

a) Structured daily reflection and system analysis within the research team: Each researcher is asked to continually test the information gathered – through document analysis, interviews, informal conversations and viewings of projects – for consistency and plausibility and, when possible, to identify interconnectivity with other projects and previously identified drivers on the city level. A daily 2-hour team meeting serves to identify systemic relationships and to capture these graphically.
b) Two full-day workshops in the cities being researched ("Morgenstadt Labs"): A unique workshop design was developed, and successfully tested, for the Morgenstadt Labs. It allows the researchers to cross-examine their own assumptions about drivers in the city and provides them with the opportunity to both compare and enrich their ideas and analyses with knowledge and information from the other disciplines. The starting point is the formulation of at least two contestable hypotheses by each team member regarding identified drivers and possible strategic projects and measures. A structured discussion about these hypotheses, following a specific set of rules, allows for the discovery of systemic inter-relations and future technology- and action-fields.



[16] Compare with Vester 2003

[17] Hypothesis-based group discussion, as a method, is based on dialogue-oriented approaches for the analysis of complex systems. See Bojer 2008.

Figure 11: Integration of the four levels of analysis within the 5-step research approach[18]

The entire approach to collection and analyses was based upon the hermeneutic circle[19]. Thus, an iterative analysis of system elements (action-fields) and the system as a whole (the city) leads to a deeper systems understanding of the relationships and driving mechanisms between the city and an action-field. In doing so, a multidisciplinary research team passes through several analysis- and understanding-cycles within the space of a 5-month period, with the goal of generating interventions based on an understanding of the system elements and relationships within the sustainable development of a city.

- A preparatory phase of ca. 2-3 months allows the researchers to familiarize themselves with and begin understanding the city and its action-fields. To facilitate this, a „City Guide“ is created for each research team. It contains important information regarding the history, geography, population, politics and economy of the city as whole as well as individual sectors within it.
- A 2-week intensive on-site research phase makes up the core of the systems analysis in each of the cities. During this time, data is collected daily, interviews are held and site visits of projects and solutions are conducted. Based on the understanding gained in this first on-site research step, as well as the researchers own disciplinary knowledge, each team member develops hypotheses about the inter-relationships between the analysed system elements as well as possible solution approaches and future fields of action.
- A 2-3 month design phase aims at creating a strategic roadmap from the identified drivers and action-fields, and ensuring that the measures and projects are coordinated with one another in the most advantageous way..

3.2.2.5 Methods used during data collection:

Generally, one can differentiate between primary and secondary collection methods. In the former, data is collected specifically for the purpose of the research, while in the case of secondary collection information is gathered on the basis of existing documents and data that has already been collected or aggregated for other purposes.[20]

The data required for the City Labs originates from multiple sources and a plenitude of qualitative and quantitative data. This implies a mix of methods used for the complete collection of the data and information. The information and data needed for a subsequent and comprehensive analysis are defined in advance and collected successively with the help of a template. The mix of methods stipulates beginning first with secondary collection, then subsequently supplementing missing information via primary collection. The following methods are thereby employed:

- **Secondary data collection 1: internet research**
  two types of information will be collected via intensive internet research: a) existing data about defined indicators on the level of the city (e.g. on the websites of statistical departments, in yearly reports by city actors or on the web pages of municipal utilities or departments) and b) current strategic city documents (master plans, land use plans, infrastructural plans, urban development strategies, climate protection

[18] m:ci depiction

[19] The hermeneutic circle originally came from epistemology and claims that an iterative discussion about the object of research can lead – through the detailed "fore-structures" of understanding by individual parties – to an almost complete understanding of the object of analysis. The circle was originally used mainly by the humanities, in order to facilitate the structured analysis of texts. See Heidegger 1979; Universität Duisburg 2010.

[20] See Daenzer 2002, S. 125f

strategies, political foundational documents) as well as documents and information about the individual best practice projects.

- **Secondary data collection 2: document analysis**
  The targeted analysis of those documents identified via internet research, in terms of previously defined information and data, serves to reach a comprehensive and structured understanding of both levels of analysis. In doing so, attention will be paid to possible contradictions, inconsistencies and plausibilities. Further, the document analysis will serve as preparation for primary data collection and to supplement the general guideline by way the addition of specific and detailed questions. The document analysis engaged in here is explicitly not based upon extensive qualitative content analysis;[21] rather, it serves as a source for the collection of specific information and data defined in advance. Therefore, the careful selection of documents – in terms of their rating, quality and validity with respect to the research approach – is important.

- **Primary data collection 1: guideline-based expert interviews**
  The detailed level of understanding necessary for the analysis of the action-fields as well as the city-level strategies can only be generated by way of direct conversations with experts. To facilitate this, guideline-based expert interviews are used.[22] The identification of experts is based on their declared role within the studied best practice project, that is, their role within city governance. Two guidelines are developed to structure the interviews:
    - Guideline 1 addresses the **city system level of analysis**. This guideline facilitates the questioning of high ranking members of the municipal administration (department heads and chief officers) as well as representatives of the political operation of the city (delegates, members of parliament).
    - Guideline 2 addresses the **technology- and action-fields level of analysis**. This guideline facilitates the questioning of project leaders, CEO's, financiers, department heads, involved scientists, project members or users of the solutions being studied.

Both guidelines consist of a general and predefined section, as well as a section containing questions that have been tailored to the individual interviewee, based on the document analysis conducted previously.[23]

- **Primary data collection 2: (participatory) observation**
  All researchers and experts involved in the data collection process are encouraged to, when possible, to evaluate the action-fields to be analysed via participatory observation.[24] This is normally achieved by way of tours and viewings. The goal is for each Fraunhofer expert to be exposed to the functioning of the project, that is, to base their assessment on direct observation. In the case of an innovative public transit project, for example, participatory observation may consist of the researcher actually trying out the services offered and documenting their impressions. In the case of an innovative energy supply solution, the most important system components should be viewed and their functions understood, etc. The observation occurs in a partially structured manner, based on a previously defined template about the best practice project which functions as a checklist. Additional, and deeper, observations are based on the experience and knowledge of the individual expert.

[21] See Mayring 2002.

[22] For more information on the methodology of expert interviews see Bogner 2009 and Gläser and Laudel 2010.

[23] For more detail on the methods of guideline-based interviews see Atteslander 2010 and Gläser and Laudel 2010.

[24] To learn more about scientific observation as a method, see Greve and Wentura 1997 as well as Girtler 2001 and Martin and Wawrinowski 2014 for participatory observation in particular.

All observations, and the information collected in this manner, are systematically documented and prepared for further use in subsequent analyses.

In all cases, **data collection** occurs manually; either directly into the allocated input mask of an IT-supported data base, or first as written documentation which is then transferred into the data base at a later time.

Expert interviews are – provided the interviewee agrees – recorded on audio media, in order to enable the subsequent recording of the information within the data base. Complete transcripts of the interviews are not created, for reasons of efficiency. The interviews are recorded in writing, and only the key statements are captured word-for-word.

3.2.2.6 Methods of system analysis

Data collection and data analysis occur partly in parallel. This is, particularly in the case of the on-site research, unavoidable in order to a) utilize the available time in the most efficient manner and b) follow the postulated rules for systems analysis leading to a deeper understanding. In addition to a number of content analysis methods (qualitative content analysis, technology assessment, plausibility analysis, technological comparative analysis, discourse analysis, semantic analysis etc.), which fall within the disciplinary areas of individual researchers and are applied dependent upon the object of analysis (action-field, technology, project), the following methods are applied by the entire research team in order to identify and describe drivers and to recognize systemic connections:

- **Structured self-reflection and group discussion**
  Each team member is asked, on a daily basis, to answer the following questions for the rest of the research team:
  1. New understanding: "What surprised me today?"
  2. Drivers: "Which drivers, relevant to my areas of research, have I identified today, and how do they act?"
  3. Interfaces: "Where have I identified important interfaces between sectors and/or actors?"
  4. Discovered barriers: "Where is the process being blocked, where is the challenge?"

Based on the answers to these questions, a daily discussion takes place amongst the research team. This leads to the identification of synergies and driving mechanisms which are then evaluated on the basis of the increasing experience and understanding within the team.

- **Hypothesis development**
  As described within the research design on page 11, the independent creation of hypotheses about the object of research by the involved researchers represents a premise for the deepened understanding of the system. Hypotheses are defined as statements "[...] which postulate a correlation between at least two variables."[25] Usually, these take the form of attempted explanations or solution approaches, which – based on identified connections – are plausible, but have not yet been empirically verified. They should, however, be empirically testable.[26] To support the development of hypotheses, each researcher is given a set of questions which are based on generic elements of the analysis.

- **Structured and rule-driven group discussion**
  For the hypothesis-based group discussions within the frame of the "Morgenstadt Labs" within the Morgenstadt City Insights Phase 1) a special workshop design was developed and tested. The

[25] {Schnell 2011 #269 , S.53}

[26] See Atteslander 2010, S.49.

development of this approach occurred in an iterative manner and with the collaboration of experts[27] from the fields of city planning, technology management, sociology and organizational psychology. The goal of the design is to offer a structured and trans-disciplinary round table process with which to enable the on-site exchange, analysis and further development of the researcher's results.

- **Mind mapping**
  The identified system elements, and their relationships (technology- and action-fields as well as drivers), are first graphically documented by the research team with the help of mind maps. This successively leads to a comprehensive mind map for each city, which is worked upon, elaborated and expanded by the research team on a daily basis.[28]

- **System analysis**
  Based on the mind maps, the next step involves the application of a number of methods taken from systems analysis in order to demonstrate the relationships between individual system elements (technology- and action-fields, city system level and drivers) and to achieve an estimation of the importance of individual elements.

Within the pertinent literature, a rough distinction is made between two types of systems analyse which are based upon different traditions within systems thinking: "hard system analysis" and "soft system analysis."[29] "Hard system analysis" assumes the world is made up of mathematically tangible systems, which can be modelled and designed. System dynamics, quantitative modelling and simulation based on mathematical models are the key methods used in this approach.[30] The systems understanding upon which "soft system analysis" is based assumes that a detailed and mathematically exact representation of socio-technical systems is problematic, but that complex adaptive systems can be understood with the help of system models. In doing so, it claims that the true leverage "lies [...] in an understanding of dynamic complexity, not detailed complexity".[31] Impact diagrams, qualitative models and the ordinal evaluation of relationship intensities are the preferred methods employed by "soft system analysis."[32] This dissertation is based on a "soft system Analysis" understanding of systems and thus opts not to employ mathematical procedures or the simulation of systems using system dynamics.

The key tools employed for this system analysis are causality diagrams and cross-impact matrices. Causality diagrams are created by entering the relation of individual system elements to one another in order to make cause and effect visible. The systemic correlations between the individual elements are made more obvious with the help of directional arrows. Based on an analysis of these relations, a prioritization of action-fields and drivers is generated.[33] These causal diagrams additionally assist in the identification of important feedback loops. Positive feedback loops, which lead to self-reinforcing mechanisms (e.g. exponential growth), inhibitory or promotional causal impact chains and negative feedback loops – which can lead to exponential shrinkage – can thus be identified for the best practices being researched.

A cross-impact analysis of identified technology- and action-fields provides insights about the strength of the relationships between individual fields as well as their character and importance. Cross-impact analysis can be traced back to the systems theorist Frederic Vester. It is a method which is employed in order to structure

[27] Alanus von Radecki (Fraunhofer IAO), Prof. Heiko Roehl (Univ. Freiburg), Steffen Braun (Fraunhofer IAO), Dr. Dominik Kalisch (Fraunhofer IAO), Gerhard Stryi-Hipp (Fraunhofer ISE).

[28] The use of mind maps as an epistomological tool and scientific method in this research is based on the work of Buzan 2005, Eipper 1998 and Hugl 1995.

[29] See Mingers and White 2010; Checkland 1983.

[30] See Miller and Page 2007 and Mingers and White 2010. A good example for "hard system dynamics" is found in Howick and Whalley 2007.

[31] Senge 2011, p. 92.

[32] See Vester 2012

[33] For more detailed information about methods of system analysys see CRGRAPH 2012.

complex impact interactions and to estimate action intensities within a complex adaptive system.[34] In doing so, the degree of impact each element exerts on each other element is estimated on a scale of 0-5 and, subsequently, the passive sum and active sum of each element is aggregated.[35]

Due to the differentiation made between two different system elements (action-fields and drivers) an influence analysis of the drivers based on cross-impact analysis takes place, instead of a cross-impact analysis of the action-fields. In doing so, the identified drivers are cross-tabulated and differentiated with one of the following values: 0 = no impact, 1 = direct impact, 2 = indirect impact. The depiction of results obtained in this manner occurs in the form of plot-diagrams.

3.2.2.7 Structure of the on-site research

After an initial preparatory phase, a team of experts (the "City Team") travels to the selected city in order to spend at least two weeks answering the research questions and deepening their understanding on site.

A rough description of the two-part research stay follows. As shown in the figure above, an interdisciplinary workshop, the so-called Morgenstadt Lab, is planned for the end of each week.

Week 1:

Each member of the City Team spends the first week interviewing experts within their particular sector, analysing best practice solutions and fields of application within their area and documenting and interpreting the data collected. In parallel, each member of the City Team develops hypotheses about the identified drivers as well as possible measures and future solutions for the sustainable development of the city.

Near the end of the first week, the entire city team conducts a joint one-day workshop. This is called the "Morgenstadt Lab I". The point of this workshop is to discuss and verify the insights won and hypotheses formed with experts from other sectors as well as local experts. The goal is to analyse and describe success factors relevant to the city-level, as well to identify solutions and potential measures for the future. In this way it is possible to identify patterns and structures that have an effect on the city.

Week 2:

The second week is dedicated to more in-depth data collection. Using insights resulting from Morgenstadt Lab 1, additional interviews / analyses / observations are conducted in the individual sectors. The interviewees may be new, however, the goal is to consult previously interviewed individuals with questions of deeper understanding. All data collected is simultaneously documented.

The second workshop, "Morgenstadt Lab II", occurs at the end of the research stay. This workshop uses the same methodology as was applied in Morgenstadt Lab I. In addition, urban boundary conditions and framework factors, defined at an earlier point, will be analysed in terms of their relevance for the city of interest. The goal is to capture and document the most important drivers on the level of the city.

[34] See Vester 2012.

[35] For additional information about cross-impact analysis methods see Cole 2006 or Vester 2012, p.184f.

3.2.2.8 Research process

The research approach has been selected to provide each City Team member with the ability to start by analysing a number of technology- and action-fields independent of one another, by way of interviews, while nevertheless working within a joint framework.

The collection of relevant data and the execution of the research is the responsibility of the individual City Teams.

Overall, the selection of this research approach ensures the collection of data regarding all relevant topics, such as technology, needs, processes, regulations, business models and sub components occurs in relationship to one another. This is important for the comprehensive evaluation of the data via the methods described above.

3.2.2.9 Data Analysis and Results

The in-depth analysis structured in three levels of analysis is important to understand the current sustainability performance of cities and come to coherent strategies and an integrated roadmap for development. A mixture of quantitative benchmarks and qualitative data analyses makes sure that an objective performance profile of the city can be generated by at the same time respecting the individual factors of the city that make a direct comparison with other cities difficult and point towards an individual strategy for Prague.

By applying the Morgenstadt Framework researchers analyse three different levels:

1. Indicators
2. Action Fields
3. Impact Factors

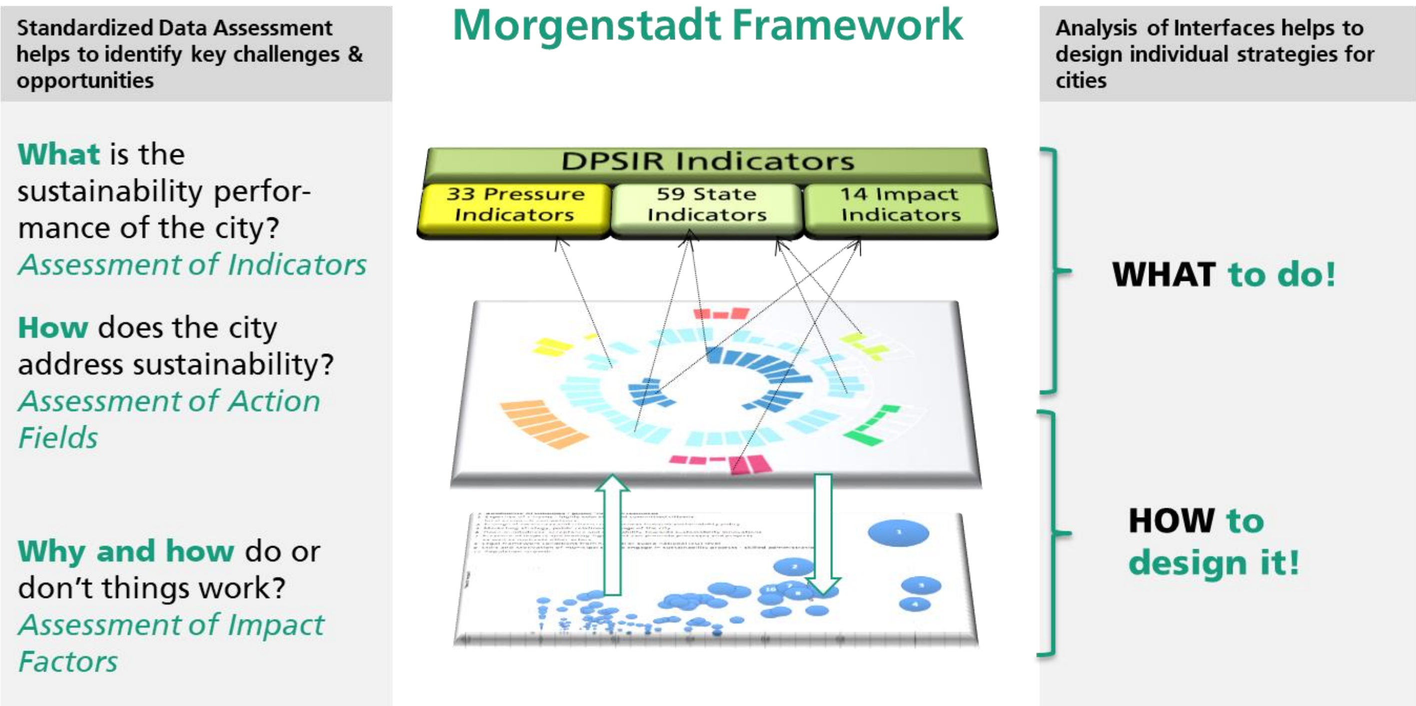


Figure 12: Overview of Morgenstadt City Lab Framework

The analysis of the data is following the larger fields of urban development and helps identify strengths and weaknesses within the city. Throughout the analysis the City Team assesses the current status of more than 80 action fields that are important for a sustainable urban development. In addition, over 100 indicators are assessed in order to check the pressures that impact on the current state of a range of sectors in the city (mobility system, energy system, socio-economic parameters, security system, water-infrastructure etc.) and the current impact that the city has on society, economy and environment. Large parts of the indicator-based assessment were following the ISO 37120 International Standard on city indicators.

Interviews with stakeholders help to create an analysis of systemic impact factors that help understand external pressures, underlying forces, dynamics, socio-cultural and historic implications that are present within a city and impact (often unnoticed) on decisions, structures, strategies and measures taken on the city level and on the project level. The integration of members of the city hall into the entire assessment and project development process was designed as a capacity development process for the local counterpart team, making sure that knowledge and expertise about the methodology, the technologies and the process is being formed to enable a strong sense of local ownership and a strong uptake of projects after the roadmap has been delivered to the city.

The results of the analysis are gathered in a report, consisting of an overview on the current state of the city and the city profile that graphically shows the results of the analysis (action fields, cf. Figure 13).

The results of each of the topics is separately evaluated by the experts to find the critical and semi-critical indicators and problems, the city should tackle. It may also happen that there is a good reason why some results seem to be critical at the first sight.

3.2.2.10 Developing the Roadmap

To take the first step from analysis to action, the Morgenstadt approach builds on an integrated reference of indicators and action fields. Each indicator is compared to a benchmark to find out the critical ones. The results of the analyses are displayed in a diagram such as the one shown in Figure 13. Each colour represents a different area of action, such as energy, mobility and governance. Each of those categories has several sub-categories in which the relation to the benchmarks is displayed by the filling of the individual bars.

After the cross- integration of all analysis, close collaboration with the experts and discussions and workshops with stakeholders the city team creates a comprehensive list of measures that are suggested for implementation. Ideally, all measures are interconnected with each other and should be developed and organized in a way that respects the systemic character of the suggested roadmap. There are causal interrelations, but also interrelations based on time, resources, stakeholders and technologies to be deployed during implementation. The roadmap should therefore be closely discussed in relation to an overarching strategic management of a sustainable development of the city.

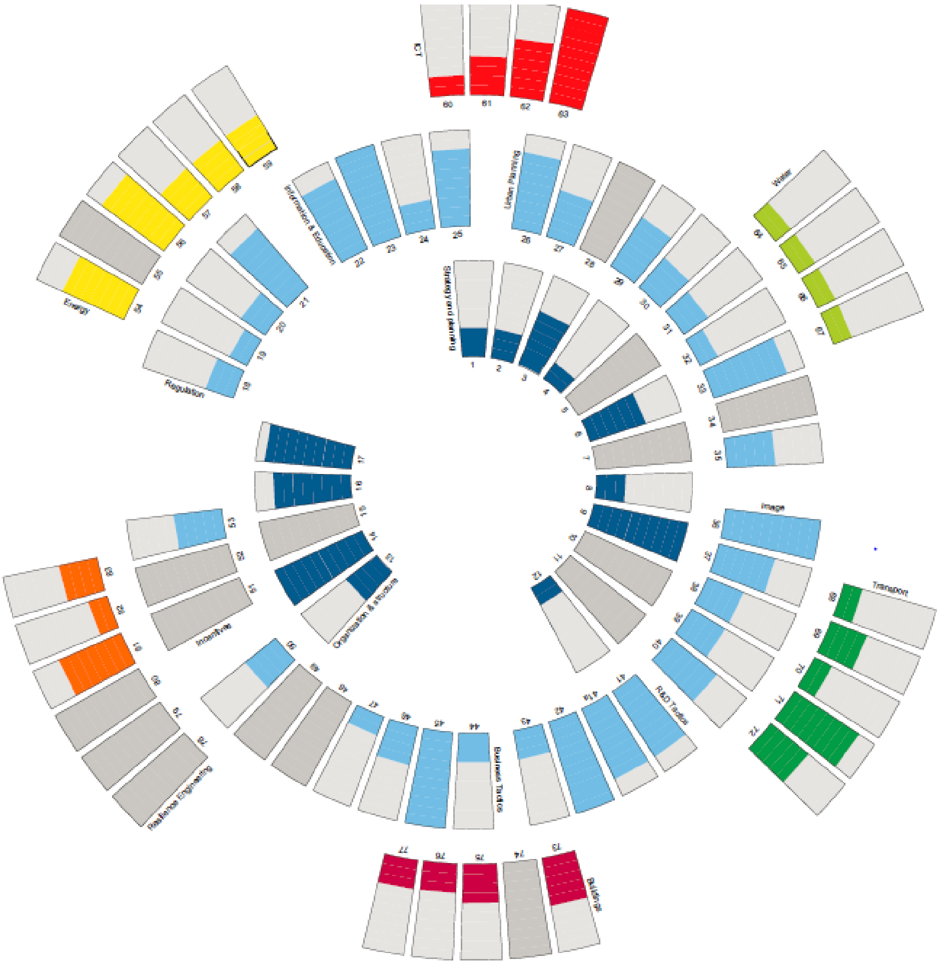


Figure 13: example result diagram from Morgenstadt City Lab Approach

4 Methodology description

The overarching goal of WP6 and the Triangulum project is replicating the technology based implementations from the LCs to the FCs. This includes both, reusing the insights and proven results gained within the LCs and supporting the FCs in the process towards implementation. This framework (Task 6.6) collects the results and processes from Tasks 6.1, 6.2, 6.4, 6.5 and 6.9 in order to directly support Task 6.7.

Following the above description, the replication process within Triangulum is structured two-ways:

1. A process to structure the learnings within the LCs and provide it to entities that want to replicate: the **“technology transfer approach”**
2. A process to support FCs in developing their own customized Implementation Strategies: the **“customer centric approach”**

The **technology transfer approach** is given through the setting and agenda of the Smart Cities and Communities program. At its core it aims to grab the learnings from the implementations within the LCs and provide actionable insights in meaningful formats to the FCs. Through intensive direct exchange with the representatives of the FCs it became clear those insights can by no means be limited to the technologies themselves – instead also have to contain for example:

- In depth knowledge about processes, milestones and decisions
- The reasoning of why a specific technology has been chosen
- local supportive factors
- business and financing models
- relevant stakeholders and their roles within the project
- lessons learned
- primary and secondary benefits provided

As discussed before technology within the replication process shall be seen as an enabler to achieve the goals a city has set itself. The unit that was introduced is the Smart City Module. The concept of the Holistic Value Model includes information about the technology, linked and necessary technologies, the corresponding processes, the business model, stakeholders and their roles as well as a wide range of direct and indirect benefits.

One can easily spot the overlap of information between the theoretical concept and the practical information required by the FCs. When collecting the information the researcher has to choose between the level of generic technology based solutions or practically implemented Use Cases. To satisfy the need for actionable information, the project team chose the latter to be the unit of replication within Triangulum. This enables the project to provide more information on actual impacts and lessons learned. An in-depth description on the unit of replication can be found in Chapter 5.3.

It has to be acknowledged that the way the Holistic Smart City Value Model was practically executed in Triangulum is mainly on a descriptive basis (i.e. structured information being provided on all those levels). Transferring Smart City Solutions in a structured process was carried out through the FCTM, dedicated and driven by the needs and opportunities within the FCs and not driven by the holism of the concept described in Chapter 3.1.

Within the original proposal it was only thought to gather and transfer the knowledge of the implementations directly funded within the Triangulum budget. However to increase the potential impact and only possible through the increased efforts of the LC partners, Use Cases closely linked or in any way relevant to the FCs were also added to this line of action.

An additional source of information became available during the course of 2017: with the cooperation agreement between all Smart Cities and Communities Lighthouse Projects being signed, the implementations of those projects came into reach. However with the Implementation Strategies of the Triangulum FCs being due in early 2018, the structured gathering and transfer of these information would take too long to be taken into consideration. However it was ensured that available information were provided and used in the best possible way.

The technology transfer approach is feasible not only transfer the knowledge to the FCs of Triangulum, but also to FCs from other lighthouse Projects or any other interested parties. In fact the template used within Triangulum was shared and discussed with the other SCC01 projects and is now used in the joint Replication Task group.

The information provided through the first approach help the FCs to create points of condensations to start the process of becoming a Smart City. It is not only possible but supported in all possible ways that the Triangulum FCs develop an SCIS fitting the needs and vision of their own cities. Any transfer of knowledge is therefore supportive and not imperative.

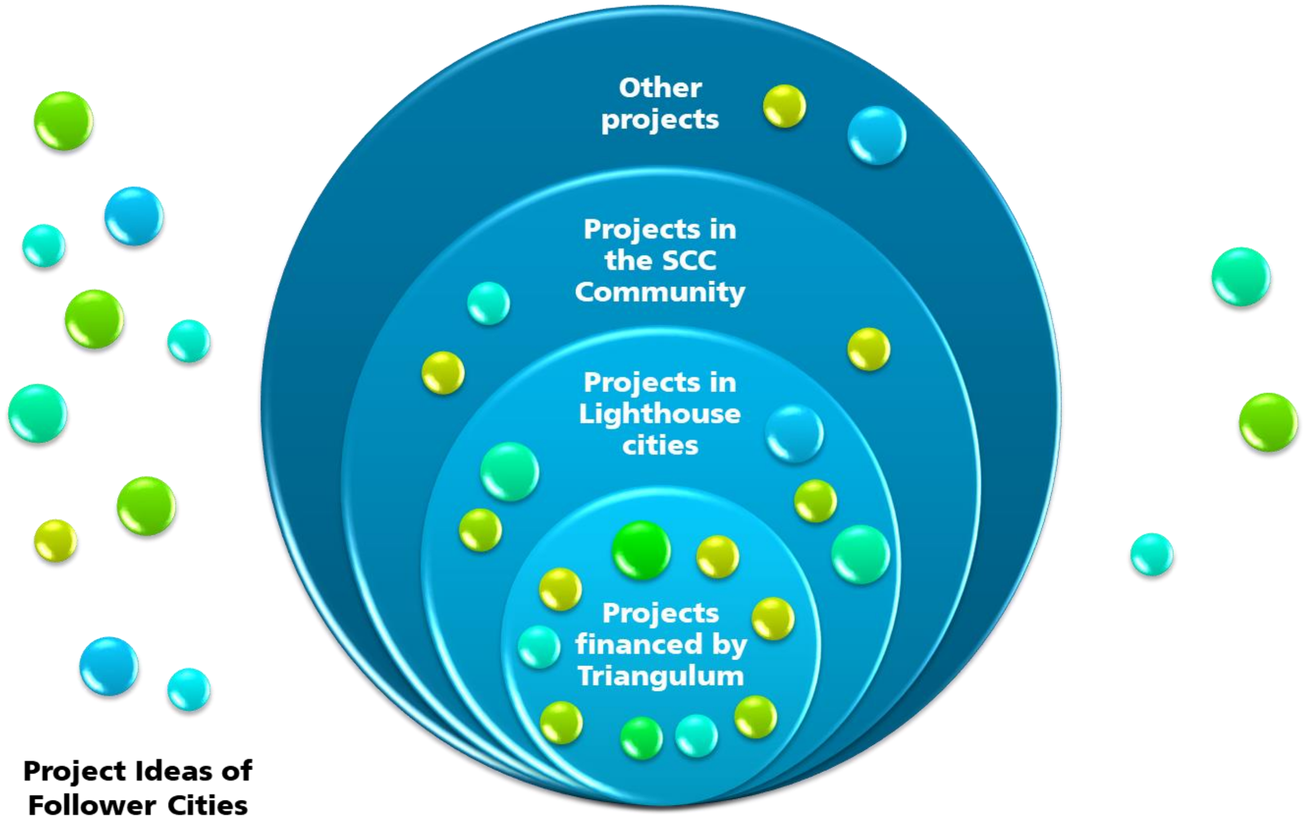


Figure 14: sources of inspiration and information for FC implementation projects

In order to support this process, a 2nd integrated approach was planned and executed as part of the replication process: the **"customer centric approach"**. This was the outcome of intense discussions with the FCs after the on-site visits in the LCs and FCs. It is designed to help the FCs getting ready to process the information and create their own SCIS consisting of a variety of different projects, both taken from Triangulum and other sources:

- Supporting the local administration
- Enabling the political procedures

- Enabling and including the ecosystem incl. the corresponding culture
- Taking cultural differences into account
- Allowing chance and random actions to influence

In order to support this process in the most impactful way, the FCs directly stated their city specific needs to the WP6 team. The team then designed a process to deliver the needs as part of the FCTM.

Within an on-site visit to each FC, a City Lab process as described in Chapter 3.2 was performed. The process includes local relevant stakeholders into an ideation and co-design process based on a quantitative analysis of the city needs. The ideation also showed significant potential for the use of Use Case related information that were not financed directly by Triangulum. To leverage on this potential, information from outside Triangulum were provided to the FCs as displayed in Figure 14.

The FCTM is the vehicle that helped to transfer the knowledge and also allowed for the FCs to receive direct feedback to their own plans. The program was executed during the year 2017 and is described in more detail in Chapter 6.2.

The main difference between the **technology transfer approach** and the **customer centric approach**, is the starting point – both however shall lead to implementations within the FCs. The starting point of the technology transfer approach is the realized implementation of a smart technology or process in a city, whereas the customer centric approach starts with the identified and stated needs of our customers: the FCs. A comparison of the process and steps of the two approached is displayed in Figure 15.

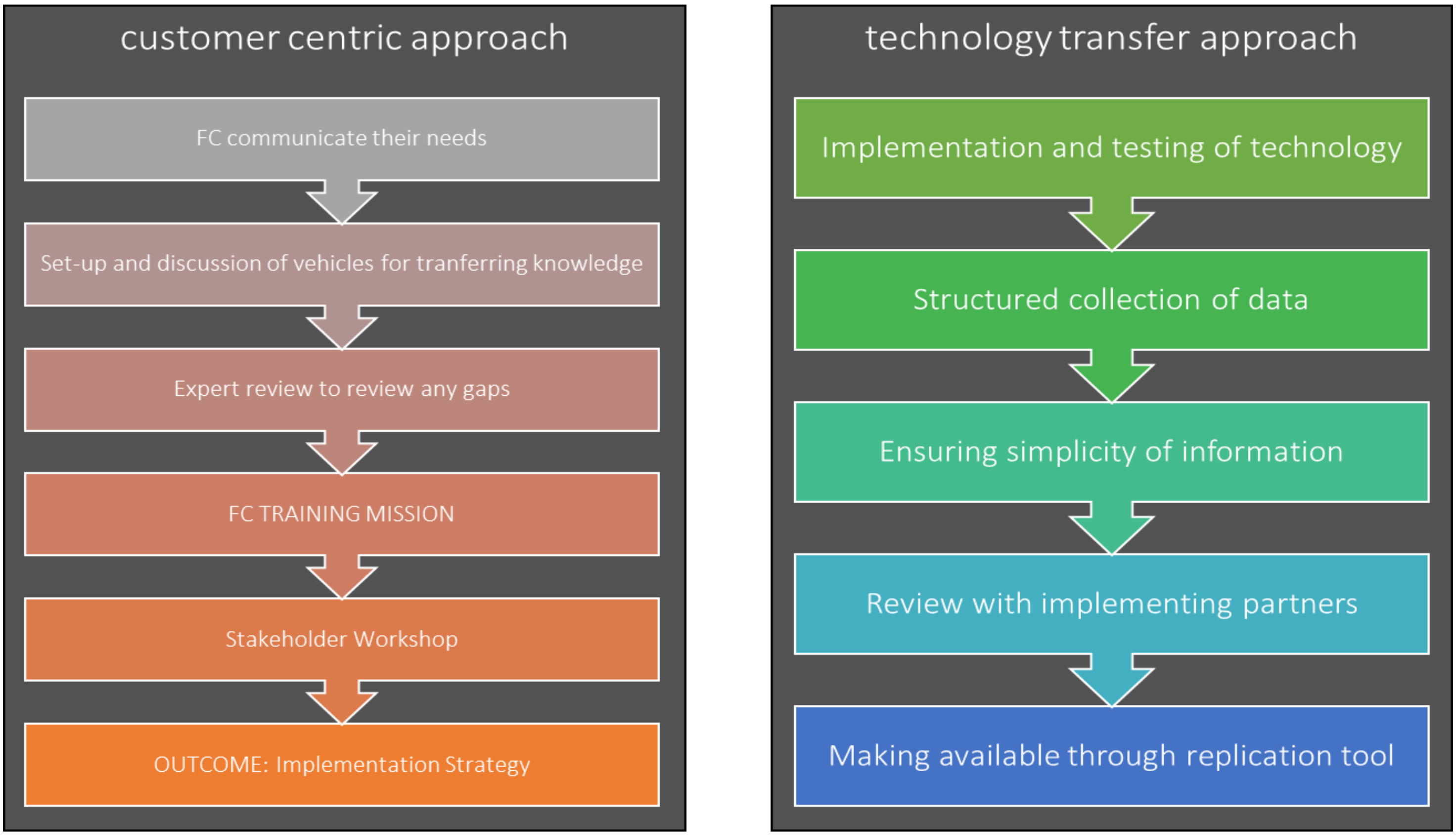


Figure 15: comparison of customer centric and technology transfer approach

The source of information for both approaches however is the same. It comes from knowledge and insights gathered by the Triangulum partners during Smart City implementation projects within the LCs, mostly within the parts financed Triangulum. The crucial importance of practitioners from both city administrations and from the industry partners for this process cannot be overstated. Their experiences on trial and error are the sole source of practical knowledge fueling both the customer centric and technology transfer approach as displayed in Figure 16.

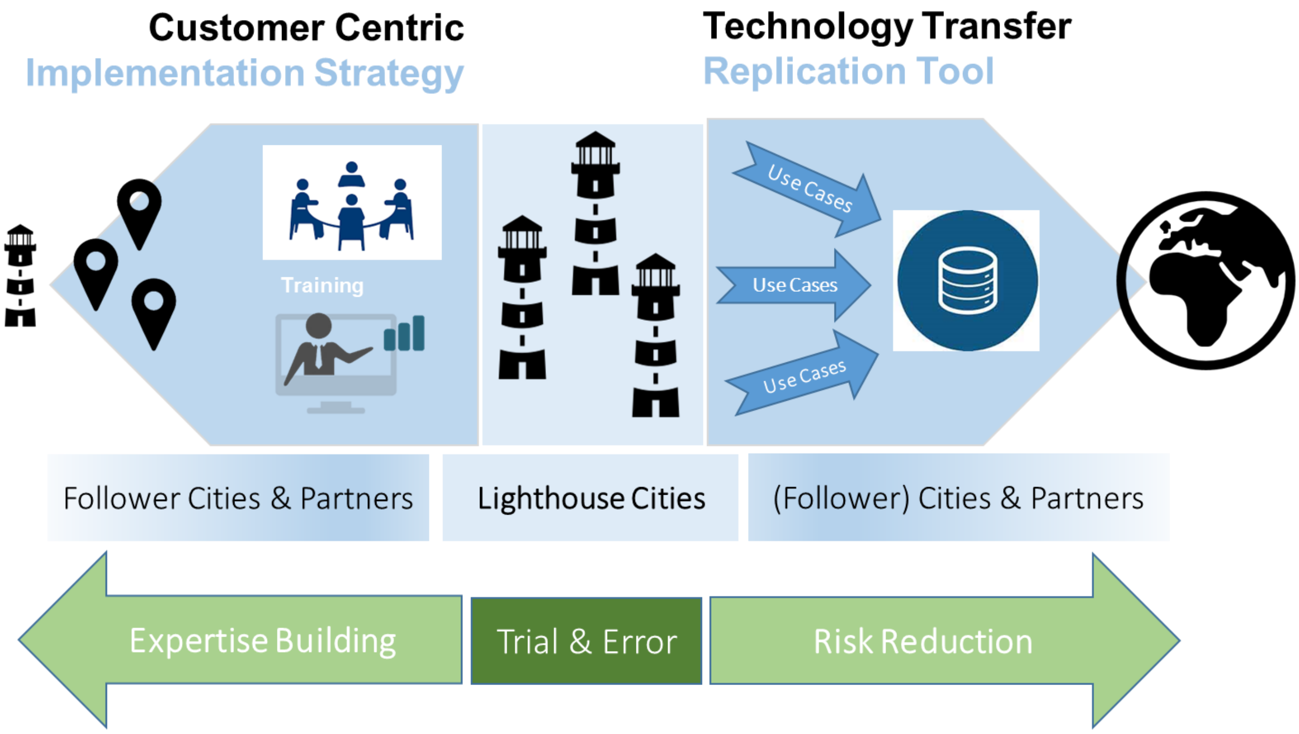


Figure 16: LC implementation projects as source of information for the whole replication process

Chapter 5 will now introduce the technology transfer approach in all detail, containing the process of gathering information on pre-conditions and other relevant information, as well as in-detail information on the implementations. It will also explain why Use Cases have been chosen as the unit for replication. In addition it will show the structured template including all before named information for the Use Cases with ICT information being shown by a newly developed Reference Architecture. If available, the template also already includes first results from the monitoring of WP2.

Chapter 6 then introduces the customer centric approach with the analyses results of the FCs, the stated and defined needs and the FCTM as the process of information transfer.

5 Technology transfer approach

The technology transfer approach gathers structured information on the implementations within the three LCs. It is the process that is the basic principle of the Grant Agreement regarding replication: to transfer the learning from publicly funded implementations in LCs to FCs in order to decrease the risk of other cities planning to implement similar technologies.

As shown in Figure 17 the process starts with collecting a variety of information (cf. Chapter 4) relevant to be transferred from the LCs to the FCs.

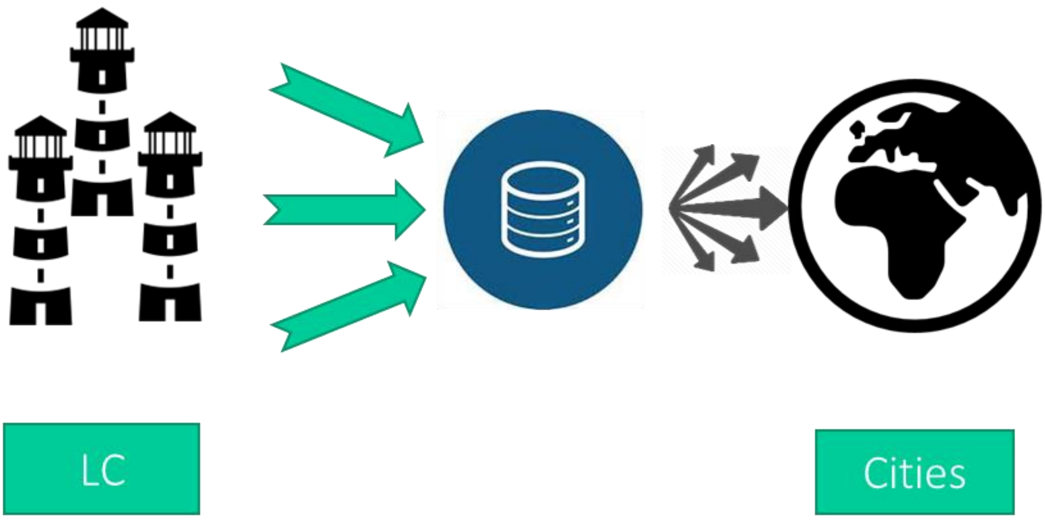


Figure 17: overview of the technology transfer approach

Chapter 5.1 described the process of gathering relevant data including context data within the LCs in two on-site visits.

Chapter 5.2 displays the relevant context information for the three LCs Eindhoven (NL), Stavanger (NO) and Manchester (UK). Those include a brief insight into their history, a few chosen relevant Smart City Projects, insights into the innovation ecosystem and the indicator analysis amongst others.

Chapter 5.3 discusses the different possible units of replications and justifies the “Use Case” as the most suitable one. It also introduces a template to capture many relevant information regarding the Triangulum Use Cases.

Chapter 5.4 introduces the ICT Reference Architecture as a structured way to classify and catalogue the Smart City Use Cases. It captures interfaces, data formats and protocols and provides an overview of the design of a Use Case at a glance.

Chapter 5.5 introduces the Cloud Data Hub as a mean to gather and process quantitative information for monitoring Use Cases.

Chapter 5.6 shows the full collection of the Triangulum related Use Cases with all relevant information including the ICT architecture and monitoring protocols.

Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.** introduces the Decision making tool helping to f ind the most relevant Use Cases to e.g. tackle city challenges, reach development goals or comply with EU/National regulations.

5.1 Data collection process in Triangulum

The data collection process for the technology transfer (i.e. within the LCs) approach in Triangulum can be divided into four distinct steps:

Step 1: pre-on-site analysis:

During this step quantitative and qualitative information on the city and district level have been collected following parts of the Morgenstadt City Lab Approach described in Chapter 3.2. The outcome was used as a basis to identify particular strength and therefore relevant transfer areas within each LC. It lead to an improved preparation towards the 1st on-site and an important input for the development of the whole Smart City Replication Framework.

Step 2: 1st on-site visit

The 1st on-site focused on the status quo of each city. Each LC was visited approximately 2 weeks within the first year of the project to discuss the current and future Smart City implementations of the city. The data were collected in individual interviews with the relevant stakeholder on technical, management and political level. The main goal of this step was to receive insights into the LCs to be able to define the scope of the data collection process of the 2nd on-site visit and to feed into the development of the Smart City Replication Framework.

Step 4: 2nd pre-on-site analysis

All the partners involved into implementing Use Cases within the LCs had individual 1.5-2h discussions with the WP6 and WP2 team on the status of the implementations and were updated on the status and proceedings of data collection within the replication process. The first draft of the standardized template that was used for the Use Case template was discussed and next steps agreed individually.

Step 4: 2nd on-site visit

During the last months of implementation the LCs were visited again for an approximately 2 week long on-site visit. During these visits structured sets of data were collected in different types of workshops. Those data contained: in-detail information about each Use Case, general pre-conditions, Smart City design principles, data on the innovation ecosystem and structured information for the ICT Reference Architecture. Most of these data are direct and final outcomes of the technology transfer approach and have in parallel been shared and distributed amongst the FCs.

The following sub-chapters provide a more in-depth overview of the four steps performed to collect the data for the technology transfer approach.

5.1.1 1st pre-on-site analysis

As an early preparation and for the FCs and the research team to receive initial insights into the strength and weaknesses of the LCs, an analysis of indicators according to the City Lab model described in Chapter 3.2 was performed. The focus during this approach was less to receive full datasets on a quantitative basis. The data collected contained some indicators as shown in Table 2 and documents such as strategies and policy documents from each LC.

Table 2: cut from the data input for the indicator analysis (example: City Indicators, General, Eindhoven)

Indicator name	Indicator scope	Units	Value
Total Area		m^2	88,870,000 m2
Population size		Inhabitants	212,000 people
Geografic factors (30 years period recommended)	Average temperature	°C	9.4°C
	Average rainfall	mm/a	741 mm/a
	Average sunshine hours per day	h/day	1604 hour/a
	Average solar radiation	KWh/m²	2.74 KWH/m2
	Average wind speed at 100m above ground	m/s	6.1 m/s
GDP of city	GDP per capita	€	33045,66

The data collected fed directly into the 1st on-site and are represented in the analyses results of Chapter 5.2.

5.1.2 1st on-site visit

The goals of the 1st on-site were to understand the story and reasoning behind becoming a Smart City, political and management processes, what it means to be a Smart City and receive a general but detailed understanding of the framework conditions behind a Smart City.

The two-week-long on-site visit included experts Fraunhofer, University of Stuttgart and TÜV-SÜD ImmoWert as well as representatives from the Follower Cities to each of the Lighthouse Cities. This core team was amended and supported by a local counter team of the city implementation team (city administration, local university and local business partners). Throughout the stay, 2 workshops with local stakeholders and ca. 25 structured interviews were conducted in each city with the involved stakeholders; between 30 and 50 people were interviewed. Topics covered were success factors and barriers out of the categories: Citizens and stakeholders; technologies and standards; ICT Reference Architecture; Policy & Planning; Business Models and Finance.

The trans-disciplinary analysis of results was an integral part of daily team-meetings, allowing for the development of a systemic understanding of the success factors, barriers and local impact factors of each city and each solution. Having read the revised implementation plans of the FCs, the workshops also covered internal trainings for the LCs and treated specific topics relevant for them to support the implementation of actions.

Research participants for workshops and interviews were selected through a process of expert/ purposive sampling thus the focus was on individuals with specific knowledge and expertise and the choice of research participants was theoretically driven. Experts were sampled from the institutions and organisations (public sector, companies, research institutions and civil society) which are identified through the contact with local representatives within the Triangulum Project.

The respective dates for these on-site visits are displayed in Table 3:

City	Dates of 1st on-site
Stavanger	30.11. – 09.12.15
Eindhoven	12. - 20.10.15

Manchester	11. – 20.01.16

Table 3: LC dates of 1st on-sites

Interviews were conducted on three different levels:

1. political level (to understand the agenda and roadmaps of the municipality)
2. management level (to understand the business model and strategic implications of the solutions)
3. technical level (to understand the bottlenecks and hands-on challenges and opportunities of the solutions)

According to the precondition of informed consent, , all participants taking part in the research were informed fully and meaningfully in regard to what the research is about and how it will be disseminated. This was done by providing a leaflet about Triangulum and the purpose of the research so that the prospective participants could make an informed decision about their possible involvement. In addition participants were supplied with an agreement in written form and asked to sign it off to ensure that the research is conducted in an open and transparent way.

5.1.3 2nd pre-on-site analysis

The goal of the preparation for the 2nd on-site visits were to present the first ideas on a single solution (later Use Case) template, explaining the process of gathering data and agreeing on action items for further replication. Researchers from WP2 (impact assessment) joined the appointments to increase feedback on available data streams and explain the process of data processing in the Cloud Data Hub.

All the partners involved into implementing Use Cases within the LCs had individual 1.5-2h discussions with the WP6 and WP2 team on the status of the implementations and were updated on the status and proceedings of data collection within the replication process. The first draft of the standardized template that was used for the Use Case template was discussed (cf. Table 4) and next steps agreed individually (cf. Table 5).

Table 4: excerpt from single-module template (2nd pre-on-site)

Standards & Technical Details

Service & Business Model

Input/Output Parameters	*optional*

Benefits *(please mark)*										
Nr.	Benefit	Mark (X if applicable)	Quantity measure	Unit	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6
1	Autonomy of fossile resources									
2	Reduction of carbon emissions									
3	Energy peak shaving									
4	Reduce energy bill									
5	Increased comfort for user									
6	Traffic reduction									
7	Enable new business opportunities									
8	Improved Data availability									
9	Increase in safety									
10	Behavioural change									
11	Expand knowledge									
12	Increased resource efficiency									
13	Better planning									
14	Better management of service providers									
15	Greater transparency									
16	Social integration									

Benefits *(please add)*										

Finanzing					
Actor		Cost		Benefit	Comments /Details
	Name	Investment	Annual Running Cost	Annual income/saving	
A1					
A2					
A3					
A4					
A5					
A6					
Total Sum					

Life span		*Years*	Implementation duration		*Years*
Life cycle cost		*Euro*	Share of public/external funds		*%*

Table 5: list of action items and timeline for solution template

Partner	Call date	Call time start	Call time end	filled in template sent until	Action items agreed during the call
Clicks and Links	28.11.2016	16:00:00	18:00:00	14.12.2016	• IAO send the 2nd version of the Reference Architecture to C&L • Clicks and Links is filling in the templates for modules identifiers (432 and 433) and works together with the University of Manchester

City of Eindhoven	29.11.2016	10:00:00	12:00:00	14.12.2016	none
Woonbedrijf	30.11.2016	09:00:00	10:30:00	13.01.2017	• IAO gives template "refurbishment" to KPN to fill in for private owners
Volker Wessels	01.12.2016	13:00:00	15:00:00	14.12.2016	• Chat project manager of one solution to fill out templates • VW fills out a few solution templates till 14th December and the rest based on preferences of FCs
Kolumbus/Rogoland	05.12.2016	10:00:00	11:00:00	13.01.2017	none
Lyse	05.12.2016	09:00:00	10:00:00	13.01.2017	none
Stavanger Kommune	05.12.2016	09:00:00	11:00:00	23.12.2016	not discussed
Manchester City Council	06.12.2016	15:00:00	17:00:00	23.12.2016	none
Siemens	06.12.2016	13:00:00	15:00:00	13.01.2017	none
University of Stavanger	09.12.2016	13:00:00	14:00:00	23.12.2016	• Meeting with ICT Reference Architecture in 2017 • Clarify interaction of UiS and ICT Reference Architecture

This phase was performed in order to allow in-depth and complete data collection during the 2nd on-site visit.

5.1.4 2nd on-site visit

The 2nd on-site visits to the LCs were the core and most important step of the data collection process. During the approximately 2 week long visits all information gathered in previous processes were finalized and additional information gathered where feasible.

The data collection processes were organized in workshop formats instead of interviews as it was in the 1st on-site visits. The 2nd on-site consisted of the following four workshop categories:

1. General Precondition Session (GPS)
2. City administration session
3. ICT Reference Architecture session
4. Module partner sessions

Figure 19 shows how the sessions were organized during the visit. In addition and as the last part of the on-site visits, the gathered information and knowledge was transferred directly and in condensed 1.5 days to representatives of the FCs. These sessions were called the FC Days and are explained in more detail in Chapter 6.2.1.

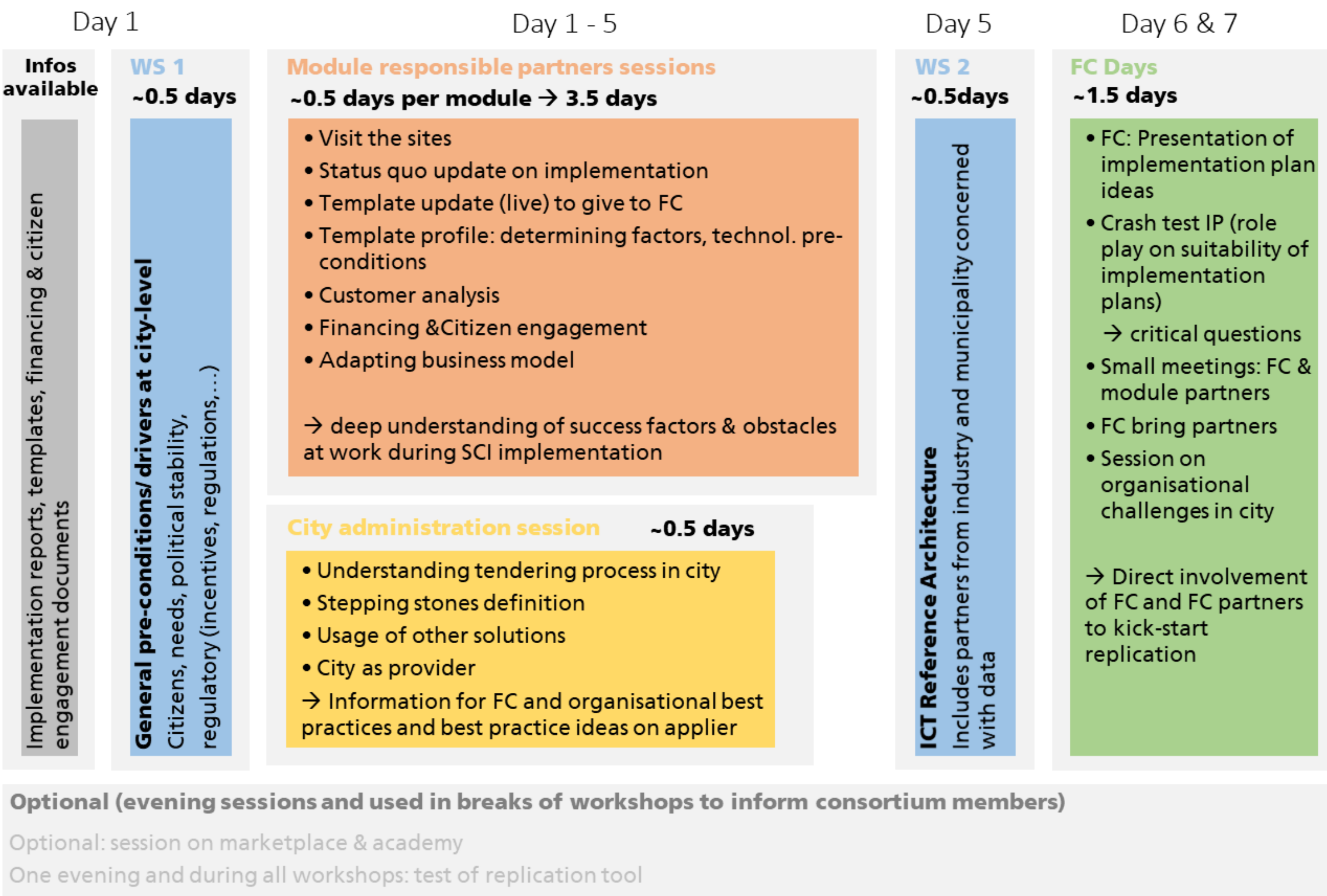


Figure 19: structure of the 2nd on-site visits in the LCs

General Preconditions session

Each on-site started with a 2-3h workshop with the project team of each LC including the city representatives, University, private partners and other entities if suitable. The goal of this session was to identify in more detail and with a standardised scientific approach, the pre-conditions for Smart City developments in the city. In detail the following topics were discussed: what makes the LC unique, the design principles of the project consortium, the innovation ecosystem and focus areas for replication. The results of this session are included in Chapter 5.2

City administration session

During the 1st week of each on-site a separate session with the city administration has been organized. The goal of this session was to better understand internal processes, such as tendering, vision development and project management. The results of this session are included in Chapter 5.2.

ICT Reference Architecture session

The team from Fraunhofer FOKUS working on the ICT Reference Architecture within each city organized a separate session to receive feedback and ensure practical applicability of the ICT Reference Architecture. The results of this session are included in Chapter 5.4.

Module partner sessions

About 80% of the time during the on-site visit was spent in sessions between the WP6 team and each partner responsible for a specific Use Case implementation. During these sessions the information gathered on each implementation was completed and discussed in detail to ensure the highest possible quality. During these workshops also alterations of the business model and focus areas and important factors for replication were discussed. The results of this session are included in Chapter 5.6.

Table 6: schedule for 2nd LC on-site visits

City	Dates of on-site	Dates of FC Days
Stavanger	02.05.17 - 05.05.17 & 10.05.17	08.05.17 - 09.05.17
Eindhoven	12.06.17 - 19.06.17	19.06.17 - 20.06.17
Manchester	26.06.17 – 30.06.17	03.07.17 – 04.07.17

Table 6 shows the scheduling for the 2nd on-site visits. Figure 20 displays some picture from these actions. The Triangulum observer city of Tianjin was invited to the workshop in Manchester, however despite huge efforts from the Manchester project team were not able to attend and are invited for additional workshops for the time after this deliverable is written.

Figure 20: impressions from 2nd on-site visit

5.2 Analysis of the LCs

As described before, the basis of the technology transfer approach is to take the learnings from the LCs and provide them to the FCs. The first key step in this process is to gather structured data on the LC level. The data of the following chapters have been collected during the on-site visits to the LCs.

5.2.1 Eindhoven (NL)

5.2.1.1 Introduction

Eindhoven is in the south of the Netherlands in the province of North Brabant and has a population of 227.000[36], making it the largest city in the south and the fifth-largest city of the Netherlands. The Smart City development in the city is strongly driven by an innovative city leadership that collaborates closely with various stakeholders (quadruple helix). Development started when the city suffered a severe economic crisis in the early 1990ies.

5.2.1.2 Drivers of Smart City development

The city is influenced **strongly by the industry** in the region. Eindhoven was a rural farm town when Philips was founded in 1891. The gradual evolution of Philips into a multinational company was turning Eindhoven into a major industrial centre. Along the growth of the economic landscape, there was a period of rapid urban growth during the 20th century in the City of Eindhoven with the development leading to a prospering metropolitan area with about 2 million inhabitants. Next to the creation of jobs, Philips played an active and important role in the urban development within different sectors, e.g. building neighbourhoods for workers, running schools, health care, the library, the fire brigade, the local football team and supporting the Technical University Eindhoven TU/e. Thus, the companies shaped the city not only through building a massive number of factories and office buildings, but also through having influence on various aspects of urban life. [37]

During the **recession in the 1980s**, Philips was facing a restructuring process and moved its manufacturing processes to cheaper production sights, which included the giving up of around 14,000 local employees until 1993. Additionally, the collapse of DAF cut 2500 jobs. Due to the city's high dependence on the companies in the economic context but also in several further urban sectors, the city reacted vulnerable to the economic situation. Local stakeholders were forced to take the responsibility of the situation and the further development. The Regional Authority for Greater Eindhoven was set up in the 1980s as a governmental initiative to improve the economic situation through cooperation on the regional scale. Although the national government eventually stopped its support for regional governance, the economic development office (NV REDE) was founded in the 1990s and kicked off the strong collaboration between the local stakeholders, e.g. the Chamber of commerce, TU/e and municipalities. Their work aimed at mobilizing the European economic funding and resulted in the foundation of the Commission for Regional Opportunities with the aim to develop a high class technological region in Eindhoven.

This collaboration eventually led to the foundation of the regional level public-private partnership Brainport Eindhoven, which has actively been shaping the region towards an innovation centre.

Innovation System

[36] https://www.thisiseindhoven.com/en/about-eindhoven

[37] https://www.tue.nl/en/education/studying-at-tue/studentcity-eindhoven/history-of-eindhoven/

Along with the restructuring process, **open innovation** became the systematic model for the R&D of the company Philips. Since, the company has aimed at fostering innovation through the perforation of boundaries between the company and its' environment. Thus, Philips expanded their research facilities to push for open innovation in Eindhoven. The Philips High Tech Campus (HTC) was established in 2003 welcoming also other firms to locate at the science park in direct vicinity to the Philips Research Centre.

Today the open innovation model is a fundamental aspect of the Brainport Eindhoven and has been adopted by firms and other stakeholders within the area. Due to the principle of openness, innovation is enabled through the integration of a variety of knowledge sources, like companies, start-ups, research organizations and the municipality. New technologies, services and systems are being invented in interdisciplinary teams to solve societal challenges and improve the lives of people.

Much of Eindhoven's success in innovation and sustainability is depending on the Brainport Foundation and its' **Triple Helix** approach. The development of the Brainport Eindhoven began in 2006 as a way to secure the economic competitiveness of the Eindhoven region through strengthening ties between the local policy makers, firms, and academic institutions. It succeeded and within the Monitor 2015 Brainport was described as a leading technology region in Europe and as one of the fastest-growing regions of the Netherlands. With the Brainport 2020 strategy, the Eindhoven region plans to expand its capacity and influence. The Triple Helix approach of university-industry-government relationships has been successful in its goal to meet the regional challenges of de-industrialization and economic downturn with joint economic development. Thus, the Triple Helix approach has formed the innovation landscape of today's Eindhoven and established (itself) as the main driver for innovation and economic success on all levels within the city.

With over 50,000 jobs the Eindhoven region has together with Amsterdam and Rotterdam become **one of the three economic engines of the Netherlands**. The economic growth of the area reached 2,1% in 2014, exceeding the national average of 0,9%. In addition to the high density of start-ups and spin-offs, several globally leading companies are in the Brainport Eindhoven region, e.g. Philips (R&D department, National Headquarters, Philips Lighting, Philips Medical Systems), TomTom, DAF Trucks, ASML, NXP, FEI Company. The success has been driven by the Brainport organization and its concentration on the sectors of high-tech systems, machines and materials, medical technology and life sciences, food and nutrition. Furthermore, especially the successful Triple Helix approach has helped to develop the Brainport towards a leading region for high tech.

The strong economic growth and the successful transformation from low-end manufacturing to high-value added and knowledge-intensive activities was mutually dependent to the development of a **strong innovation system** (R&D facilities, co-working, laboratories) within the city of Eindhoven. With a density of 22.6 patents for every 10,000 residents, Eindhoven was in 2013 ranked as the number one city in the world in terms of its patent intensity.

Co-creation and cooperation became essential within the economic restructuring in the late 80s and 90s, leading to a change from a strong hierarchical network with leader firms and dependent suppliers into interconnected cluster of large firms, SMEs, start-ups and research institutes. The increasing relevance of collaboration between the different actors, together with the open innovation approach, led to a concentration of high class R&D facilities and research and business centres on the area, like the following:

- **High Tech Campus (HTC)** The science park High-Tech Campus is a leading location for incubation and highly specialized facilities for technology start-ups and large multinational firms. There are over 140 companies and institutes with more than 10,000 researchers, developers, and entrepreneurs working on future technologies and products. In 2011, HTC accounted for 42% of patents filed in the Netherlands.
- **TU/e Science Park** The TU/e Science Park is located in an attractive, central location within Eindhoven. Its facilities enable students, researchers and entrepreneurs to meet and collaborate. In addition to being

among the leading locations in Brainport for engineering, science, education, and research developments, the TU/e Science Park also has residential, business and green spaces that offer more amenities than a normal science park.

- **Brainport Industries Campus (BIC)** Although not yet completed, the BIC is the newest location for the high-tech manufacturing industry technology. Located in NW Eindhoven, fairly close to the airport, BIC is a key component to the success of the fourth industrial revolution in Brainport. Its 200 hectare park will house five buildings in close proximity to each, creating a new complex style fostering synergies within the cluster of firms. Not only will BIC help revive the manufacturing industry in Eindhoven, but also integrate several training, development, and prototyping facilities that will enable collaboration between higher education students and companies.
- **Strijp-S** as one of the lighthouse districts within the Triangulum project, has been developed from Philips' R&D Hub towards a "living lab" combining urban living with a creative design sector.

Eindhoven has an increasingly **vibrant tech start-up economy** that is forming an optimal pre-condition for the development of business models for new Smart City products and services. The density of incubators, co-working spaces, accelerators, labs, and other highly specialized facilities for tech start-ups is high. Technical University Eindhoven, with a strong focus on research and design, is a central actor within the tech start-up scene. The TU/e Innovation Lab helps to bridge the gap between innovation and markets with its open innovation campus, a proven resource for start-up development. Since its foundation, 120 spin-off companies and 40 start-ups have seen the daylight and altogether 60 TU/e patents, 60 licenses, and 500 patents with third parties have been calculated. Another important actor, Startupbootcamp HighTechXL, located at High Tech Campus, is the leading accelerator program for high tech hardware innovations, focusing mainly on robotics, IoT, Sensor Technologies, energy solutions and advanced materials. Moreover, Eindhoven has a comprehensive financing landscape with several start-up initiatives like Brightmove (pre-seed and proof-of-concept funding), Startup Eindhoven, Brainport Development, and Wonderlab-S.

The people in the Netherlands and noticeably in Eindhoven have a **strong entrepreneurial culture**[38]. Due to open mindedness, there is a low fear for failure when developing new technologies and services. Therefore, when it comes to joint piloting and development of new products and services with citizens and local businesses, this is a great success factor for Eindhoven.

The **interplay of technology and design** is a strong driver for innovation and Smart City development in Eindhoven and has shaped the USP of the city. The core success factor is the understanding that breakthrough technologies need to be designed for people's demands; due to the philosophy of Philips, they need to be simple, functional, beautiful and emotionally relevant. Behind this is the long history of the interplay of technology and design in the city, as the head office of the design arm of Philips is in Eindhoven. Today, there are both high tech and design clusters in the Brainport region - the design ones performing as a catalyst for creativity within the technology cluster. The alignment of the universities enables this connection as there is the Design Academy, the University of Technology and the Fontys University of Applied Sciences. The universities aim at connecting technology with design, e.g. organizing creative exhibitions linking new forms of production like 3D-modeling and rapid prototyping with crafts and design. TU/e has many design-oriented departments, such as the department of industrial design, focusing on the design of intelligent systems, services and related products for societal transformation, e.g. intelligent lighting systems. Furthermore, design is a tool for co-creation in the development of the city. For example, "The Perfect Schoolday" project involves students and teachers in co-creating a more optimal school experience through design and experience research (planning sessions and learning strategies on vocational education and learning).

[38] http://gemconsortium.org/country-profile/92

The strong interplay between design and technology and the overall transdisciplinary nature of Eindhoven form the specific way to address social challenges and develop new and innovative solutions for the urban life. Also, the annually in Eindhoven organized Dutch Design Week mirrors the region's importance on the field of connecting technology and design.

Eindhoven has applied the **concept of living labs** to develop and test new technologies, products and services for the city of the future in a real-life setting. The living labs focus on promoting co-created and user-driven innovations with Public-Private-People-Partnerships (4P) approach and thus broadening the triple helix model to a **quadruple helix** one. In 2014, Eindhoven Living Labs became a member of the European network of living labs ENoLL. Besides the Triangulum district Eckart Vaartbroek performing as living labs for co-creation of energy and health solutions and the district Strijp-S modelling as a living lab for new energy, light, mobility and co-innovation solutions, several further living lab projects are being implemented, e.g.:

- Living Lab Stratumseind d2.0: An urban nightlife area, where the quality of life at daytime will be increased via the application of innovative lighting concepts, social media and sensor data collection.
- Living Lab Solar-powered vehicles: The vehicles will be developed and tested in a strong collaboration between the University and industry partners.
- Living Light Labs: University and industry test new innovative forms of lighting in the public space.

All the mentioned Living Lab examples include a social component that is vital for their success. With citizens' direct involvement, such as the participation of inhabitants in Eckart Vaartbroek through kitchen table discussions or ICT-based participation tools, citizens' demands become main components of the open innovation process.

To reach the development goals such as becoming fully energy neutral by 2035-45 (as declared in the Climate Strategy), the municipality has designed **development roadmaps** in the fields of energy, lighting, sustainable urban mobility and ICT.

The "Vision and Roadmap Urban Lighting Eindhoven 2030" is an advanced and future-oriented one, pushing smart urban development. This roadmap has been developed in a joint approach between municipality and the TU/e. The Roadmap sets the goal of using lighting in public space in an innovative way as to improve the quality of life. The Roadmap calls for new business models and procurement procedures to find funding sources for the implementation of the planned measures.

The implementation of the "Vision and Roadmap Urban Lighting Eindhoven 2030" has started with an **innovative procurement procedure** in form of a competitive dialogue. The goal is to use the whole city as a living lab for smart lighting applications in public space and to upgrade public lighting infrastructure by developing new integrated services. Due to the complexity and broadness of the task, the municipality has decided to leave the task open for negotiation and not specify the measures in advance, in accordance to the European tender procedure. The procedure included the following steps. After the publication of the contract notice, municipality selected three operators for the dialogue (3 consortia including private companies as well as research organizations). Then the municipality initiated a dialogue process with the three operators to fine-tune the offers and reach the suppliers' expertise. After the dialogue process, the city awarded the one consortium as the contractual partner for the next 5 years in 5 selected areas. If the consortium is successful, an option to extend the contract until 2030 for the implementation of an innovative lighting concept on the city scale exists. A similar process of innovative procurement for sustainable buildings will follow, to bring together interdisciplinary teams for the development of highly qualitative architecture solutions.

Eindhoven 365 is the city marketing organization of the City of Eindhoven. The marketing strategy was developed together with the municipality, local businesses and creative institutions with the goal of becoming one of the 10 most innovative regions in the world by 2020. The strategy was developed in a co-creation process of a virtual design agency and designers from competing companies resulting in a brand that was introduced in 2013. Eindhoven was to become a hotspot of technology, design and knowledge. Besides branding activities, Eindhoven is known for its marketing, hospitality and PR, and media events, see the examples below:

- Dutch Technology Week “Think Tomorrow”
    - Initiated in 2011
    - Exposition of new technologies and developments from companies in the region
- Smart City Lighting Event
    - Began in 2010
    - Brings together policy makers, politicians, designers, researchers and inventors, scientists and visionaries, technological companies, investors and engaged citizens
    - Demonstration of highly intelligent lighting systems

- Dutch Design Week
  - Began in 1998
  - Incorporates 2400 designers
  - Includes exhibitions, lectures, prize ceremonies, networking events, debates and festivities

- Maker Fair
  - Began in 2014
  - Incorporates inventors, artists, engineers, software developers, game makers, designers, architects, hobbyists, and crafters
  - More than 80 maker presentations and demonstrations

- Glow Light Festival
  - Began in 2006
  - Artists and designers present light art and design applications
  - Incorporates light installations, sculptures, projections and performances

- Eindhoven Innovation Day
  - Showcase of innovation action lines, business development results and education activities

These events help to foster innovation, enable co-creation, and share knowledge. They attract new talents, start-ups, students, fans, etc. The Wired Magazine article in the October 2015 issue entitled "8 Cities That Show You What the Future Will Look Like"[39] validated the success of the marketing for Eindhoven. Besides the successful development of the city, city marketing surely has helped reach this stage of visibility in terms of Smart City development, innovation, co-creation, design & technology.

5.2.1.3 Design Principles

During the second on-site assessment, a workshop took place to find out what the basic design principles for designing a Smart City are. To start projects and to make sure they are successful, Eindhoven relies on several core values:

- Quadruple Helix
  Beginning in the 1990ies the City of Eindhoven established a triple helix, consisting of the municipality, industry and research. Representatives of those sectors met regularly and discussed strategies and started projects. Later, this circle was extended with representatives of the citizens. This is essential to make sure that projects deliver a benefit to the people, living in the city.

- Municipality as the organizer
  Participants of the workshop believed that the municipality should always keep control and steer the Smart City development, as its goal is the overall benefit for the citizens. The municipality also has the "big picture" and can react if some developments do not bring the expected results.

- Freedom for innovation
  This credo goes along with two of the other principles: Be experimental and accept and learn from failure. The city gives space to developers to test and proof their ideas and concepts. E.g. in the district of Strijp-S, sound sensors are mounted to the lamp post to test if they can identify suspicious noises like gun shots or

[39] http://www.wired.com/2015/09/design-issue-future-of-cities/

fights correctly. Giving companies and research organizations the room to find out, if a product works helps them to find adequate solutions. Being so innovative, the city is also aware of the risk of such projects. As a frontrunner, it is not possible to ensure that every single project is a success but it is important to learn as much as possible from failure. Eindhoven lives this principle on every level of decision-making. Even the major stated the "license to fail" at many occasions.

- Technology can help to tackle multiple problems of cities. Eindhoven uses it to push progress and to improve the liveability of the city. For a start the city believes in projects with a "Wow"-factor. Citizens will recognize the projects and see progress.

- Citizens first
  Being very technology-affine, Eindhoven never forgets to put the citizen's benefit in front. This is already documented by the quadruple helix and the city being the organizer of Smart City development. All interview partners during the on-site assessments always underlined, that liveability is a priority in the city.

5.2.1.4 *Innovation ecosystem*

As mentioned above, Eindhoven has a strong innovation ecosystem. Since the early 1990ies there has been a strong collaboration between stakeholders such as the municipality, the universities, industry and citizens. To develop innovative solutions and use the knowledge of the various stakeholders, there are several roundtables and think tanks.

<u>Roundtable Smart Mobility</u>

The Roundtable Smart Mobility makes use of the technological knowledge of the university in the projects of the city. It provides living labs for technological innovations. It consists of 8 partners:

- TU/e Smart Logistics
- TU/e Smart Data
- TU/e Mobility modelling
- TU/e Smart mobility technology
- City Sector Project Management
- City Data
- City European Strategy Desk
- City Mobility Experts

<u>City Development</u>

The City Development group organizes workshops and events to facilitate the implementation of effective projects. Partners are:

- City of Eindhoven
- Volker Wessels
- Knowledge Institute
- Developers
- Users

<u>Open Innovation Lab</u>

The open innovation lab consists of two levels: Biannual high-level executive’s meetings and weekly or monthly meetings of the action level to create customer-centric innovation. Participants come from:

- Municipality (innovation officer)
- City technology officer / Designer
- Research Institutes
- Business Competitors
- Local Businesses and Stakeholders

<u>Brainport Foundation</u>

High-level executives meet in this format with focus on health, energy, mobility, food and safety to develop projects and programs. This group is very important for the triple-helix collaboration and is equipped with budgets of 7m funding per year from 21 municipalities. The strategic board of the Brainport Foundation consists of 5 Industry Partners (ASML, Huibregts, Philips, NTS, Vanberlu), 5 knowledge organizations (TU/e, Summa, TNO, TiU, etc.), 4 municipalities (Eindhoven, Veldhoven, Best, Helmond) and the Municipality innovation officer, who meet every 6 weeks.

5.2.1.5 Overview of implemented Use Cases

During Triangulum, the City of Eindhoven implemented several Use Cases (cf. Chapter 5.6) like bike and car sharing, smart lighting or sound sensors for vehicle operation safety. The overarching goal of those projects was to improve quality of life. 65 % of all Use Cases in Eindhoven supported this goal. Other Use Cases improved the data availability to the municipality, but via open data platform also to start-ups and SME's that can use the information to create new services. But implementation has also helped to be more efficient with regards to personnel and operation costs and even supported the city to reduce greenhouse gas emissions.

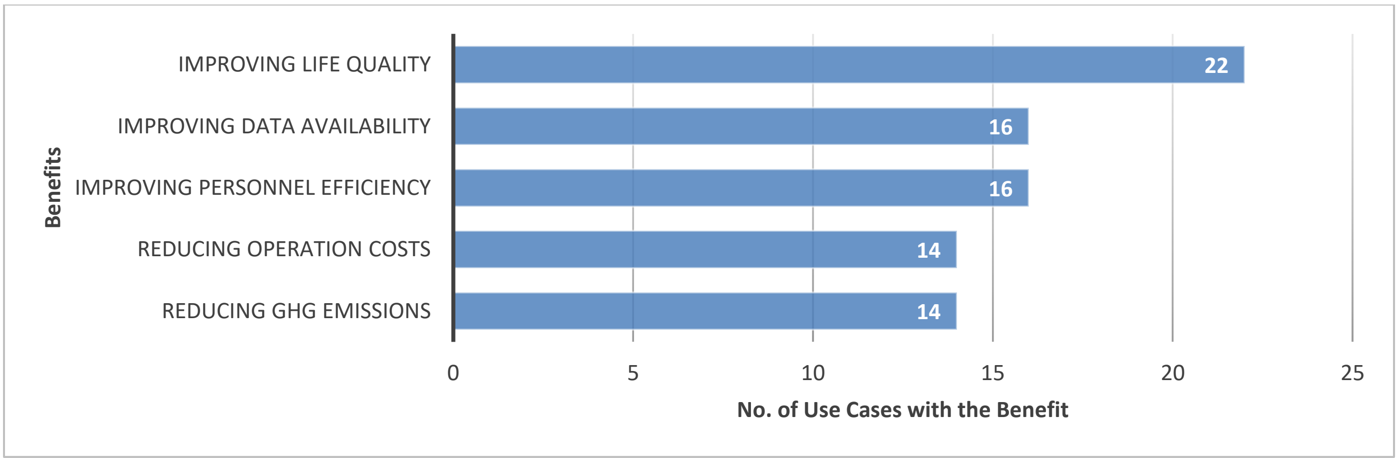


Figure 21: five most recurring benefits in Eindhoven Use Cases

5.2.1.6 Replication focus

As one of the most innovative cities worldwide, Eindhoven is happy to share experiences and solutions with other cities and regions to help them with their Smart City development.

Participants of a workshop on the topic of replication felt, that on a European level solutions and projects from Eindhoven could especially be successful in countries like Belgium, Germany, Denmark, Norway, Sweden, Finland, Ireland and Iceland. Those countries were categorized as "brother/sister-countries" in terms of culture, climate, infrastructure, demographics and politics. Countries like France, UK, Spain, Italy, Croatia, Romania, Greece, Bulgaria, Czech Republic, Latvia and Estonia are regarded as "cousins", meaning that replicated projects and solutions still have a good chance to be successful. For countries in northern Africa and Eastern Europe the chance is lower due to differences in the mentioned factors.

Some of the solutions might also be replicable worldwide. Especially "tech regions" like Detroit, Pittsburgh, Austin, Atlanta in the US or Taipei would be likely to adopt some of the Use Cases.

5.2.2 Stavanger (NO)

5.2.2.1 Introduction

The city of Stavanger stands out for its strong technological and infrastructural advances. Already today, it shows one of the highest numbers of electric vehicles per capita in Europe and a high share of renewable energy in the electricity grid. Furthermore, many initiatives and a generally positive attitude towards innovation contribute to the strong drive and potential the city shows with regards to Smart City development. Additional factors that favour this development are the high wealth level of the population and the relatively small size of the city.

The city of Stavanger holds the status as the European capital of Energy. It aims at becoming one of the world's most sustainable cities by further integrating ICT, energy and mobility. Within the Horizon 2020 Triangulum project Stavanger is one of three LCs which serve as testbeds for innovative Smart City Solutions. This will help to increase the sustainability and the quality of life in Stavanger making it a true pioneer in the European Smart City development.

5.2.2.2 Drivers of Smart City development

External Drivers

One of the most distinct drivers in Stavanger is the current shift from being an oil capital to becoming a post **oil city**. Since the discovery of oil in the North Sea in 1969 the city has been the on-shore centre for the Norwegian oil industry and most of the city's growth and employment resulted from the oil boom. The huge investments in the oil and gas business most importantly formed the present entrepreneurial culture with strong innovation drive and fostered technological development in the region. However, with the current oil price crisis and the depletion of the fossil fuel resources (Figure 3), unemployment has been rising in the past years hitting 4,4% in 2015 compared to the usual ~1%. To secure future prospect and wealth, the city must think ahead and achieve a reorientation of businesses, research and the citizens. Thus, the oil crisis also serves as a driver to discover new business areas and has opened an arena for Smart City businesses to grow, especially in the fields of smart living or smart health care.

The transition from oil and gas industry to the post-oil one has been accompanied by a change of **mind-set** within the Norwegian society. Budget cuts, reduced incomes and increasing unemployment rate have forced businesses, government, universities and citizens to change their way of thinking and acting. To tackle the challenges of the oil crisis, the Norwegian funding system increased the amount of money to support economic development, and set up the instrument "Innovation Norway" to encourage innovative development of Norwegian enterprises and industry. On the level of the municipal government measures have been implemented to deal with local challenges and support local economic development. Moreover, a series of various support programs has been established (e.g. business incubators, Start-up weekend Stavanger, co-creation spaces, etc.). At the same time, established businesses are strongly pushing the exploration and development of new markets and therefore are closely cooperating with research organisations and creative industries. Entrepreneurs are pushing the development of new ideas and founding new businesses, and universities have intensified their efforts in applied research to tackle real-life challenges. The ongoing developments are embedded into the local system of acceptance due to the awareness of the need for transformation within Stavanger's society and the corresponding openness to new and innovative developments which are an answer to the crisis and a driver for urban growth and stability.

The **entrepreneurial mentality** of Stavanger's society has been strongly shaped by the city's industrial past. The approach "pitch a topic and go for it" has become common for Stavanger's entrepreneurs, decision makers, and civil society. This mentality has its roots in the onset of the oil boom of the 1960s when oil fields were first discovered in the North Sea. The government of Stavanger reacted faster than its counterparts in other Norwegian municipalities and undertook massive efforts to attract oil companies, with the result of Stavanger becoming the “oil capital” of Norway.

Another important driver for smart solutions has been the generally **high labour cost** in Norway. Since workforce is expensive, innovation was necessary and a market and demand for solutions and technologies replacing labour force has developed. An example here would be the technological solutions for collecting road tolls which replaced the workers in former toll cabins.

Being gifted with the high availability of **cheap renewable energy** (mainly hydropower), Norwegians consume about 7,3 MWh (2013) per inhabitant compared to the European average of 1,6 MWh per inhabitant[40]. Electricity prices are roughly 0.7 NOK per KWh plus 0.03 NOK taxes – however are subject to changes due to an increasing access to the spot market of electricity. As most citizens using electric heating, approx. 80% of the household’s primary energy consumption is in the field of generating electricity[41] and due to the low-price citizens are not motivated to save energy. Thus, new approaches are needed to achieve higher energy efficiency and solutions which couple energy savings with other needs. This can provide a great chance for new businesses to grow and diversification strategies to develop.

Citizen Structure and Attitude

Sustainable and smart development is often demand driven and thus also a response to changing society. With the **demographic change** and the increase of elderly in the overall population of Stavanger, the demand for care and welfare services will rise. Additionally, many people in Greater Stavanger region are wealthy and want to stay at home if possible when getting old. These developments exert pressure on the municipality which provides the institutional care. Since labour force is expensive, smart solutions might help in finding adequate solutions to this issue.

The **high level of wealth** also constitutes to Smart City development. The wealth and high willingness to pay become evident when looking at the example of e-mobility. Even though consumer prices in Stavanger are 56.58 % higher than those in Eindhoven, the local purchasing power exceeds that of Eindhoven by 6.37 %. This also holds true for the prediction that in Stavanger there is a high willingness to invest in increased comfort which is e.g. generated through smart home solutions.

In addition to the citizen structure, important Smart City drivers also stem from citizen awareness and attitude. Citizens of Stavanger are generally quite **open to use new technology** which is a result of the early presence of technology (e.g. the digital infrastructure which has been in place for years) and the high-tech equipment used in the oil industry. Besides, a high level of (technological) education contributes to the openness for Smart City Solutions. 41% of Stavanger’s inhabitants have enjoyed higher education and 22,4% a below upper secondary education[42].

Lastly a **high level of citizen engagement** has been identified, most significantly being the willingness of individual citizens to engage in unpaid and voluntary actions for the common wellbeing of society (“dugnad”). This may be

[40] https://www.ssb.no/en/energi-og-industri/statistikker/energikomm/aar/2011-02-22

http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Households_consumption_of_electricity_per_capita,_MWh_per_capita,_2013.png

[41] https://www.ssb.no/en/energi-og-industri/statistikker/elektrisitet

[42] http://www.ssb.no/en/utdanning/statistikker/utniv/aar/2015-06-18?fane=tabell&sort=nummer&tabell=225172

due to the fact that the Norwegian management and organization model is built on egalitarianism and flat hierarchies. Everyone is equal and employees solve problems together instead of the leader giving orders.[43]

Governance

The municipality of Stavanger has put quite some effort into building more flexible governance structures, **cross-sectoral collaboration** between different departments and more holistic ways of working to overcome the previous silo thinking situation within the city administration. This has mainly been achieved through joint workshops, regular leader meetings, the identification of common action fields and projects, as well as the creation of a cross sectoral management unit 5 years ago.

Furthermore, a strong **cooperation between city administration and other stakeholders** is present in urban development processes, following the joint vision: "together for a vibrant city". The city is especially used to work in a triple helix with research, industry. Due to flexible management structures, flat hierarchies, low bureaucracy and the small size of the city, face-to-face cooperation is possible resulting in fast decision making and a high innovation capacity.

Cooperation and co-creation can also be found **within the Greater Stavanger Region**. There is a strong collaboration between the 16 municipalities which follow a strategic development plan. This is ensured through the municipality-owned organisation *Greater Stavanger Economic Development* which focusses on business development and innovation. Furthermore, Lyse as one of the main actors in Stavanger's Smart City development is jointly owned by these municipalities. It is also under discussion to join the individual planning departments to address the challenge of silo-thinking. This strong collaboration is an important driver to tackle cross-border challenges and opens possibilities for further replication of Smart City Solutions within the region.

On an **international l**evel, Stavanger is home to people from over 130 different nations and has a big international network. It signed the Covenant of Mayors Agreement in 2009 and is partner in the Future Cities National Programme, as well as associated member of the EuroCities' environmental and knowledge forum. The city has a very ambitious office in Brussels which is initiating international projects such as Triangulum. Besides, international events such as the Nordic Edge are being developed to strengthen Stavanger's international position and to further push Smart City development.

Stavanger has set some **ambitious development goals** such as the reduction of CO2 emissions by 20% until 2020, 50% by 2030 (1990 base) and complete carbon neutrality by 2050. Other target areas refer to air quality, regulation of new buildings and the recycling of waste. However, these goals are not being achieved at the moment which shows the need for new (smart) solutions to be developed. In this regard, the city has started engaging in innovative and pre-commercial procurement, creating a dialogue with providers to jointly find the best solution.

Citizen participation and communication strategies may be one of the most important future drivers in Stavanger, which is pushing the development from the triple helix towards a quadruple helix. The short ways, the open-mindedness and the commitment of the citizens will favour this development. Already today, citizen feedback is essential to formal procedures and citizen workshops and the participation of children in urban development are being encouraged. Stavanger is strong at communicating via social media such as Facebook, twitter and Instagram. However, means have to be developed to reach a wider group of people, as well as underrepresented groups, e.g. the elderly population.

[43] https://www.mm.dk/scandinavian-management-model-makes-good-bottom-lines

http://www.expatarrivals.com/norway/doing-business-in-norway

Another challenge is the **handling of data**. Stavanger is struggling to build a beneficial and acceptable environment for data to be opened to the public. Triggered by Triangulum and the planning of a data platform, this is seen as big chance for new start-ups, service generation and innovation. Until now, no good system exists and major problems are ensuring privacy issues, data reliability, as well as the prediction of citizen behaviour.

Infrastructure

Core of the Smart City development in Stavanger is the **high density of fibre-optic cable**, connecting 60% of all households and covering 85% of the population with 1GB[44]. Being developed since 2001 though the strong commitment of Lyse, it has put Stavanger in a pioneer position and is the main enabler for the development of ICT based Smart City Solutions.

An infrastructure enabled by the rollout of fibre-optic cables is the installation of smart meters in homes and public buildings. There is the **regulatory requirement** in Norway to implement smart meters in all homes by 2019 and priority is given to this topic through dedicated R&D programs by the Research Council of Norway (RCN), academia and industry[45]. Smart meters will then become an important driver for smart building solutions.

Another driver to be considered is the **transport sector**. Challenges, such as the need for commuting, lead to growing traffic volumes and associated problems. The enormous urban expansion due to the oil boom and the concentration in three main working areas (namely the city centre, Forus and Dusavik) have led to many commuters: In 2014, 34,688 employees were commuting in and 23,092 out of Stavanger.[46] Most of them prefer their own car instead of public transport. So far, no transport plan exists for Stavanger and transportation issues are included in the Climate and Environment Plan and the Stavanger Region Plan.[47] Smart mobility solutions might help to tackle this problem.

Stavanger has the **highest density of EVs in Europe** and EVs have been doubling each year for the last three years. Reasons for this increase are subventions and financial incentives for EV purchase by the national government, such as reduced tax and VAT. Further benefits include no road and ferry tolls or parking fees, less insurance fees and free electricity charging. Within greater Stavanger region, around 60 charging stations and 6932 EVs are registered. The high density of EVs and EV charging stations and the possibility of free charging lead to a high-energy use challenging the electricity grid. Furthermore, the incentives counteract with the goals of traffic reduction and lower the motivation to use public transport. Still, the development of electric mobility in Stavanger creates awareness for new sustainable forms of mobility and reduces the cities carbon footprint in the transport sector.

Research and Business

[44] http://www.ssb.no/en/teknologi-og-innovasjon/statistikker/inet/kvartal/2016-02-22#content

[45] http://www.globalsmartgridfederation.org/2014/03/31/smart-grid-developments-in-norway/

http://smartgrids.no/wp-content/uploads/sites/4/2014/04/IPEC_Hiroshima_20H3-4.pdf

[46] https://www.ssb.no/statistikkbanken/selectvarval/saveselections.asp

https://www.ssb.no/statistikkbanken/selectvarval/saveselections.asp

http://archive.northsearegion.eu/files/repository/20150701205354_ToolboxresultsRogalandNorway.pdf

[47] https://annisasontani.files.wordpress.com/2015/05/stavanger-regionen-redigert.pdf

https://www.stavanger.kommune.no/Documents/Natur%20og%20milj%C3%B8/Aktuelt/Climate_and_environment_plan_2010-2025.pdf

Lyse is a power and infrastructure company which is owned by 16 municipalities in Greater Stavanger. It operates 11 power plants (10 hydroelectric and 1 thermal), the power grid of the 16 municipalities, the fibre-optic broadband and smart home services. The ROI which is thereby generated is a direct source of income for the municipalities; however, enough money is left with the company to enable further development and investment in innovations. The biggest strength of Lyse is the tight connection with its customers. Since the company's services can be found in most of the homes, it is well-known and trusted by Stavanger's population, generating a good basis for the introduction of new smart home services. In 2013, the daughter company Smartly was launched to provide services that allow customers to control diverse functions in their home through a tablet computer or smartphone (smart home functions including lighting, heating, alarm, and welfare technology; launched in 2014).The diversification and simplification strategy has led to the development from energy provider to service provider, making Lyse a strong driver of Smart City Solutions.

The **University of Stavanger** is one of the main players in Stavanger's research and development environment. It has always fostered a strong link with the local industry and thus is strongly focused on oil and gas. However, the orientation is changing towards more IT based topics and close collaboration with Lyse is driving Smart City research. There is a joint technology transfer office which is working on the commercialization of ideas developed by research. Funding from Innovation Norway is available for pushing new start-up generation. Furthermore, UiS is the base of research centres like the International Research Institute of Stavanger IRIS which focusses on cutting edge technology and the CIPRSI whose research is placed around IP-based service innovation, reflecting the technology enthusiasm of Stavanger's researchers.

To have more actors entering the business and development arena, the Norwegian funding system has increased the amount of money to **support start-ups and innovations**. As an example, the innovation fund of the national government supports Smart City Solutions and in 2016 a new funding programme was introduced by a publicly owned business development company with a volume of 10 million NOK. Moreover, the city is supporting innovative projects which increase value creation, investments and job creation. In recent times, co-working spaces such as Mess and Order and Prekubator have developed.

All in all, it becomes evident that companies are under pressure to deliver innovative solutions to cope with the challenges presented above and to **create new market and business environments apart from oil**. Future possible areas mainly include the smartification of the health and welfare sector, as well as smart home solutions and products for an aging society. The Norwegian Smart Care Cluster (NSCC) is a good indicator here, including over 60 businesses, research partners and the public sector. Another success was the Nordic Edge which already profiled Stavanger as future centre of Smart City and smart home technologies. The research which will be needed to further support these areas has a focus on transdisciplinary and the inclusion of technology and social science.

5.2.2.3 Indicator analysis

From the 30th of November to the 9th of December, the Triangulum on-site assessment took place in Stavanger. 32 project partners and local politicians, including Mayor Christine Sagen Helgø, were interviewed in 16 expert interviews. An interdisciplinary assessment team led by the Fraunhofer Society and TÜV SÜD focused on understanding the Smart City Solutions which are being implemented as well as the local context, which enables such developments to be successful. At the end of the assessment days a workshop was held with important stakeholders which include Lyse, Smartly, the Municipality of Stavanger, the University of Stavanger, Kolumbus and representatives from Rogaland and Greater Stavanger. Benefits and beneficiaries of the Smart City Solutions were identified and important issues for the future development were discussed. Through the great support of the city management team and all local partners the knowledge on the Triangulum activities in Stavanger was greatly enhanced.

A report that is under constant development summarizes some of the key findings of this on-site assessment. It structures and presents the Smart City context and the drivers which have helped the city to develop, as well as the state and the replicability of the Smart City Solutions which are being implemented within Triangulum.

5.2.2.4 Design Principles

The Stavanger municipality sees itself as a service provider for the citizens. Therefore, they use smart solutions to simplify and improve services and increase transparency. The last one shall be achieved by involvement of different constellations across local authorities, industry and commerce, organizations and academia but also as much citizen involvement as possible. The development always must be based on the citizens' and users' needs.

Apart from citizens there is a strong focus on sustainability and CO2 reduction. Although most of the electric energy is already generate with hydropower, the city is eager to reduce the overall use of fossil fuels.

The city supports Start-ups and SMEs to upscale successful pilot projects.

5.2.2.5 Innovation ecosystem

Stavanger created several working groups around the tasks within Triangulum in order to accomplish the goals and to learn as much as possible from the project.

In the Local Consortium Meeting senior leaders of the five main partners (Stavanger municipality, Lyse AS, Rogaland County Council, Greater Stavanger and University of Stavanger) meet on demand to discuss and take decisions. For WP5 there are several groups:

- WP5 TRI-Team consisting of the project leaders who meet monthly to give updated, exchange process and work on the execution together. There are sub-groups for WP5.1 – 5.5.
- Another monthly meeting is held in the Communication and Dissemination Group where the strategy for communication of the milestones and achievements of the projects is decided.
- To control project finances, a legal advisory team meets quarterly. This group als meets on demand in case of any legal matters (e.g. relation of EU-law to Norwegian law).

Another group is the Healthcare Innovation Group, a medium level executive meeting that connects local stakeholders in the health field.

5.2.2.6 Overview of implemented Use Cases

Implemented Use Cases in Stavanger have a clear focus on energy, electric mobility and ICT solutions. The Smart Gateway that was developed by Lyse can help to "smartify" conventional buildings like private homes, but Lyse proved during the project that it is also suitable for schools and nursing homes. The technology helps to control and reduce energy consumption by enabling independent control of lighting and heating systems. Like most of the Use Cases in Stavanger, it also helped to improve data availability. Like in Eindhoven, this combined with other factors can help to encourage digital entrepreneurship and create new business opportunities, which were the second and third most mentioned benefit of the projects. This was also particularly pushed by the development of the Cloud Data Hub, a computing platform and the data analytics toolkit (cf. Chapters 5.6.60, 5.6.62 and 5.6.63) by the University of Stavanger and enhanced transparency. With their video solution, Lyse increased the safety, especially for elderly. Due to demographic change and high labour costs, this section of the population is of special interest to the municipality. Using a camera and a normal TV, doctors or nurses can get in contact with patients and e.g. check it someone took medication.

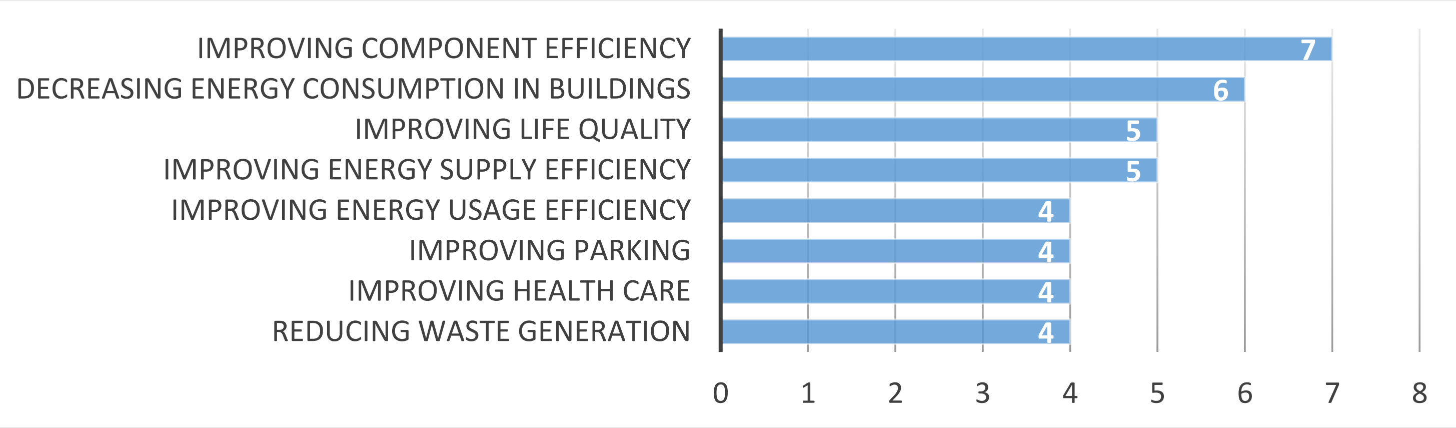


Figure 22: Most Recurring Primary Benefits - Stavanger

5.2.3 Manchester (UK)

5.2.3.1 Introduction

Manchester lies at the heart of the Greater Manchester metropolitan region. With a regional population of 2.7 million, it comprises the second largest economy in the UK outside of London and generates 4% of national GDP. The city of Manchester has enjoyed rapid economic growth over the last decade, fuelled by unprecedented levels of investment, a skilled workforce and an entrepreneurial business sector. In the same period the population has grown by 19% making it the fastest growing city in the UK, with a population of approx. 520,000 generating €63 billion GVA annually.

The city has elaborated a Smarter City programme to explore new ways to make the city work better by using technologies. The programme takes as a base thing that the city is already doing around transport, health, environment and energy efficiency and encourages further investments by supporting pilot demonstration projects and working with partners in the universities, business and the public sector. Further work is being done for developing the strategic framework for Manchester´s smart and digital activity.

The Manchester Smarter City activity focuses on 6 key topics established to achieve the best possible outcomes for the city and its citizens:

Live: how and where people live; quality of life and place; retrofit, regeneration and expansion.

Work**:** What new skills exist, and are needed, what new industries and start-ups; social innovators and entrepreneurs.

Play**:** Access to amenities, a better environment and a richer cultural life, by promoting sport activities, etc.

Move**:** Getting around in a seamless, low-carbon and healthy way- stablish a connected, walkable city, city of bikes, trams, trains and buses, international connectivity.

Learn**:** the self-learning city: how people continue learning throughout the various life stages: the university, schools, colleges and apprenticeships, libraries and community learning.

Organise**:** how the neighbours shape their future': including citizen's engagement in policy: an open city government, providing 21st century city services.

5.2.3.2 Drivers of Smart City development

Even if Manchester lost two bids to host the Olympic Games, this was a part of a process that helped to raise the international profile of the city. The Commonwealth games in 2002 was a successful story and an important driver for the sustainable development of the city. Huge investments in infrastructures came to the city and it was the beginning of strong partnerships that last until today.

Furthermore, Manchester is the leading the **Northern Powerhouse**, a proposal to boost economic growth in the North of England that was pushed by the 2010-15 coalition government and 2015-20 Conservative government in the United Kingdom, particularly in Liverpool, Leeds, Sheffield, Newcastle and Manchester. The focus is put on urban agglomeration, improvement to the transport links, investment in science and innovation, devolution of powers in so called City Deals and aims to balance the economy away from London and the South East.

City Development

During the industrial revolution, the textile manufacture was strongly developed; Manchester was for some time the most productive centre of cotton processing and also the world´s largest marketplace for cotton goods. Manchester became the first and greatest industrial city in the world. Trade and the rapid growing population, demanded a large and well-functioning transport and distribution infrastructure. The canal was extended and the Liverpool and Manchester Railway was built.

Manchester turned into a centre of capitalism with many manufacturing and engineering companies. Between the 1950´s and 1980´s many of those companies died; cotton processing and trade started to fall and the exchange was closed in 1982. The economy was affected by Margaret Tatchers s policies, the industry suffered a downturn and more than 150 000 jobs were lost. Regeneration began in the late 1980´s, a period where Manchester rised as a financial canter in the region and showed initiatives as the Metrolink, the machester Arena, etc.

The last 30 years have been about rebuilding and diversifying the economy with special focus in a creative media sector (ITV, BBC), strong financial sector and global leading sciences around the universities (graphine), biomath, nuclear, e-health technologies.

Companies and Businesses – the Corridor as the focus area for the Triangulum project

The corridor Manchester is a unique business location, at the heart of Manchester´s knowledge economy. With a 60.000 strong workforce, it hosts two of the UK´s most important universities: The University of Manchester and the Manchester Metropolitan University as well as the Central Manchester University Hospitals NHS Foundation Trust. This not only makes the Corridor not only the largest academic campus in the UK but also the largest clinical academic campus in Europe.

This 243-hectare collaborative ethos was founded in 2007 and is currently recognized as an innovation district and good example of the triple helix governance model. It counts with around 70,000 students, leading higher education, health, cultural and important commercial assets it is an ideal area in which to take the leading research and apply it to a specific location. The Corridor is the focus for the Triangulum and other innovative projects to demonstrate smart green growth, new approaches for smart cities, citizen engagement and cutting edge technologies. All the partnerships inside Triangulum are based on previous partnerships.

Regarding the city of Manchester, it has not been very successful acquiring head offices, however many companies move to Manchester if they do not have to be at London.

Citizen structure and attitude

In order to engage directly with citizens, Manchester is currently looking for new forms of communication with the aim to do consultations on what the citizens want the city to be like and to help to redesign it. Some work has already been done in the identification of people’s needs, using surveys on improvements.

Governance and collaboration

As already mentioned above, the corridor is characterized by strong partnerships between the City Hall, Universities and Central Manchester University Hospitals Foundation Trust, businesses and others. These partnerships allow for better networking and are enabling fast and joint innovation.

5.2.3.3 Design principles

Manchester as a LC is regarded as one of the more advanced cities in Europe with regards to Smart City development. In order to help the FCs to learn as much as possible

During the on-site assessment main design principles have been identified that are the basis of the successful Smart City development in Manchester. At the core of all Smart City Projects are the citizens' benefits. This shall be kept in mind from the very beginning of each project. Citizens shall also be involved in the processes as much as possible during all project-phases. Projects are implemented to test new technologies and therefore the city identifies test bed areas like the Corridor. Still the municipality chooses projects where the technology implemented is replicable and scalable for the whole city.

- Implementation in line with strategies
- Politics, municipality, public and private partners
- Build trustful partnerships
- Citizen involvement
- Identify replicable technology
- Citizens befit in mind from the start
- Identify test bed areas
- Adequate time and support

5.2.3.4 Innovation ecosystem

Manchester's innovation ecosystem relies on several boards and work groups that take care of certain tasks. As the Corridor is the focus area for implementation of Smart City Projects, the city established a corridor board that drives the strategy for the area and adds value to the partner's activities. The board consists of senior representatives of the main stakeholders in the area who meet every four months:

- University of Manchester
- Manchester Metropolitan University
- Central MCR NHS Trust
- Arup
- RNCM
- Manchester Science Park
- Bruntwood

There is also LEP – Local Enterprise Partnership, consisting of city leaders, representatives from key industry players, University of Manchester and Manchester Growth Company. The group exists to empower business leaders to influence the strategic course of the city, to allocate funding for strategic projects and to engage with the SME community.

Apart from those panels, there are some groups with specific tasks like the WP3 board, the WP3.2 Technical Governance, WP3.3 Technical Forum that work on tasks within Triangulum.

5.2.3.5 Overview of implemented Use Cases

As Siemens is one of the key partners in Manchester, reduction of energy costs and intelligent energy management is a key element of the projects. The company developed and implemented a Demand Side Response (DSR) control for office blocks, public buildings and student accommodation. This technology is controlled by the city energy controller (also developed by Siemens) and temporarily changes the operating state of approved systems in the buildings to deliver load reduction.

The focus of Manchester Metropolitan University and the University of Manchester is on electric mobility. The University of Manchester could replace 7 diesel vans with new electric vans that are now used to deliver mail and for operational services. Manchester Metropolitan University established a sharing scheme to reduce the number of own cars and to increase the use of EVs. The system is managed by a third party and includes an online booking system. The two Nissan Leaf promote sustainable behaviour and increase personal efficiency.

85% of all Use Cases implemented in Manchester have in common, that they reduce operation costs. Promoting sustainable behaviour is also a benefit of the projects, such as the reduction of GHG emissions and the reduced use of fossil material to generate energy.

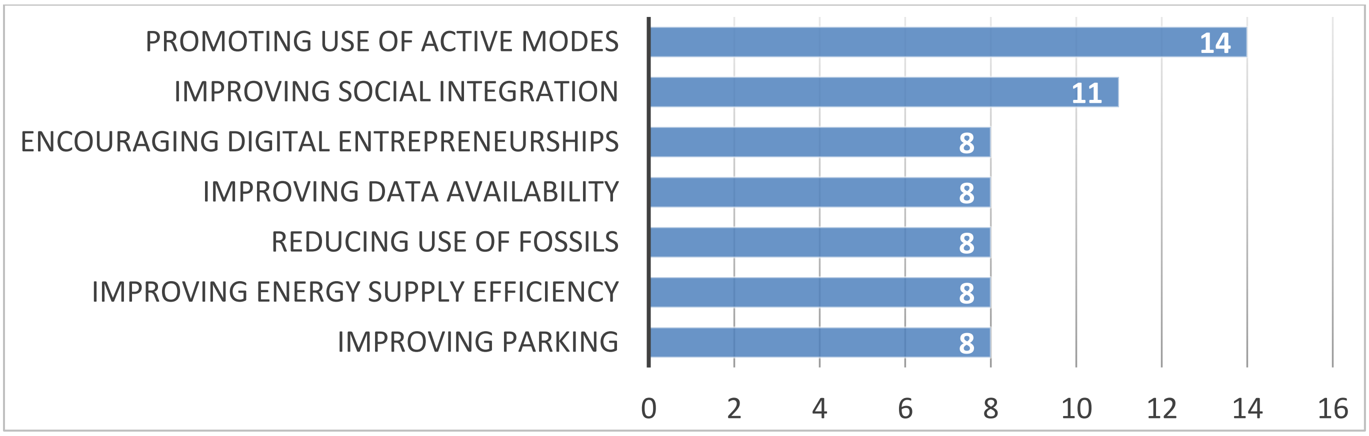


Figure 23: Most Recurring Primary Benefits - Eindhoven

5.2.3.6 Replication focus

Participants during a workshop that was part of the second on-site assessment saw great potential to scale the solutions implemented in Manchester and replicate them in many parts of Europe and worldwide. The focus within Europe included all western European countries like France, Germany, UK, Ireland, Sweden, Norway, Finland but also most of the southern European countries like Spain and Italy.

Cities in north and South America but also most parts of Asia, including China and India, and Australia could be potential partners and learn from experiences of Manchester.

5.3 Use Cases as replication units

To facilitate replication of Smart City Solutions it was necessary to identify bundles of technologies and processes as the basic unit for replication that are meaningful to be implemented in a FC by themselves.

5.3.1 Justification

As per the grant agreement, the Smart City Solutions from Triangulum have been categorized into "Smart City Modules" which are system solutions for Smart cities. They represent core technologies that are organized around a business model and pursue a specific goal for cities and citizens. The project serves as test case to develop a modular framework which consists of the several Smart City Modules developed in the LCs, to systematize the factors that lead to a successful design and implementation of smart districts and prove the benefits of smart and sustainable technologies in cities.

The replication tool is expected to facilitate replication and dissemination of these modules developed in Triangulum LCs to other cities and districts in Europe. Hence, a Smart City Module was initially identified to be basic blocks of replication for each of which detailed information would be collected. However, on further analysis it was realized that a technology when used for different applications produced different sets of results, lessons learned, business models and needed different KPIs to be measured. Hence, there was a need to be more specific and package the building blocks in suitable replicable bundles.

Hence, a Use Case was identified and defined as follows:

'A Use Case is an application of a module in a specific setting whose impacts can be measured independently and which can be replicated by itself. It is a package of different products/technologies and the corresponding processes that are meaningful to be implemented independently.'

Figure 3-9 shows the three different Use Cases of the module Smart Gateway implemented by the company Lyse in Stavanger. Smart Gateway is an IoT system which funnels the data from smart meters and other sensors to take meaningful actions based on the data input.

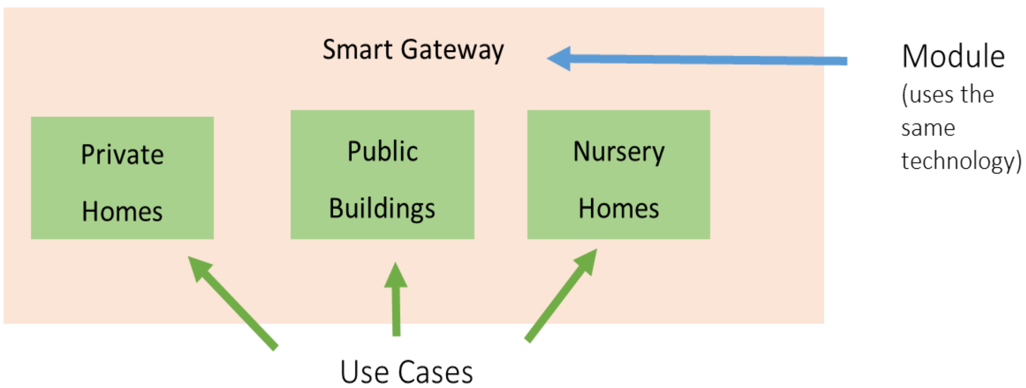


Figure 24 - Three Use Cases of the Smart Gateway module in Stavanger

In the Smart Gateway module of Triangulum, Lyse is implementing the gateway for three different applications:

Private Homes: In this Use Case, it enables supplier and user of energy to control and reduce consumption effectively. It can provide added automation services like controlling heating-cooling and light control through the application.

Nursery Homes: In this Use Case, it enables independent control of lighting and heating systems in each room by the patients and the nurses. As part of Triangulum it is done in 8 rooms in the nursing home. It reduces the time spent by nurses in doing mundane tasks enabling them to provide better care for patients.

Public Buildings: Finally, in this Use Case, it enables air quality control in public school gyms and thus ensures good indoor air quality for maintaining the health of the students.

As can be seen, each of these Use Cases is a different application of the Smart Gateway module and technology. While implementing each of them, Lyse faced different challenges, had different supporting factors and business models to support the technology. Also, the effectiveness of each of this application will be measured with different KPIs owing to the different results achieved from them. Hence, the tool considers a Use Case as the basic unit of replication.

A Use Case focusses on using a technology to reach specific goals in a defined context or setting. A particular Use Case would have various supporting factors which enabled its implementation in this specific setting. When replicating the Use Case, another city or organization could reproduce similar supporting factors for their local context or consider the different impact replication would have in the absence of these factors.

5.3.2 Information Capturing

Since the Use Cases are from a variety of different sectors implementing wide-range of technologies, developing a universal template which describes each of them justifiably has been a considerable challenge.

Another important challenge was to strike a balance between the required details and making the template easy to fill in. This is mainly important with respect to the scalability of the tool as implementers would not eagerly fill in a template which takes too much time and efforts.

5.3.2.1 Adaption of Business Model Canvas

Through a survey jointly carried out with the Replication Task Group, cities identified business model details as the most crucial information for choosing to replicate a solution. Hence, the Use Case template contains several parts of a standard business model canvas adapted to Smart City Use Cases with the aim of helping a replicator learn from the previous implementers. Apart from the general description, financial and organizational details, and stakeholder analysis the template also covers lessons learned, challenges faced and possible future financing options. It is also designed in a way to guide the implementers' thinking process to extract maximum possible information and to be able to be filled independently by the implementers.

5.3.2.2 Ranges instead of exact values

In most cases, replicating a solution in a different city and country changes the investment costs, return on investment and implementation times to some extent owing to local factors like labor costs, taxes, etc. Hence, it is not necessary for replicators to know the exact figures. Also, it is a challenge for implementers to fill in these exact numbers. Hence, all such information has been converted to meaningful ranges and drop downs.

5.3.2.3 Benefits: the connecting link

Cities implement solutions to e.g. improve services offered by the city, improve life quality or boost the local economy. Projects are chosen in a way to ensure these goals are reached. As the intended goals inherently have a positive connotation, the general value offered by the implementation of solution is called benefits.

The benefits form an integral part of the tool and the Use Case template as they are the connecting link between the User Input and the Use Cases. To be able to categorize the Use Cases based on the impact they have, a list of 40 benefits divided in five different categories (economical, environmental, eco-environmental, social, other) has been developed. Initially, for each Use Case the implementer had to specify whether the benefits are an effect of the Use Case or not. However, after filling in the Use Cases multiple times, it was identified that some benefits are the primary effects of a Use Case while some are secondary. Hence, in the final version of the tool a higher degree of classification was identified: Primary, Secondary and No effect.

5.3.2.4 Feedback on Template

As part of the Triangulum On-Site visits over the course of May and July 2017, around 70 Use Cases have been added to the database. Based on the learnings from these sessions and direct feedback from implementers who filled in the template, it was updated and improved on various occasions. Factors like language barriers, nomenclature, effectiveness of sections were monitored closely to improve the template. Overall, the implementers were satisfied to fill in details of Use Cases in the template. They found it comprehensive and easy to fill in. It was also identified that the template helped them think in a structured way and enhanced the quality of information they could provide.

5.4 ICT Reference Architecture

As Smart Cities emerge as a social, academic and industrial topic, it becomes increasingly clear that Information and Communication Technology (ICT) is at the heart of research and development efforts in that area. The topic of Smart Cities covers a large amount of aspects with the goal to improve the quality of life for citizens within an urban environment, especially given current predictions that in near future the majority of humans will be living in cities. Some of the main topics for Smart Cities, which are considered by current R&D efforts, are constituted by Energy, Transportation/Mobility, eHealth, Water, Building Automation and further that emerge out of the specific needs of the city in question.

In all above-mentioned aspects, ICT plays a crucial role as being the vehicle to enable the exchange of information between the involved modules and components towards the realization of relevant scenarios within the domain in question (e.g. energy or transportation/mobility). Thereby, ICT can be fairly seen as the glue, the key enabler, which offers a platform for meeting the requirements of the society.

Given the importance of ICT, it is paramount to approach the ICT aspects of Smart Cities in a structured way that is able to accommodate the diverse needs and possible/available solutions on the market. Hence, there is a need for a reference model, which would be able to capture in an abstract manner the general structure of ICT solutions for a Smart City - especially such consisting of multiple independent interoperating components, e.g. from different vendors. Thereby, the reference model could borrow some principles and ideas from other very successful reference models from the area of Internet and traditional telecommunications, such as the TCP/IP model or the ISO/OSI model.

What is typical for such Reference Architectures is that they do not try to explain in detail the functioning of a particular system, but instead aim for a very abstract description, which can be mapped to or can accommodate a large number of concepts, ideas, and solutions. In that sense, a reference model provides a general structure and taxonomy regarding the ICT eco-system within a city. Furthermore, a reference model serves as a theoretical platform, which can be instantiated for various Use Cases and solutions.

During the work of Triangulum, researchers from Fraunhofer FOKUS specified such an abstract reference architecture for ICT in Smart Cities. This architecture has been used to structure the ICT aspects of the Smart City solutions, which will be developed and deployed within the project. Furthermore, the emerging ICT Reference Architecture will be used to enable the instantiation and replication of ICT based Smart City Solutions, which will need to be transferred from the LCs to the FCs.

The rest of this section is organized as follows: The following subsection 5.4.1 summarizes the key challenges that should be addressed by the design of the proposed ICT Reference Architecture. Subsection 5.4.2 constitutes the main part of this section, presenting the structure of the ICT reference model and the different views on it, such as *Technical* or *Organizational* view. Lastly, subsection 5.4.3 outlines a first evaluation of the proposed ICT Reference Architecture and contains high-level results from the on-site assessments as well as a mapping of the modules (identified within the involved Triangulum cities) to the layers of the Reference Architecture.

5.4.1 Key Challenges on ICT Reference Architecture

Diversity and Partiality of Existing Smart City Architectures: A Reference Architecture can be defined by extracting essentials of existing architectures (e.g., methods and services or usage of standards). Guidance in form of best practices and/or formalized engineering processes can be associated to Reference Architecture to instantiate domain-specific architectures from the Reference Architecture [17]. Examples of Smart City implementation projects have demonstrated a very broad diversity of ICT architectures. These individual and partial solutions do not yet constitute a normalized evidence base to be extracted for describing a generic ICT Reference Architecture.

Nevertheless, they are starting points for the identification of several ICT architecture components. This deliverable and belonging concepts should aim at combining findings from existing Smart City architectures and existing architectural framework (e.g., TOGAF [32], GWAC [11]) with academic research results on the field, for defining a comprehensive ICT Reference Architecture.

Complexity of Smart City systems: As broadly discussed and agreed, Smart City architectures should follow a holistic view on Smart City systems. Such systems are related to different application domains, e.g., transportation, environment, energy, health care, safety, education, and demonstrate complex operation and maintenance processes, mainly related to their nature, and involvement of multiple stakeholders from different disciplines and domains. Besides the operational complexity, various Smart City systems have to fulfil strict quality requirements such as reliability, availability, maintainability, security and privacy [25]. Due to the complexity of Smart City systems, following a holistic view over different application domains is a challenging task to be addressed by the current research.

Identification of useful and missing standards: The list of useful Smart City standards might be long and overwhelming. Therefore, for the identification of useful and missing standards, a well-defined method to support standard gap analysis and its presentation is required.

5.4.2 Design of ICT Reference Architecture for Smart Cities

The proposed ICT Reference Architecture constitutes a key aspect that enables the implementation of Smart City concepts within the involved LCs and FCs. The starting point regarding the definition of such an ICT Reference Architecture are given by the discussions, which were taking place among the consortium members during the project definition phase. This includes the experiences of partners such as *Fraunhofer FOKUS* and *Clicks and Links LTD*. Different illustrations of layered architectures were taken into account, which were proposed by the experts from various IT service and consulting providers from the involved cities. In the course of these discussions, the involved partners defined the core of the emerging ICT Reference Architecture as a **high-level blueprint of the common IT and communication technology artefacts (components and modules)** to be deployed within a Smart City. Thereby, the ICT Reference Architecture is meant to provide the basics and facilitate a **common understanding regarding the ICT related terminology in the city context** as well as to outline the **standard/common sources of data** and the belonging **data consumers**. Another key aspect – it can be even claimed as the most important one – is given by the facilitation of **interoperability** among the identified components, modules, layers, and general artefacts within the emerging reference model. The interoperability aspect is supported by pointing out the **interfaces** among the above listed items. This theoretically enables the combination of and freedom to select different vendors providing solutions/implementations, which map to the parts of the emerging ICT Reference Architecture. Thereby, the interoperability features ease the replication of the ICT based solutions among the involved cities – especially with the focus of transferability of concepts and components from the LCs to the FCs.

The following constitutes a tangible list of main goals for the emerging ICT reference model, which specify and elaborate further the above considerations:

1. Provide a **unified view and understanding on the ICT strategies and deployments** of the involved cities
2. **Identify interfaces** between standard ICT components in a city, which implies the specifications/selection of suitable **data formats** (e.g. XML/JSON scheme, RDF and Ontology vocabularies) **and protocols (**HTTP, REST, 6LowPan, ZigBee, COAP, Real-Time-Publish-Subscribe Protocol)
3. **Accommodation of legacy systems** within the concepts and artefacts of the ICT Reference Architecture
4. Enable the **exchange and interoperability** of components and solutions thereby employing the **identified interfaces** to combine and let them operate together in Smart City scenarios

5. Strengthen the use of **Open Source components**, in order to **enable cities and communities to become vendor independent**
6. Strengthen the usage, publication and dissemination of **Open Data as a key enabler of a Smart City**
7. Enable the **replication of Smart City concepts** between lighthouse and FCs (and in general to other cities)

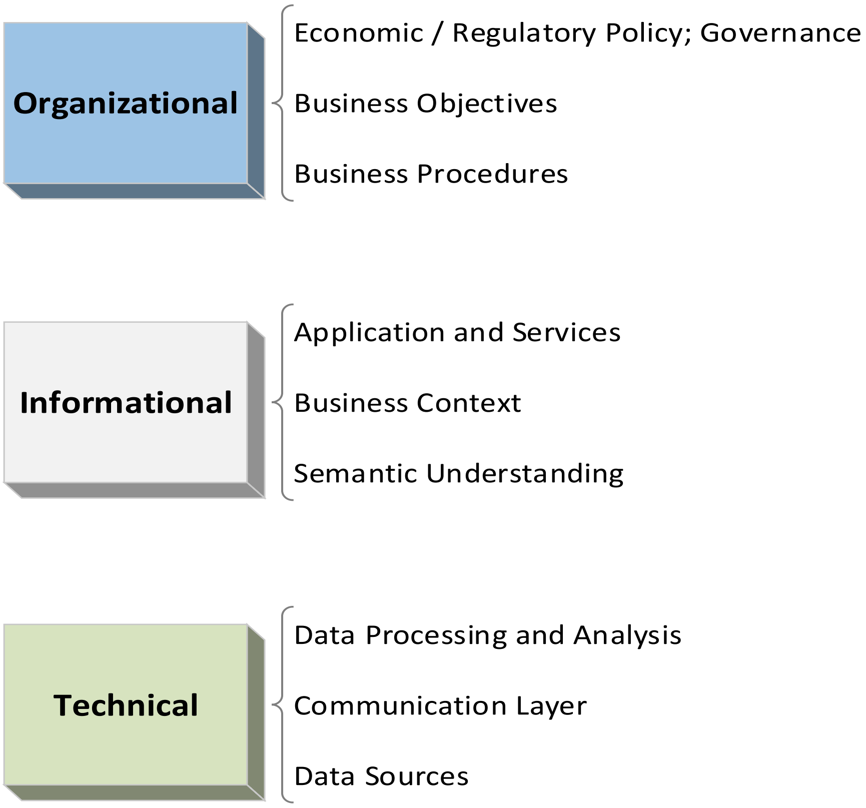


Figure 25 - The different views on an ICT Reference Model for Smart Cities based on the work described in [24].

In accordance with the above considerations, different views on the emerging ICT reference model are taken into account. These views also drive and structure the current line of thoughts and presentation and are illustrated in Figure 25. The structure is dominated by the *Organizational*, *Informational* and *Technical* views on the left-hand side. The *Technical View* is focused on the raw data sources and the communication means to fuse data together and make it available for further processing and analysis. The data processing and analysis interconnects and correlates different aspects of the raw data enriching and enhancing it to become *Information* thereby moving into the Informational view. With the Informational view, the information is refined, structured and enriched as to support semantic relations and a Semantic Understanding of the raw data and resulting information items. That means that different data/information pieces can be put in relation to each other leading to an enriched and deep understanding of the possible influences and implications in complex situations. Furthermore, the semantically enriched data/information is put into a Business Context that drives the development of advanced Applications and Services for Smart Cities, e.g. mobility or energy. Finally, the above technical and informational aspects should be properly organized according to Business Models (including Business Procedures and Objectives) as well as various governance and regulations aspects. For example, it is possible to implement various billing and charging models for data, in case of commercial (non-open) data providers.

The above explanations refer to a broader interpretation of the model presented in [24]. For the current ICT Reference Architecture, we adopt the *Views* but lay down a slightly different structure of layers within the views (as can be seen in Figure 26).

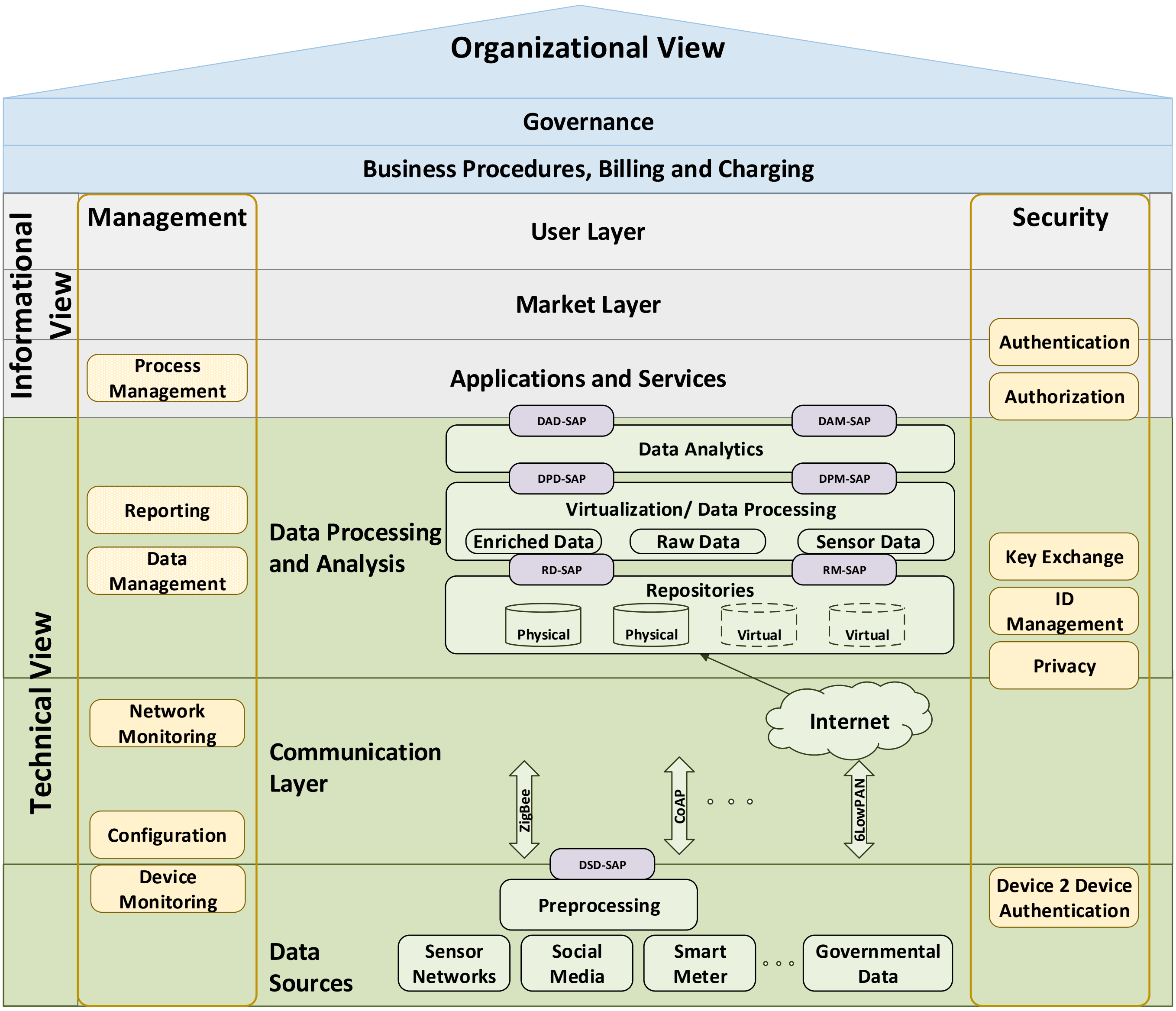


Figure 26: full overview of Triangulum ICT Reference Architecture, focused on Technical View

5.4.3 First Evaluation

The following subsections will describe high level results of the filled templates and a mapping of modules, which are being developed within Triangulum, onto the layers of the ICT Reference Architecture.

5.4.3.1 High-Level Results of Information gathered during first year on-site assessments

In this high-level results section, a first aggregation of the results of the on-site assessments is presented. These results give general insights about the developments of the different modules (mainly ICT solutions in that case) that help to understand the diversity and similarities of the modules with respect to ICT. Each examined item of the template for extracting ICT related information during the on-site assessment will be briefly described and elucidated on with respect to general observations.

Interfaced Third Party Systems: The kind of interfaced third party systems strongly depends on the type of Use Case, which were encountered during the on-site assessments. As to be expected, nearly all Use Cases (except for 2 out of 14) depend on or interact with third party systems. The interfaced systems can roughly be divided into three categories: 1) large systems such as decentralized energy management system, business systems, and open data platforms 2) local systems and applications like backend clients, home automation system and surveillance system 3) sensors and actuators like smartphone, smart meter, smart door and alarm systems. Not all systems interface the three categories equally.

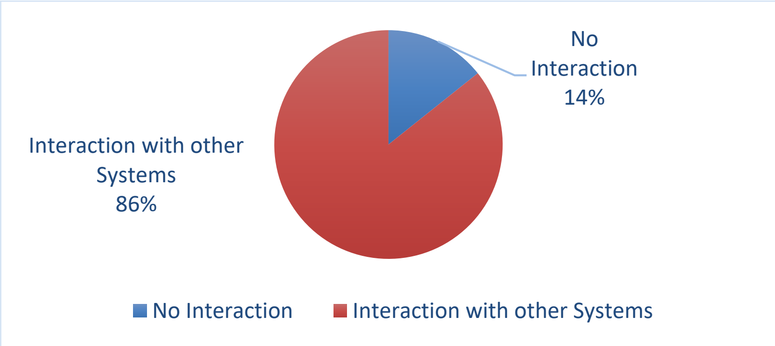


Figure 27 - Interaction with other Systems

Own interfaced Components: Most of the modules interface with own components (except for 4 out of 14). Like with the interfacing of third party systems, the kind of interfaced systems strongly depends on the type of Use Case. These own systems are mostly local systems, sensors and actuators.

Open Interfaces: The information about the usage of open interfaces between the systems and Smart City Solutions across the Triangulum cities is vague at this stage. However, some open or standardized interfaces have already been identified during the on-site assessment.

Table 7: Standards for external interfaces

Name	Description	Standardized
BACNet	Vendor neutral standard for data communication in building automation.	through ASHRAE, ANSI, ISO 16484-5
IEC 60870-5-104	Vendor neutral standard for tele-control of power system automation.	Part of IEC 60870
OPC DA	The OPC Data Access Specification is a group of client-server standards that provides specifications for continuous communication of real-time data.	OPC Foundation

MQTT	Message Queue Telemetry Transport (MQTT) is an open message protocol for Machine-to-Machine (M2M) communication	through OASIS

Utilized Interfaces: The different modules utilize a wide range of interfaces and protocols that cover the wide spectrum including IoT technologies. Most of the utilized interfaces are standardized, except for some proprietary ones following the REST paradigm and utilizing XML or JSON on top of REST.

Table 8: Utilized interfaces

Name	Description	Standardized
BACNet	Vendor neutral standard for data communication in building automation.	through ASHRAE, ANSI und als ISO 16484-5
Bluetooth low Energy (BLE, BT LE)	Short-range low power wireless communication.	Bluetooth Special Interest Group
GPRS	Packed oriented mobile data service on cellular communication.	ETSI, now 3GPP
IEC 60870-5-104	Vendor neutral standard for tele-control of power system automation.	Part of IEC 60870
IP		
Modbus	Client/Server based communication protocol.	de facto standard, (Modbus TCP via IEC 61158)
MQTT	Message Queue Telemetry Transport (MQTT) is an open message protocol for Machine-to-Machine (M2M) communication	through OASIS
OPC DA	The OPC Data Access Specification is a group of client-server standards that provides specifications for continuous communication of real-time data.	OPC Foundation
RFID	Radio-frequency identification uses electromagnetic fields to attach information to objects.	ISO/IEC 18000, ISO/IEC JTC 1/SC 31, ISO/IEC 20248
SOAP	A protocol specification for exchanging structured information in XML (orig. Simple Object Access Protocol)	W3C
SPARQL	Query language and protocol for the Resource Description Framework.	W3C
TCP	A transmission control protocol defining the way in which data is exchanged.	W3C
webRTC	Is an (browser) API for real time communication (voice, video and P2P).	IETF, W3C

ZigBee	Low power low bandwidth wireless communication protocol	Extension of IEEE 802.15.4, ZigBee Alliance
Z-Wave	Secure low power wireless communication protocol	Z-Wave Allianz (ITU-T G.9959)

Licenses and Openness: The utilized licenses are not clear for all scenarios at this moment of time. The fixed, already available Use Cases utilize open source as well as proprietary licenses. The scenarios in itself look homogenous with regard to license application. Scenarios driven by companies in a mature environment tend to mostly use proprietary commercial licenses, probably linked to commercial requirements like liability and quality of service guarantees.

Relation to Open Data: Most of the scenarios (2/3) deal with Open Data: They either store, utilize or provide Open Data. Few scenarios will not deal with Open Data because of domain specific restrictions (e.g. video surveillance). Privacy and security is here one of the main concerns and inhibitor for adoption of Open Data. Some scenarios are at this point not sure if they will interact with/provide Open Data.

Installation and Deployment: There are local as well as centralized deployments in the observed ICT Smart City scenarios within the Triangulum cities. Some of the scenarios will utilize cloud technology or will transition to the cloud in the future. In some cases, the deployment is defined by the utilized underlying technology. In other cases, the deployment is imposed through the nature of the scenario (e.g. FTTH scenario).

Data Storage Technology: Information about the data storage was unclear, because most scenarios used whatever technology that is already available. One scenario will utilize a distributed file system.

5.4.3.2 Mapping of the Modules onto the Layers of the emerging ICT Reference Architecture

For the evaluation of the currently proposed Reference Architecture, it needs to be seen whether the Reference Architecture can or cannot accommodate legacy or standard solutions for Smart Cities. Some Use Cases within Triangulum encompass ICT modules that are either city specific solutions or are part of a bigger Use Case. We aim to assign each ICT component identified during the on-site assessments to one or more layers of the *Technical View* of the emerging ICT Reference Architecture. Factors considered during this assignment include the ease and complexity of the fit ("Do all the components of the ICT module/component fit somewhere and are the connections comprehensible?") and unambiguity ("Is each component limited by the layers' boundaries?"). In order to achieve this, information from the on-site assessments as well as the structure of the project – in terms of WPs and tasks – are used in order to approach the challenge of *"explaining the ICT modules in the involved cities through the emerging ICT Reference Architecture*" in a structured way.

A common way of referring to single modules and technologies is introduced in Table 9. For each of the LCs, a designated WP was created; these work packages are subdivided into tasks (Project Management, *Energy, Mobility, ICT* and Communication) and subtasks that fall into one out of the three highlighted tasks. These subtasks usually include or correspond to a single module; in a few cases, even two or not even a single module can be assigned to one subtask. As an example, Table 9 shows all subtasks pertaining to the ICT task of WP5.

Table 9 - Overview of the modules and technologies included in the subtasks of the Stavanger Implementation Plan

WP	Task	Sub	Title	Modules	Technologies

5			CITY OF STAVANGER IMPLEMENTATION PLAN		
5	4		ICT		
5	4	1	Innovative video	Innovative Video	T1: New state of the art video services; T2 (existing): Fiber to the Home Infrastructure (FTTH)
5	4	2	Big data analytics	Big Data Analytics	T1: Framework; T2: Generic tools
5	4	3	Sustainable citizens service development	Sustainable citizen service development	None

The modules described in Table 9 consist of multiple components (an abstract basic unit used for mapping) that ideally correspond to the defined technologies within the scope of the module. The knowledge gained during the on-site assessments enable the mapping of these different modules, technologies and components along with their characterizing interfaces onto the ICT Reference Architecture. The following paragraphs along with the included Figures display the results of this mapping process. Solid lines within those figures define the interfaces between the components. It has to be noted, that in this section only few mappings will be elaborated.

The Manchester module regarding the optimization of energy usage in different university buildings (in WP3.2.2) includes both more localized Energy Control Devices (T1) and Building Management Systems (T2). Data are initially measured by device sensors that are directly located on e.g. single heating units. Therefore, these device sensors fall into the Data Sources Layer. The Energy Control Devices pool this data and forward it to the building-central management system (T2). From there on, the data finds its way either by means of a BACNet to IEC-1-104 protocol converter or a PLC unit to a Decentralized Energy Management System (DEMS, see WP3.2.3). The major task for both of the two technologies (T1 and T2) in the module is the transfer of information and thus, they were mapped to the Communication Layer of the ICT Reference Architecture.

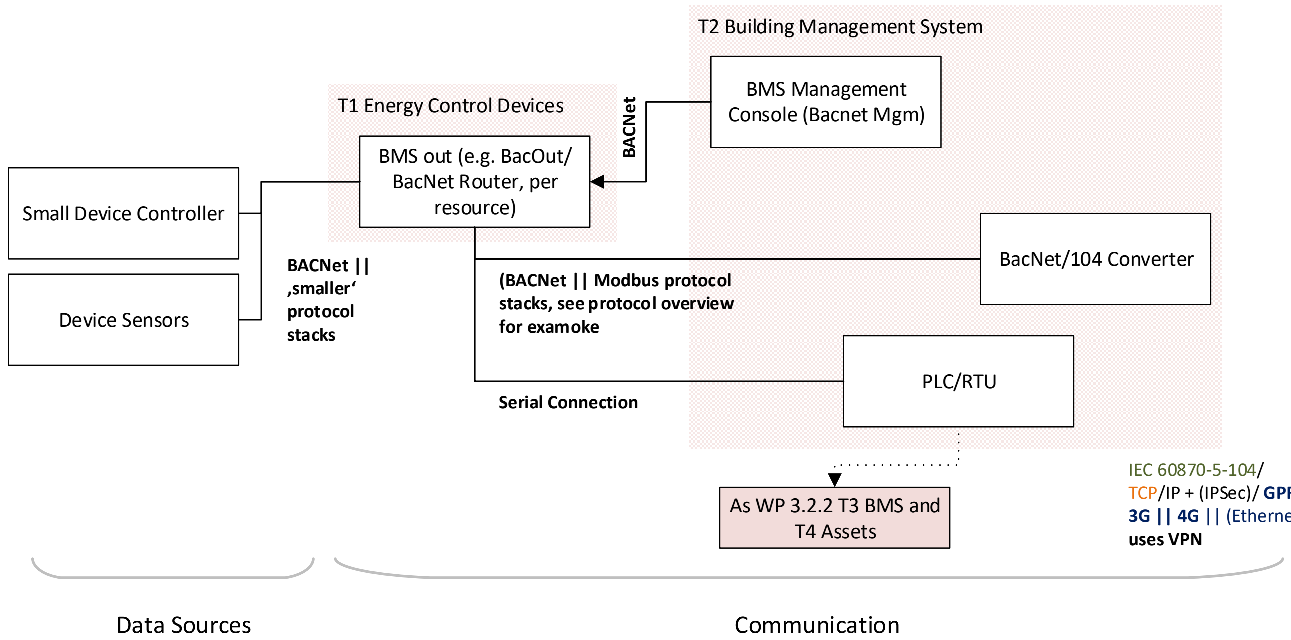


Figure 28: Sketch of the interconnections between the components and technologies included in the "Implementing energy optimisations within buildings" module in WP3.2.2.

Figure 29 includes the mappings of the two modules included in WP3.4, which are closely intertwined. The Triangulum-I platform is the precursor of a greater Manchester-wide platform (Manchester I). This platform (T1/WP3.4.1) contains a data cataloguing system and tools that can access data contained in the different data platforms (e.g. Dimer and City Verve) of the city. For that purpose, it was assigned to the Communication Layer. The mentioned data platforms serve mainly as repositories and therefore fall into the *Data Analysis and Processing* Layer and so does the planned Data Visualization Platform (T1/WP3.4.3) whose main task is the support of data analysis.

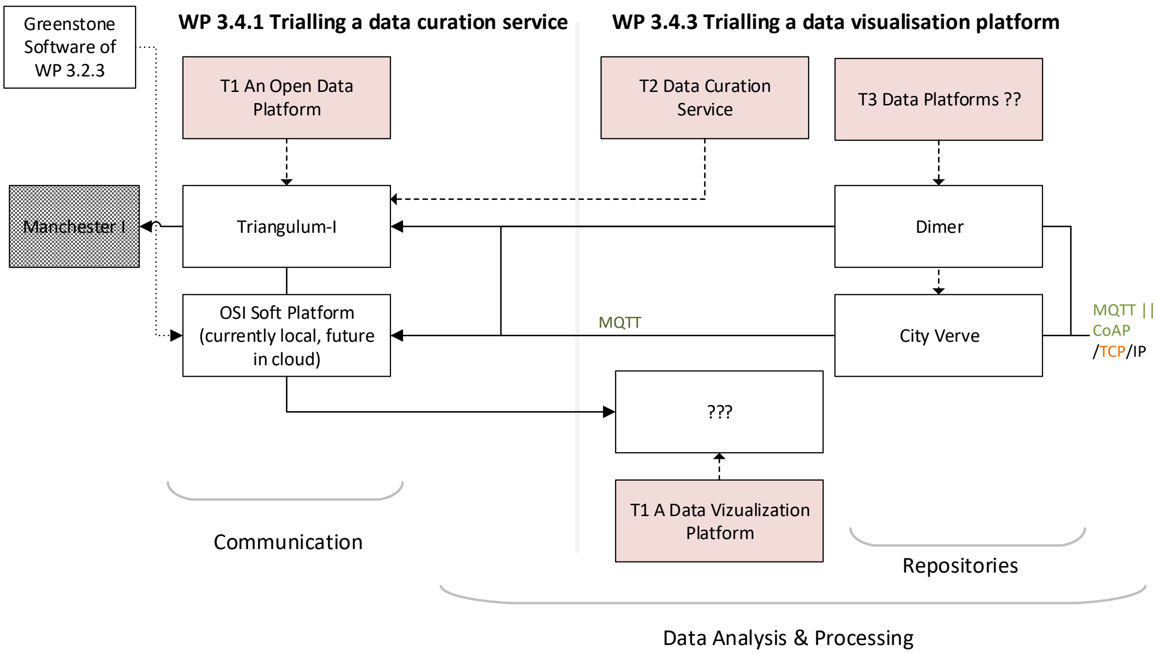


Figure 29: Sketch of the two modules ("Data curation service" and "Data visualisation platform") contained in WP3.4.

The innovative video Module (WP5.4.1), whose mapping can be found in Figure 30, uses HD cameras for recording high-quality video that are controlled via low-energy Bluetooth. These cameras are the sole source of data within the module. Fibre optic cables are necessary for the data transport and communication, as high-definition video material necessitates high data throughput rates.

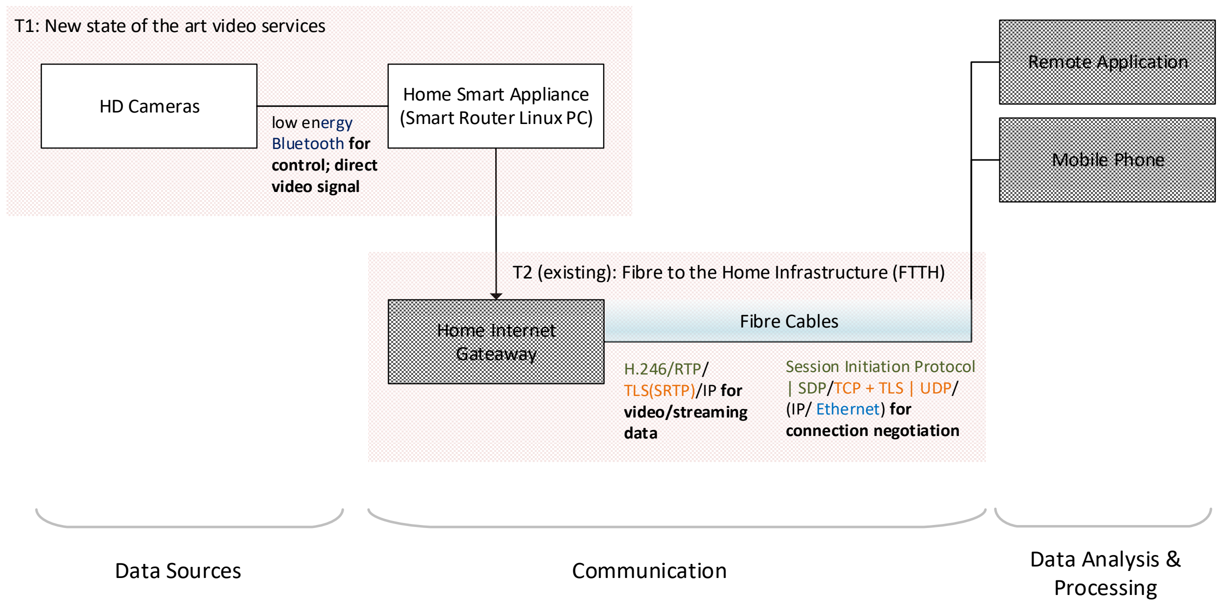


Figure 30: Sketch of the "Innovative Video" module in WP5.4.1.

Lastly, WP5.4.2. foresees the creation of the system capable of Big Data Analytics. This system is shown in Figure 31. Technology 1 (T1) spawns both the *Communication* and the *Data Analysis and Processing* layer. The *Communication* layer includes all the connections from the first sink of the sensors network up to the premier entity, which either stores the data for a longer period of time and allows external access to it, or builds the basis for further processing in the *Data Processing* layer (i.e. a repository, in this particular figure: University Data Center). Note that data generated during data analysis and processing (e.g. enhanced data) can move between different repositories by means of the *Communication* layer. Metadata storage hubs thereby serve as cataloguing entities and provide information about available data and their location within the repositories. In addition to that, it may register data streams from the sensors. Both these functions are realized by engine-specific interfaces, which in some cases can be extended (e.g. by plugins for CKAN or *Socrata*).

Technology 2 (T2) in Figure 31, is located on the third layer of the Technical View of the emerging ICT Reference Architecture. It includes storage systems such as Open Stack Swift and optionally Cinder, the Hadoop Distributed File System (HDFS) and the CEPH distributed file system. Each of those provide different APIs (e.g. the standard command line API of the HDFS or the web-based one called WebHDFS) in order to allow for data exchange. Furthermore, different processing engines (based on the given file systems) and other components - such as user-facing command line or web interfaces for e.g. application submission/job execution or entities enabling the interoperability of processing stacks - are encompassed.

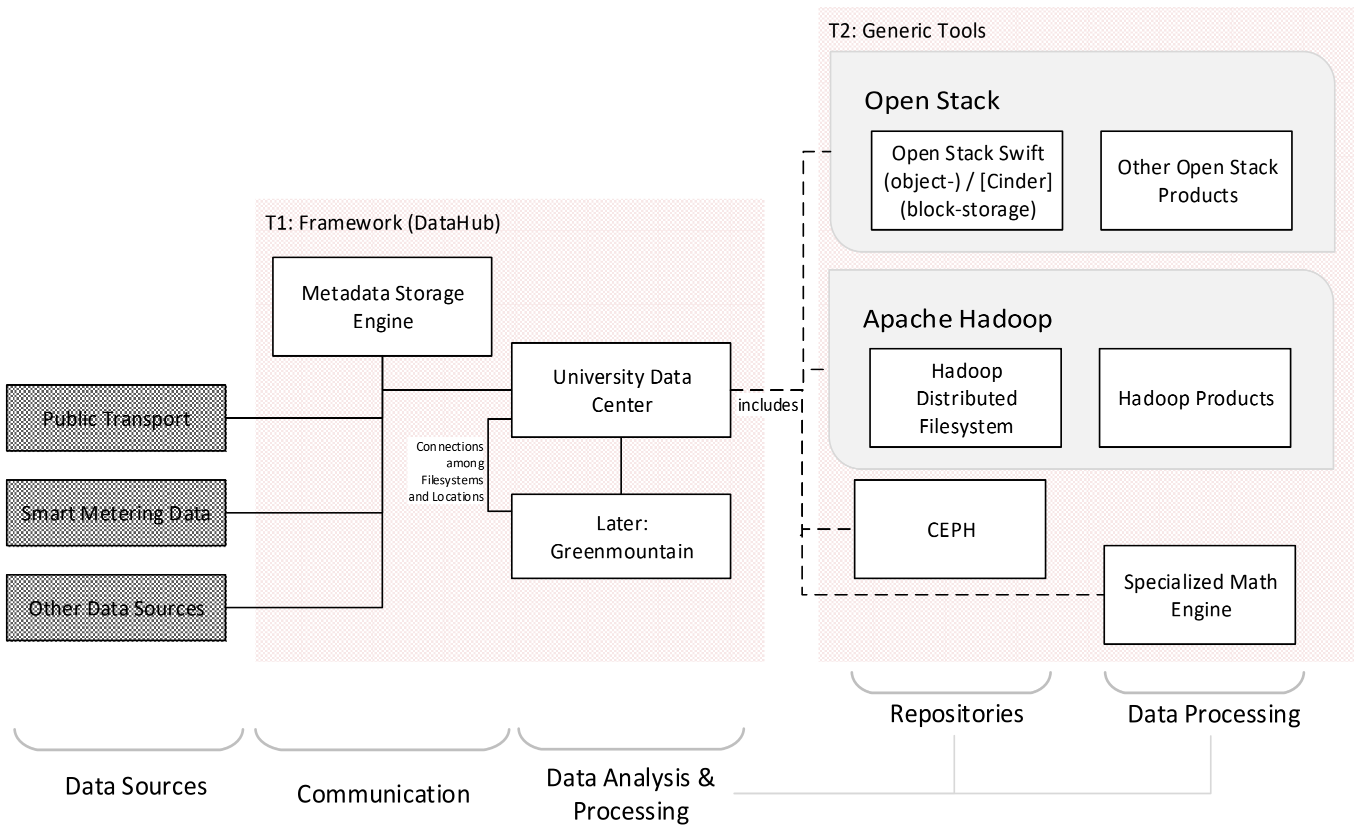


Figure 31: Sketch of "Big Data Analytics" module in WP5.4.2.

The mappings of all defined modules onto the Reference Architecture are summarized in Table 10.

Table 10: Mapping of the modules onto the different layers of the ICT Reference Architecture.[48]

Module	Data Sources	Communication Layer	Data Analytics and Processing
3.2.2 Implementing energy optimizations within buildings (Heather Stapleton /Siemens)			
3.2.2 Installing low carbon energy generation assets			
3.2.3 Trialling a central energy controller (Virtual Power Plant?)			
3.3.2 E-Bike based district logistics			
3.3.2 Support for EV purchases			
3.4.1 Data curation service			
3.4.3 Data visualization platform			
4.2.1 Sustainable Energy Supply and Soil Sanitation			
4.2.2 Modernization of a gas-fired to a biomass-fired CHP Utility			
4.2.3 Smart Energy Management for Offices			
4.2.4 Refurbishment of family homes on a participative basis			
4.2.5 Installation and smart distribution of locally produced renewable energy (Woonbedrijf)			
4.3.1 Smart charging infrastructure for electric vehicles			
4.3.2 Mobility Management Upgrade			
4.4.1 Smart City ICT open data platform (Eindhoven municipality)			
4.4.4 Implementation and integration of a fibre-optic data infrastructure (VW)			
4.4.5 Stimulating the development of innovative services and applications			

[48] Strong green shading indicates that a higher focus on the components of the respective layers is set. Grey shading indicates that this module does not have any components of relevance for the technical view

4.4.6 Smart street lights (VW)			
5.2.1 Smart Gateway introduction and energy management			
5.2.2 Geothermal Well Park			
5.2.2 Modernization of old central heating (natural gas and electric heaters to hydronic boilers and pellet heaters)			
5.3.1 E-Bus Demonstration Project			
5.3.2 EV Charging Infrastructure Update			
5.4.1 Innovative Video			
5.4.2 Big Data Analytics			
5.4.3 Sustainable citizen service development			

In addition to that, the utilized communication protocols and other technical details that were recorded during the on-site assessments are assigned to the corresponding links between the components and form the preliminary interface descriptions. Interface descriptions for one module ("Smart Gateway introduction and energy management" in WP5.2.1) were excluded from this deliverable, as the responsible partner voiced concern due to business confidentiality. Nevertheless, this information has been incorporated into the ICT Reference Architecture on a more abstract level that does not allow for the identification of solution-specific details.

All relevant modules have been successfully mapped onto the proposed ICT Reference Architecture without any noteworthy problems and thus, the Reference Architecture can be considered to mirror well the general structure of the modules and solutions of the involved partners.

In order to assign common or recommended interfaces to the different layers of the Reference Architecture, it is of interest to find multiple instances of similar connections in different modules spanning the same layer boundaries. Therefore, similarities and synergies within and among WPs have been worked out and their advantages and disadvantages are compared. Some example synergies include:

- In addition to the *Big Data Analytics* module shown in Figure 31 and currently being implemented in Stavanger (subtask 5.4.2), also Eindhoven and Manchester are looking into the creation of similar entities (subtasks 3.4.1 and 4.4.1). Going further into detail, we also find agreement on the level of technologies, e.g. both WP3 and WP4 include 3D-Visualization tools (subtasks 3.4.3 T1 and 4.4.2 T6).

- All three work packages include approaches to smart metering and analysis of energy usage data (subtasks 3.2.2/3, 4.2.3/4 and 5.2.1/5.4.1). Whereas in Stavanger, focus is put onto smaller units such as single flats, Manchester aims to equip multiple university buildings with metering technologies. Therefore, the latter module might include an additional intermediary component for data pooling. These points to the 'size' of the solution as yet another dimension that might be considered in future abstractions of components and interfaces to characterize the layers of the ICT Reference Architecture.

- E-Vehicle charging and the utilization of renewable energy sources are also featured in all three work packages. Smart public ICT infrastructure is included in both WP4 and WP5

As can be seen by looking at the heterogeneity of used protocols and APIs in modules that realize similar functions, these common interfaces may be implemented in different ways. To guide a good choice for a specific implementation, recommendations that include factors such as security, privacy, resource efficiency, ease of handling and implementation, reliability, interoperability with other (open) systems and the possibility for future extensions can be made. An example of such a recommendation can be found in Table 11. Therein implementation recommendations, along with their advantages and disadvantages, have been listed on a per layer transition and per SAP manner.

Table 11: Interface recommendations for a Smart Energy Infrastructure and Management module.

Inerface a transition of layers	**SAP(s)**	**List of Recommendations ordered by strength of recommendation**			**Advantages / Disadvantages**	**As used in Common Modules**
		Protocol Stack	*Software/API*	*Data Format*		
Smart Energy Infrastructure / Management						
COM <-> DaAlyProc	DPD (?)	MQTT||CoAP||Threat/TCP/IP/ (Ethernet)	Paho, MQTT.fx (?); IBM Message sight (???)	JSON + Binary	more up to date, flexibility	Smart Meter / BMS Console, Central Controler for (multiple) Buildings, Building Management System (Big Scale)
	DPM	TR-069			for configuration	
	DPD	IEC 60870-5-104/TCP/IP + (IPSec)/ GPRS || 3G || 4G || (Ethernet)				Central Controler for (multiple) Buildings
DS <-> COM	RD	Threat || Zigbee || Zwave || MQTT || CoAP /UDP/IPv6 + RPL + 6LoWpan/802.15.4 Mac & PHY			for server/controller sides	Smart Gateaway / BMS Interm Node, Heat/Water/Electicity Sensors
		(ZIGBEE/ 802.15.4 Mac & PHY)				
		Zwave AppL / ZwaveTL/ ZwaveNL/ Zwave Radio	-		proprietary	
		XComfort/[illegible]./[illegible]Radio	-		proprietary + low functionality (?)	

Such an approach allows various concrete technologies to be put in place within the abstract interfaces among the layers of the emerging ICT Reference Architecture, and to prepare the interoperability and replication of ICT solutions across the involved cities.

5.5 Impact Assessment

This chapter lines out the integration of the impact assessment and replication steps within Triangulum. The results of the indicator analyses however are not included and shown in the corresponding Deliverable 2.1. The next chapter will outline properties and benefits from the Cloud Data Hub and display the development of monitoring protocols as being provided in WP2.

5.5.1 Cloud Data Hub

The implementation of modules at UiS, Module 542 Data analytics toolkit and Module 544 Cloud data platform, was motivated by a desire for a standard ICT solution for documenting and analysing the impacts of all modules in the Triangulum project, as well as the opportunity for undertaking more advanced analysis of the data collected.

In order to capture such data and to enable insightful analysis, a system is required that can correctly ingest, reliably store, and intelligently process the data. A cloud computing solution can address all these criteria. Furthermore, a cloud computing solution based on locally situated hardware may in principle enable greater security and control than outsourcing cloud computing solutions to overseas commercial vendors. Finally, an open-source, commodity hardware cloud computing solution lowers the economic threshold (i.e. financial cost) to adopt this solution among Follower Cities and others who wish to replicate the present work in part or in full. Some of the main properties and benefits of the Cloud Data Hub are discussed in more detail in the following.

Figure 32: overview of four stages of data usage improved by Cloud Data Hub

More efficient storage

The Cloud Data Hub contains the inherent property of being able to store data in a secure and centralized manner. Operating a server system and backing up data is more cost-efficient and secure in a cloud-based platform than in several local and not-interconnected servers.

Managing protocols and access systems

Data are often provided into cloud platforms via automated APIs (application programming interfaces). As those interfaces are developing over time, interfaces need to be updated from time to time. These developments need to be monitored constantly. Managing this process in a centralised platform instead of with each data owner, increases efficiency and decreases the amount of missing data due to incompatible protocols. In addition, a central Cloud Data Hub can provide a management system for accessing the data.

Setting rules for metadata

In order for data to be useful for further usage a high quality and consistency of metadata has to be ensured. Metadata in general may provide information on how the data were collected, what they actually contain and therefore provide crucial information for the analyses and interpretation of results. A harmonious set and rules for metadata can improve usability and therefore applicability of datasets.

Central point of reference

Instead of a user having to contact each data owner/provider individually, he/she can go to fewer points of reference and receive the data and relevant meta-information. From the user-perspective, this increases efficiency and also increases the potential outcome as he/she might find useful additional information on the same or a linked platform.

Interaction with other platforms

As it is neither structurally nor organisationally efficient to integrate all data in one platform, the interconnection between several platforms provides the best way of making data available to the right users. One can imagine a system similar to roaming in the mobile phone or the electric vehicle charging sectors, where platforms exchange information amongst each other. In addition to the vertical integration of data between data provider on user, a horizontal integration of platforms and the corresponding search and curation functionalities could provide huge benefits to both the data owner and analysts.

In the context of EU Horizon projects the different platforms on European and project levels could be interconnected using platform-to-platform interfaces allowing all entities efficient access to relevant information.

Improved quality management

On the level of additional services that could be offered by a cloud platform, quality management is one of the most crucial ones. Unsafe, incomplete or corrupted data make usage for analysists impossible. Instead of each analysist facing the same quality issues, the central platform could provide this quality as a service and severely increase efficiency and boost the generation of valuable outcomes.

Monitoring and reporting functionalities

A Cloud Data Platform can also provide a direct information service to many different kinds of stakeholders. In order to offer this service, it needs processing capabilities and corresponding frontends. Within the Triangulum project the platform could for example provide a dashboard for the project management team to provide information o status and impact of each Use Case. It can also give condensed impact related figures directly to decision makers or to the general public. Such a service increases its impact with the number of visualisation options available on the platform.

5.5.2 Monitoring protocols

Next to the actual build-up of the Cloud Data Hub, its specific monitoring related tasks are underpinned by a logic of developing the right indicators to assess the impact of the Triangulum modules and Use Cases. The methodology of creating and calculating this set of indicators is set out in so called monitoring protocols.

The seven-stage methodology adopted by WP2 for developing impact indictors and calculating impacts is described in Deliverable 2.1 (the Common Monitoring and Impact Assessment Framework). The stages of the methodology are reiterated to aid interpretation of the impact report. The actual results and corresponding figures of the monitoring and impact reports are not part of this deliverable but can be found in the before-named documents of WP2.

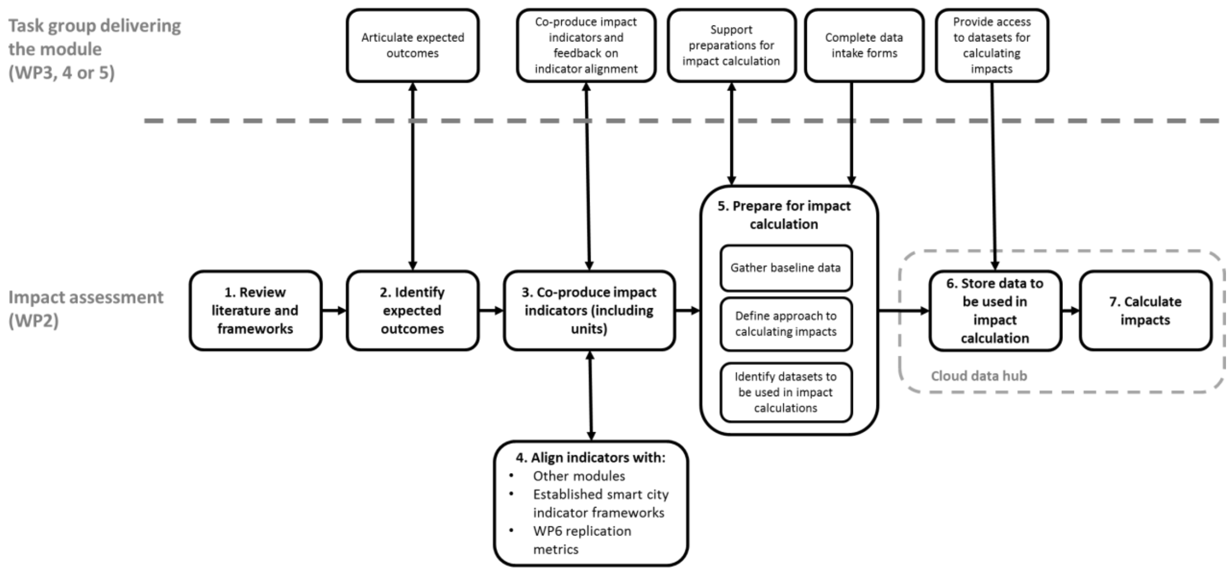


Figure 33: Seven-Stage Methodology for Developing Indicators and Calculating Impacts (monitoring protocol)

Explanation of Seven-Stage Methodology for Developing Indicators and Calculating Impacts (monitoring protocol):

1. **Review of existing literature and frameworks.** WP2 conducted a desk based review of the key literatures on sustainability and Smart City indicator development and assessment. WP2 conducted a review of on-going sister projects developing Smart City indicator and assessment frameworks. The desk study was used to determine the general framework and parameters for the work, as presented in sections 3 and 4 of this report.
2. **Identify and document expected outcomes.** WP2 will engage with the city task groups delivering the modules to identify the scope and expected outcomes of each module. In each LC, a local university researcher is tasked with developing impact indicators and associated reports for the modules of the local partners. Engagement will be aligned with the operation of the task group. Methods used will include contributing to task group meetings, conducting workshops and semi-structured interviews, electronic consultation and opportunities to feedback on draft WP2 documents.

3. **Co-produce and document impacts, indicators and datasets.** Based on the expected module outcomes and review of existing literature and frameworks WP2 proposes impact indicators including quantitative units. The task groups will also be invited to propose impact indicators. The set of indicators for the module is then collaboratively refined by WP2 and the task group through workshops and inviting comments electronically on draft WP2 documents. FCs also provided input to this process at the General Assembly (GA) in Berlin 2015.

4. **Align and verify impacts, indicators and metrics.** The impact indicators for each module will be included in analyses which identify opportunities to align: with other indicators across energy, ICT and mobility activities across the three cities; established Smart City indicator frameworks (CityKeys and SCIS); and, WP6 replication metrics. The aligned impacts, indicators and metrics will be verified with the task groups through electronic consultation.

5. **Prepare for impact calculation.** With support from task groups WP2 preparation for impact calculation will including: gathering baseline data; defining the approach to calculating impacts; and, identifying datasets that could be used in the calculation of the impacts. Two modes of engagement will be used: (1) ongoing collaboration through workshops and interviews; and, (2) task groups completing a *data intake form* (DIF) which formally specifies the indicators and approach to be taken to calculate them. The data

intake form will be used for more complex data sets that go beyond individual data points or simple spreadsheets. Additional work may be required to facilitate documentation and transfer of data, but partners will not be asked to perform additional work to generate the data.

6. **Store data to be used in impact calculation.** Based on the details provided by stakeholders and in the data intake form WP2 (Stavanger) has imported datasets for impact calculation into the Cloud Data Hub. Where data is not in the appropriate format or does not warrant automation, datasets have either been manually collected by WP2 researchers in each city or specific data items have been requested from dataset holders.

7. **Calculate impacts**. Impacts have been calculated in three ways. The preferred option is to calculate impacts automatically in the Cloud Data Hub. Where this is not possible, WP2 researchers have requested the relevant data to make impact calculations. Where data has been unavailable for sharing, WP2 researchers have requested pre-calculated impacts from data holders.

The following chapter displays the results and content of the implementations in Use Case format.

5.6 Triangulum Use Cases

This section provides all the results of the technology transfer approach for each Triangulum Use Case. The information is provided Use Case after Use Case in a template that was built on the theoretical basis of the Holistic Smart City Value Model (cf. Chapter 3.1), using a data collection methodology built on the logic of the Morgenstadt City Lab Approach (cf. Chapter 3.2) and being moulded by the practical insights gathered through continuous exchanges with the LCs and especially their business partners.

All together 57 Use Cases were financed by and implemented within the project Triangulum. More than half of these Use Cases were implemented in the LC of Triangulum which is partly due to the "iCity tender" that was performed by the City of Eindhoven, Volker Wessels and the Technical university of Eindhoven. This innovative, design competition-like approach delivered 8 innovative Use Cases for the Lighthouse District of Strijp-S. The distribution of Use Cases amongst the LCs can be found in Figure 34.

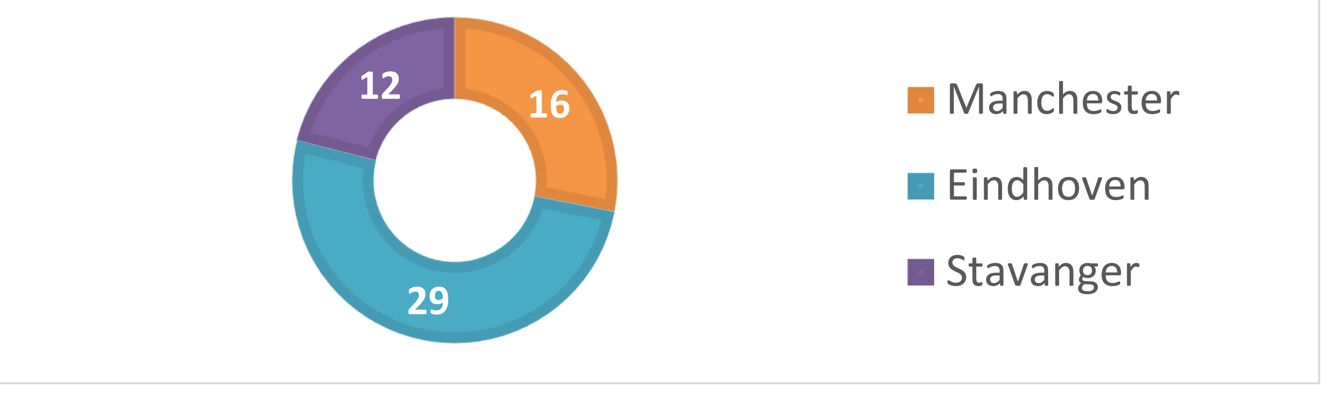


Figure 34: Use Cases in Triangulum per city

Although the main data on replication unit level can be found in the coming sub-chapters. Figure 35 displays an overview of the 5 most important primary benefits provided by the Use Cases. It does not provide insights about the quantitative impacts of the implementations, which is part of the monitoring process in WP2, but shows the main areas of innovation within Triangulum. The diagram shows, in-line with the Holistic Smart City Value Model, that all areas of Smart City developments are covered and at the centre of developments in Triangulum: social (life quality, transparency), environmental (fossil fuel use) and economic (operation costs). The importance of data availability as being mapped and understood in the ICT Reference Architecture is the last of the top 5 focus areas in Triangulum Use Cases. Whenever the subsection does not include a mapping onto the layers of the ICT Reference Architecture, the team of WP6 decided that the information generated from these diagrams does not generate any new insights and thus omitted these diagrams.

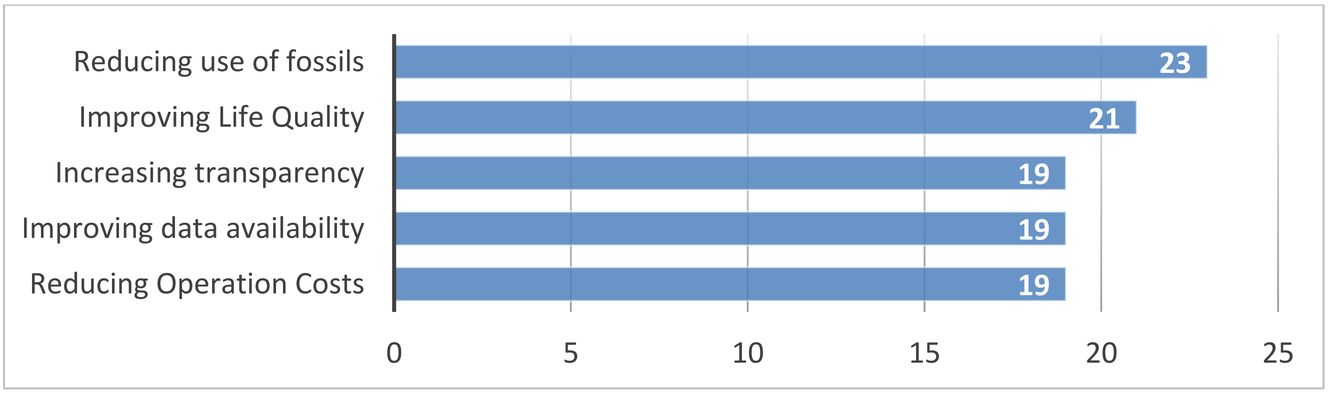


Figure 35: most recurring primary benefits (all Triangulum Use Cases)

The following chapters now provide all the captured information of the 57 Triangulum Use Cases and of 6 additional ones that are closely linked to the Triangulum implementations. Each chapter consists of three pictures including all information relevant for replication. Due to the high amount of graphics and the repeating nature of the content, the graphics have not been labelled individually. The first two graphs in each of the following sub-chapters include the information according to the Use Case template introduced in Chapter 5.3 and one graphic following the logic of the ICT Reference Architecture introduced in Chapter 5.4.

5.6.1 Demand Side Response Control for Student Accommodation (UC-321a)

Demand Side Response Control for Student Accommodation

General Information

City	Manchester	Sector	Energy
Country	United Kingdom	Triangulum	Yes (In Delivery)

Short Description
Delivering strategic load curtailment via existing BEMS, such DSR interventions will be issued by the City Energy Controller to the respective location - the Siemens Microbox will integrate with the local BEMS to temporarily change operating state of the approved systems to deliver load reduction

USP/Highlight
Scalable platform to integrate new buildings and loads/ systems as they come on line, or can be applied as a retrofit.

Project Scale	Individual site	Planning Time	0.5 - 1 years
Development Type	Retrofitting	Implementation Time	0.5 - 1 years
Participation Model	Active participation	Technology will drive passive, systems response, however wider citizen engagement will deliver active participation	

Stakeholder Analysis

Owner	Siemens & partners	Implementer	Siemens
Customer	building owners and building managers	Service Provider	Siemens

Implementation of UseCase

Supporting Factors

Legal		Geographical	Manchester Corridor is an innovation district, numerous stakeholders with similar vision to cluster and connect start-ups, business incubators and accelerators. This is combined with high quality universities and a forward thinking municipality
Infrastructural	Existing BEMS systems	Social	MCC / Corridor Manchester intend to ; * To reduce the carbon footprint of Corridor Manchester through the more sustainable management of energy and waste. * To integrate green and smart ideas into new development and investment proposals. Visibility of independent DER assets provided by CC - accessed by multiple stakeholders concurrently and can be used for engagement. DSR can be delivered with direct BMS load curtailment, but also when communicating to citizens to increase awareness of local conditions / when they should switch off
Financial	Driving load reduction to limit energy costs at high tariff times	Partners	Strong co-operation with Municipality Corridor Manchester & City Council (Aim to reduce carbon footprint of Corridor and integrate green and smart ideas)
Other			

Main Implementation Challenge
Collating existing operational information for the BEMS and agreeing new 'DSR operating conditions'

Lessons Learned
Flexibility in design required, different stakeholders will require different solutions
Existing BEMS vendors do Not all support open protocols such as BACnet as use proprietary languages. Some modifications may be required

Financing Information

Initial Investment		ROI	< 5 years
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Stakeholder; Decrease stakeholder energy costs Reducing CO2 emissions and associated fiscal penalties Network Operator; Postpone grid investment as a result of peak-lopping

Project Details

Standard & Technical Details
Siemens Microbox & associated BEMS

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Reducing use of fossils
Decreasing energy consumption in buildings	Encouraging digital entrepreneurships
Improving Energy Usage Efficiency	Enabling new business opportunities
Shaving peak Energy Demand	Improving Air Quality
Reducing energy Bill	Reducing GHG Emissions
Enhances Grid Stability	Increasing share of renewables
Improving data availability	Improving social integration
Increasing transparency	Improving Life Quality
	Promoting sustainable behavior
	Facilitating Citizen Engagement

Additional revenues can be secured through aggregation providers and participation in energy markets

Wider Benefits
Cost reduction Reducing CO2 levels More economical Better place to live Reduced energy consumption Wellbeing

Suggested Financing Options
Cost offset of energy costs (DUoS, TRIAD, Consumption charge). Additional revenue services can be delivered with DSR systems in UK ancillary services.

Prospective Customers for future
Industrial and commercial (I&C) customers, those who are billed based on 30minute consumption. Municipalities with high concentration of assets, buildings

Contact for further Details
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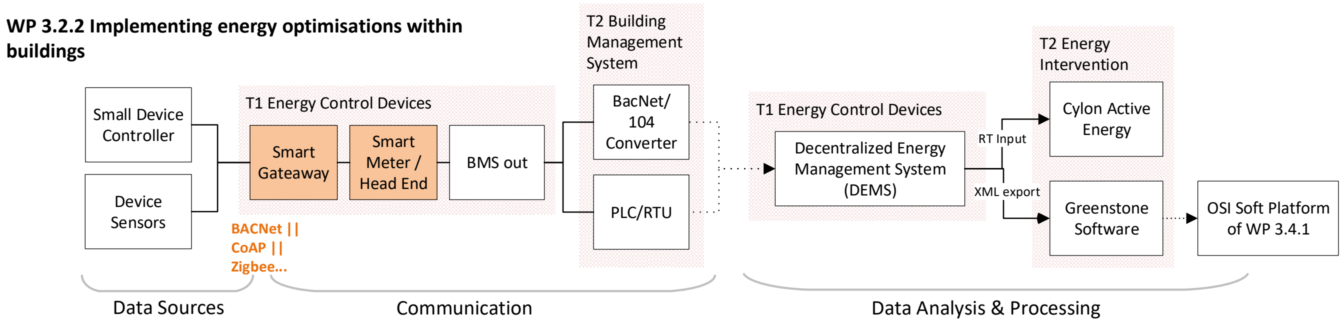

Both sensors and controllers are interfaces to the physical world. It is here that the first actual data points are discretized and therefore they can be regarded as data sources. The energy control devices and the building management system hereby are mainly responsible for the accumulation and forwarding of the collected data and therefore belong to the communication layer. Initial pre-processing of the accumulated data from all buildings happens within the decentralized energy management system that then either forwards the actual real time data or provides reports periodically to further processing engines that allow for a deeper analysis of the data, on which appropriate responses can then be selected.

Relevant Standards: Zigbee, RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.2 Demand Side Response Control for Office Block (Academic Building) (UC-321b)

Demand Side Response Control for Office Block (Academic Building)

General Information

City	Manchester	Sector	Energy
Country	United Kingdom	Triangulum	Yes (In Delivery)

Short Description
Delivering strategic load curtailment via existing BEMS, such DSR interventions will be issued by the City Energy Controller to the respective location - the Siemens Microbox will integrate with the local BEMS to temporarily change operating state of the approved systems to deliver load reduction

USP/Highlight
Scalable platform to integrate new buildings and loads/ systems as they come on line, or can be applied as a retrofit.

Project Scale	Individual site	Planning Time	0.5 - 1 years
Development Type	Retrofitting	Implementation Time	0.5 - 1 years
Participation Model	Active participation	Technology will drive passive, systems response, however wider citizen engagement will deliver active participation	

Stakeholder Analysis

Owner	Siemens & partners	Implementer	Siemens
Customer	Partners	Service Provider	Siemens

Implementation of UseCase

Supporting Factors

Legal		Geographical	Manchester Corridor is an innovation district, numerous stakeholders with similar vision to cluster and connect start-ups, business incubators and accelerators. This is combined with high quality universities and a forward thinking municipality
Infrastructural	Existing BEMS systems	Social	MCC / Corridor Manchester intend to ; * To reduce the carbon footprint of Corridor Manchester through the more sustainable management of energy and waste. * To integrate green and smart ideas into new development and investment proposals. Visibility of independent DER assets provided by CC - accessed by multiple stakeholders concurrently and can be used for engagement. DSR can be delivered with direct BMS load curtailment, but also when communicating to citizens to increase awareness of local conditions / when they should switch off
Financial	Driving load reduction to limit energy costs at high tariff times	Partners	Strong co-operation with Municipality Corridor Manchester & City Council (Aim to reduce carbon footprint of Corridor and integrate green and smart ideas)
Other			

Main Implementation Challenge
Collating existing operational information for the BEMS and agreeing new 'DSR operating conditions'

Lessons Learned
Flexibility in design required, different stakeholders will require different solutions
Existing BEMS vendors do Not all support open protocols such as BACnet as use proprietary languages. Some modifications may be required

Financing Information

Initial Investment		ROI	< 5 years
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Stakeholder; Decrease stakeholder energy costs Reducing CO2 emissions and associated fiscal penalties Network Operator; Postpone grid investment as a result of peak-lopping

Project Details

Standard & Technical Details
Siemens Microbox & associated BEMS

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Reducing use of fossils
Decreasing energy consumption in buildings	Encouraging digital entrepreneurships
Improving Energy Usage Efficiency	Enabling new business opportunities
Shaving peak Energy Demand	Improving Air Quality
Reducing energy Bill	Reducing GHG Emissions
Enhances Grid Stability	Increasing share of renewables
Improving data availability	Improving social integration
Increasing transparency	Improving Life Quality
	Promoting sustainable behavior
	Facilitating Citizen Engagement

Additional revenues can be secured through aggregation providers and partition in energy markets

Wider Benefits
Cost reduction Reducing CO2 levels More economical Better place to live Reduced energy consumption Wellbeing

Suggested Financing Options
Cost offset of energy costs (DUoS, TRIAD, Consumption charge). Additional revenue services can be delivered with DSR systems in UK ancillary services.

Prospective Customers for future
Industrial and commercial (I&C) customers, those who are billed based on 30minute consumption. Municipalities with high concentration of assets, buildings

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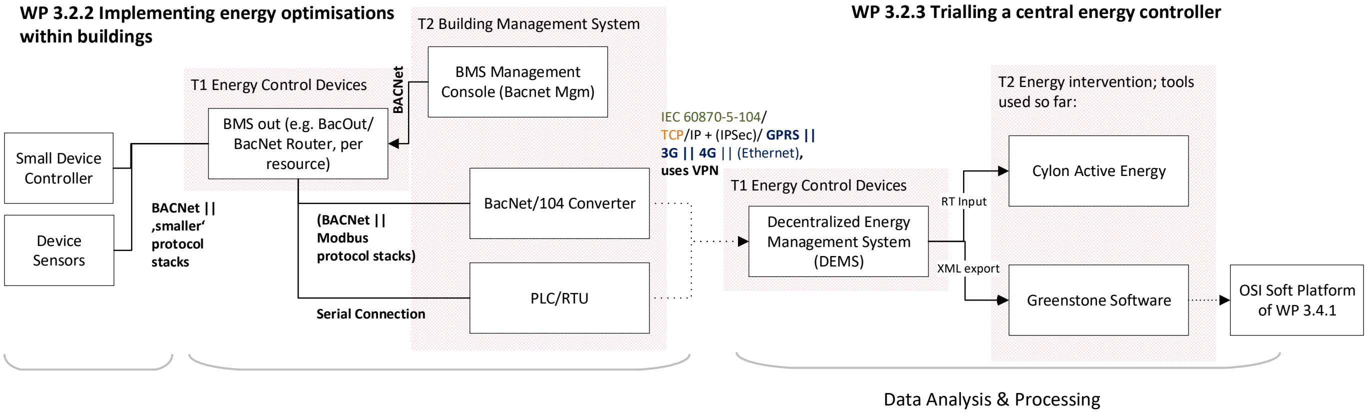

Similarly to the previous Use Case, small controllers and sensors make up the data sources and analysis is taking place at the level of the decentralized energy management system and energy intervention tools. The major difference lies on the communication layer, as no smart meters are present. Legacy technologies such as the BacNet building management infrastructure are used for data accumulation and transport to the processing hubs are used instead, that have proven suitable in the context of single and multiple floors or buildings.

Relevant Standards: ANSI/ASHRAE Standards 135-2016 (BacNet), RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.3 Demand Side Response Control for Public building (UC-321c)

Demand Side Response Control for Public buildings

General Information

City	Manchester	Sector	Energy
Country	United Kingdom	Triangulum	Yes (In Delivery)

Short Description
Delivering strategic load curtailment via existing BEMS, such DSR interventions will be issued by the City Energy Controller to the respective location - the Siemens Microbox will integrate with the local BEMS to temporarily change operating state of the approved systems to deliver load reduction

USP/Highlight
Scalable platform to integrate new buildings and loads/ systems as they come on line, or can be applied as a retrofit.

Project Scale	Individual site	Planning Time	0.5 - 1 years
Development Type	Retrofitting	Implementation Time	0.5 - 1 years
Participation Model	Active participation	Technology will drive passive, systems response, however wider citizen engagement will deliver active participation	

Stakeholder Analysis			
Owner	Siemens & partners	**Implementer**	Siemens
Customer	Partners	**Service Provider**	Siemens

Implementation of UseCase

Supporting Factors			
Legal		Geographical	Manchester Corridor is an innovation district, numerous stakeholders with similar vision to cluster and connect start-ups, business incubators and accelerators. This is combined with high quality universities and a forward thinking municipality
Infrastructural	Existing BEMS systems	Social	MCC / Corridor Manchester intend to ; * To reduce the carbon footprint of Corridor Manchester through the more sustainable management of energy and waste. * To integrate green and smart ideas into new development and investment proposals. Visibility of independent DER assets provided by CC - accessed by multiple stakeholders concurrently and can be used for engagement. DSR can be delivered with direct BMS load curtailment, but also when communicating to citizens to increase awareness of local conditions / when they should switch off
Financial	Driving load reduction to limit energy costs at high tariff times	Partners	Strong co-operation with Municipality Corridor Manchester & City Council (Aim to reduce carbon footprint of Corridor and integrate green and smart ideas)
Other			

Main Implementation Challenge
Collating existing operational information for the BEMS and agreeing new 'DSR operating conditions'

Lessons Learned
Flexibility in design required, different stakeholders will require different solutions
Existing BEMS vendors do Not all support open protocols such as BACnet as use proprietary languages. Some modifications may be required

Financing Information

Initial Investment		ROI	< 5 years
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Stakeholder; Decrease stakeholder energy costs Reducing CO2 emissions and associated fiscal penalties Network Operator; Postpone grid investment as a result of peak-lopping

Project Details

Standard & Technical Details
Siemens Microbox & associated BEMS

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Reducing use of fossils
Decreasing energy consumption in buildings	Encouraging digital entrepreneurships
Improving Energy Usage Efficiency	Enabling new business opportunities
Shaving peak Energy Demand	Improving Air Quality
Reducing energy Bill	Reducing GHG Emissions
Enhances Grid Stability	Increasing share of renewables
Improving data availability	Improving social integration
Increasing transparency	Improving Life Quality
	Promoting sustainable behavior
	Facilitating Citizen Engagement

Additional revenues can be secured through aggregation providers and partition in energy markets

Wider Benefits
Cost reduction Reducing CO2 levels More economical Better place to live Reduced energy consumption Wellbeing

Suggested Financing Options
Cost offset of energy costs (DUoS, TRIAD, Consumption charge). Additional revenue services can be delivered with DSR systems in UK ancillary services.

Prospective Customers for future
Industrial and commercial (I&C) customers, those who are billed based on 30minute consumption. Municipalities with high concentration of assets, buildings

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The mapping of UC-321c is identical to that one of UC-321b, as only the building type has changed, but the underlying technical components remain the same.

Relevant Standards: ANSI/ASHRAE Standards 135-2016 (BacNet), RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.4 Micro-grid management system (UC-321d)

Micro-grid management system

General Information

City	Manchester	Sector	Energy
Country	United Kingdom	Triangulum	Yes (In Delivery)

Short Description

Micro grid management controller, designed to integrate disparate energy assets throughout single stakeholders to deliver improved energy performance within the areas of cost, CO2, flatten peak and effective use of low carbon generation

USP/Highlight

Ability to increase levels of grid resilience and even leading to grid independence if the underlying network allows.

Project Scale	Neighborhood	Planning Time	0.5 - 1 years
Development Type	Upgrading	Implementation Time	0.5 - 1 years
Participation Model	Active participation	collaboration with building owners and managers, stakeholder participation	

Stakeholder Analysis

Owner	Siemens & partners	**Implementer**	Siemens
Customer	real estate managers	**Service Provider**	Siemens

Implementation of UseCase

Supporting Factors

Legal		Geographical	Manchester Corridor is an innovation district, numerous stakeholders with similar vision to cluster and connect start-ups, business incubators and accelerators. This is combined with high quality universities and a forward thinking municipality
Infrastructural	existing assets available, operating in isolation	Social	MCC / Corridor Manchester intend to ; * To reduce the carbon footprint of Corridor Manchester through the more sustainable management of energy and waste. * To integrate green and smart ideas into new development and investment proposals. Visibility of independent DER assets provided by CC - accessed by multiple stakeholders concurrently and can be used for engagement. DSR can be delivered with direct BMS load curtailment, but also when communicating to citizens to increase awareness of local conditions / when they should switch off
Financial	Demonstrates how independent assets can be operated efficiently together to optimise operation for stakeholder gain (CO2, £ reduction, increasing grid resilience).	Partners	Strong co-operation with Municipality Corridor Manchester & City Council (Aim to reduce carbon footprint of Corridor and integrate green and smart ideas)
Other			

Main Implementation Challenge

Acceptance of stakeholders to allow incumbent systems to be integrated with wider control platform

Lessons Learned
Access to influence/ control independent DER due to independent investment case (CHP running 17 hours per day) and local requirements of the output
Stakeholder management - individual stakeholders have individual requirements, requires engagement at all levels of the organisation including senior management, facilities, IT, faculty. End-users responsible for day-to-day operation can 'block' progress

Financing Information

Initial Investment		ROI	< 5 years
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Stakeholder; Decrease stakeholder energy costs Support increased investment in DER Reducing CO2 emissions and associated fiscal penalties Network Operator; Postpone grid investment as a result of peak-lopping

Project Details

Standard & Technical Details
Siemens Micro grid Controller

Necessary Projects
Existing distributed energy resource (generation, storage, loads/ flexibility)

Supporting Projects
Power network capable of islanding, Central Energy Controller

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Reducing Operation Costs
Reducing GHG Emissions	Encouraging digital entrepreneurships
Increasing share of renewables	Improving Air Quality
Improving Energy Supply Efficiency	Improving Energy Usage Efficiency
Shaving peak Energy Demand	Improving Life Quality
Enhances Grid Stability	Promoting sustainable behavior
	Facilitating Citizen Engagement
	Improving data availability
	Increasing transparency

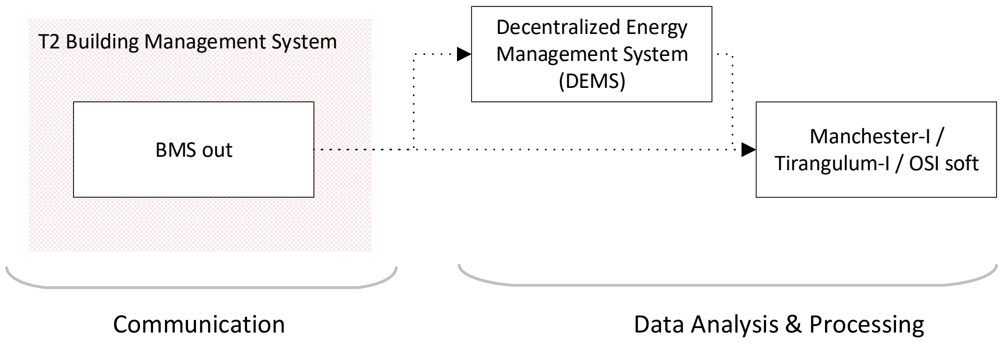
Additional revenues can be secured through aggregation providers and partition in energy markets

Wider Benefits
Cost reduction Efficient & effective mobility Guaranteeing greater safety and security Reducing CO2 levels More economical Better place to live Reduced energy consumption Wellbeing

Suggested Financing Options
Cost offset of energy costs (DUoS, TRIAD, Consumption charge). Additional revenue services can be delivered with DSR systems in UK ancillary services.

Prospective Customers for future
Industrial and commercial (I&C) customers, those who are billed based on 30minute consumption. Municipalities with high concentration of assets, buildings / generation / storage etc.

Contact for further Details
Andrew.Smyth@siemens.com



UC-321d and UC-321e are regarded in a unified fashion as the underlying principle remains the same. Data collected throughout the disparate energy assets (of either a single stakeholder, as in UC-321d or of multiple stakeholder as in UC-321e) is transferred by the building management system exit node to a decentralized energy management system, that can be either a micro grid management controller for a smaller set of assets (i.e. in the case of single stakeholders) or a virtual power plant controller. In any case, data processing happens on the level of the controller. There is furthermore the possibility of integrating these controllers with the planned Manchester-I platform that may take over further processing or data storage and visualization capabilities.

Relevant Standards: RFC 7252 (CoAP), MQTT, RFC 7159 JSON

5.6.5 City Energy Controller (UC-321e)

City Energy Controller

General Information

City	Manchester	Sector	Energy
Country	United Kingdom	Triangulum	Yes (In Delivery)

Short Description

VPP controller, designed to integrate disparate energy assets throughout multiple stakeholders to deliver improved energy performance within the areas of cost, CO_2, flatten peak and effective use of low carbon generation

USP/Highlight

Multi-owner energy portfolio incorporating energy assets from three core stakeholders which can be optimized at various levels, building, campus and city

Project Scale	Neighborhood	Planning Time	0.5 - 1 years
Development Type	Upgrading	Implementation Time	0.5 - 1 years
Participation Model	Active participation	collaboration with building owners and managers, stakeholder participation	

Stakeholder Analysis

Owner	Siemens & partners	**Implementer**	Siemens
Customer	Partners	**Service Provider**	Siemens

Implementation of UseCase

Supporting Factors

Legal		Geographical	Manchester Corridor is an innovation district, numerous stakeholders with similar vision to cluster and connect start-ups, business incubators and accelerators. This is combined with high quality universities and a forward thinking municipality
Infrastructural	existing assets available, operating in isolation	Social	MCC / Corridor Manchester intend to ; * To reduce the carbon footprint of Corridor Manchester through the more sustainable management of energy and waste. * To integrate green and smart ideas into new development and investment proposals. Visibility of independent DER assets provided by CC - accessed by multiple stakeholders concurrently and can be used for engagement. DSR can be delivered with direct BMS load curtailment, but also when communicating to citizens to increase awareness of local conditions / when they should switch off
Financial	Demonstrates how independent assets can be operated efficiency across numerous stakeholders, providing a service to optimise operation for stakeholder and city gain (CO_2, £ reduction, increasing grid resilience).	Partners	Strong co-operation with Municipality Corridor Manchester & City Council (Aim to reduce carbon footprint of Corridor and integrate green and smart ideas)
Other			

Main Implementation Challenge

Acceptance of stakeholders to allow incumbent systems to be integrated with wider control platform

Lessons Learned
Access to influence/ control independent DER due to independent investment case (CHP running 17 hours per day) and local requirements of the output
Stakeholder management - complex stakeholder map, requires engagement at all levels of the organisation including senior management, facilities, IT, faculty. End-users responsible for day-to-day operation can 'block' progress
Aligning communications and protocols between different systems which operate at different levels of the energy system, i.e. Industry, building and power protocol implementation

Financing Information

Initial Investment		ROI	< 5 years
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Stakeholder; Decrease stakeholder energy costs Support increased investment in DER Reducing CO2 emissions and associated fiscal penalties Network Operator; Postpone grid investment as a result of peak-lopping

Project Details

Standard & Technical Details
Siemens Micro grid Controller

Necessary Projects
Existing distributed energy resource (generation, storage, loads/ flexibility)

Supporting Projects
Mircogrid management system

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Encouraging digital entrepreneurships
Reducing Operation Costs	Enabling new business opportunities
Reducing GHG Emissions	Improving Air Quality
Increasing share of renewables	Increasing (primary)resource efficiency
Decreasing energy consumption in buildings	Improving social integration
Improving Energy Usage Efficiency	Improving Life Quality
Improving Energy Supply Efficiency	Promoting sustainable behavior
Shaving peak Energy Demand	Improving data availability
Reducing energy Bill	Increasing transparency
Enhances Grid Stability	

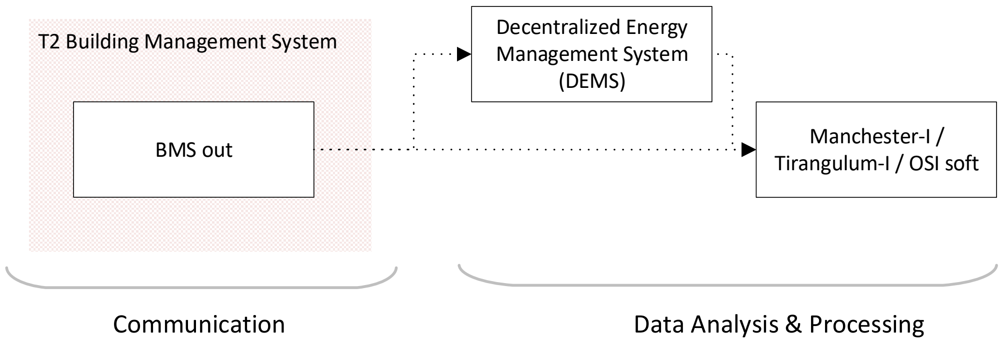
Additional revenues can be secured through aggregation providers and partition in energy markets

Wider Benefits
Cost reduction Efficient & effective mobility Guaranteeing greater safety and security Reducing CO2 levels More economical Better place to live Reduced energy consumption Wellbeing

Suggested Financing Options
Cost offset of energy costs (DUoS, TRIAD, Consumption charge). Additional revenue services can be delivered with DSR systems in UK ancillary services.

Prospective Customers for future
Industrial and commercial (I&C) customers, those who are billed based on 30minute consumption. Municipalities with high concentration of assets, buildings / generation / storage etc.

Contact for further Details
Andrew.Smyth@siemens.com


T2 Building Management System
BMS out
Decentralized Energy Management System (DEMS)
Manchester-I / Tirangulum-I / OSI soft
Communication
Data Analysis & Processing

5.6.6 Building Benchmark Assessment (UC-322a)

Building Benchmark Assessment

General Information

City	Manchester	Sector	Energy
Country	UK	Triangulum	

Short Description
Buildings are identified where energy optimizations can be implemented through a series of site assessments. Analysis of the output from the site assessments will show which buildings can be optimized through improvements to operational practices and/or through the installation of energy control devices

USP/Highlight
Standardising BMS application to support future DSR integration whilst delivering CO2 and £ operating reduction

Project Scale	Individual site	Planning Time	<0.5 years
Development Type	Retrofitting	Implementation Time	<0.5 years
Participation Model	Passive Participation	limited public interaction, mainly building managers but also occupants	

Stakeholder Analysis			
Owner	Siemens	**Implementer**	Siemens, Energy Managers
Customer	building owners	**Service Provider**	Siemens

Implementation of UseCase

Supporting Factors			
Legal	Carbon reduction commitments (city based) & reducing budgets imposed via austerity measures require OPEX reduction	Geographical	
Infrastructural	BEMS systems exist, in various vintages, many of which operate inefficiently as Not actively 'managed' post commissioning	Social	
Financial		Partners	Strong cooperation with municipality based on historic private investment locally Siemens well known, and trusted, brand within Siemens / UK - 14k national employees
Other			

Main Implementation Challenge
Acceptance of stakeholders to allow incumbent systems to be modified, this is due in part to existing O&M agreements which impact ability to drive significant change and improvement. Should be Noted that many 'BMS optimisation' schemes exist, 3rd parties proposing further improvements are often rebuffed by those responsible

Lessons Learned
Legacy infrastructure and systems sometimes require significant improvements to bring to 'expected' levels of operation before further optimisation can take place
Centralized energy billing removes, or limits, benefit of delivering significant energy improvement at a building level as these savings will Not be made available for their use. Limits effectiveness of argument and ROI's outlined.

Financing Information

Initial Investment	50,000 -250,000	ROI	< 5 years
Scale of Investment	includes benchmark of building, energy assessments, hardware replacements, HVAC controls replacement and optimization, additional energy metering		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value

Project Details

Standard & Technical Details
Siemens Design BMS systems & EN15232 EPC assessments via BBA

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Reducing Operation Costs
Reducing GHG Emissions	Shaving peak Energy Demand
Decreasing energy consumption in buildings	Increasing (primary)resource efficiency
Improving Energy Usage Efficiency	Promoting sustainable behavior
Reducing energy Bill	

improved comfort conditions

Wider Benefits
Stakeholder; Decrease stakeholder energy costs Reducing CO2 emissions and associated fiscal penalties

Suggested Financing Options

Prospective Customers for future
Replicable approach can be rolled out across city stakeholders

Contact for further Details
ivan.hewlett@siemens.com

5.6.7 Energy Storage Assets (UC-323a)

Energy Storage Assets

General Information

City	Manchester	Sector	Energy
Country	UK	Triangulum	Yes (In Planning)

Short Description

It is a grid-scale 0.5 MWh Li-Ion battery storage system which provides bi-directional flexibility from the perspective of demand/consumption and generation of energy. It is aimed for dynamic cycling (max. few days). It is located on the customer side on a private wired network.

USP/Highlight

Supports local renewable energy system operation. It is an independently owned and operated micro-grid. Matches time gaps between generation and demand.

Project Scale	Individual site	Planning Time	<0.5 years
Development Type	Retrofitting	Implementation Time	<0.5 years
Participation Model	Passive Participation	End users and stakeholder were actively engaged via negotiations and communication sessions	

Stakeholder Analysis

Owner	Siemens	**Implementer**	Siemens
Customer	University (MMU)	**Service Provider**	Siemens

Implementation of UseCase

Supporting Factors

Legal	National Infrastructure Committee promoting storage to support growth of renewable integration	Geographical	Co-located with other generation assets (PV & Wind)
Infrastructural	Presence of low carbon energy generation assets	Social	End users UoM and MMU are focused on being sustainable
Financial	Flexible energy price market for industries	Partners	Strong co-operation with Municipality Corridor Manchester & City Council (Aim to reduce carbon footprint of Corridor and integrate green and smart ideas)
Other			

Main Implementation Challenge

Finding the physical space of placing the battery (large shipping container) which needs to be next to the distribution board. Amending existing connection agreements with the network operator and the owner of the access point.

Multiple stakeholders with each stakeholder (each with different views) Difficult to contact the right person

Lessons Learned
Conduct a survey with the end users about the proposed location, power connection

Financing Information

Initial Investment	250,000 - 500,000	ROI	5 - 10 years
Scale of Investment	0.5MWh Li-Ion Battery (turn key supply)		

Financer (Contribution in Percentage)			
City		Private Sector	30%
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Stakeholder: Decrease stakeholder energy costs Support increased investment in Non-centralized Network Ancillary services Operator: Postpone grid investment as a result of peak shaving

Project Details

Standard & Technical Details
Siemens SieStorage Electrical Energy Storage System, 0.5 MWh Li-Ion Battery

Necessary Projects

Supporting Projects
Uninterrupted Power Supply, Reinforce EV Charging point connection, Distributed Energy Production, Demand side flexibility

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Reducing Operation Costs
Reducing GHG Emissions	Encouraging digital entrepreneurships
Increasing share of renewables	Enabling new business opportunities
Improving Energy Supply Efficiency	Improving Air Quality
Shaving peak Energy Demand	Promoting sustainable behavior
Reducing energy Bill	Promoting Electric Vehicles
Enhances Grid Stability	Improving data availability
	Increasing transparency

Wider Benefits
Along with other projects (City Verve) will help set best practices for City battery implementation.

Suggested Financing Options
Industrial and commercial (I&C) customers, those who are billed based on 3variable tariff. Smaller scale EES being rolled out in domestic properties also - Tesla et al. Re-finance by constant income and material cost savings.

Prospective Customers for future
Other private landlords are looking at energy storage within Manchester, aware UK municipalities also keen to understand value and implement such technology

Contact for further Details
Andrew.Smyth@siemens.com

5.6.8 Photovoltaic Installation on post 2000 building (UC-323b)

Photovoltaic Installation on post 2000 building

General Information

City	Manchester	**Sector**	Energy
Country	UK	**Triangulum**	Yes

Short Description
158kW Solar PV installed on a BREEAM 'Excellent' certified academic building. The building had existing infrastructure to install rooftop PV (slight slope with clamping mechanism). The PV system will be linked to the existing CHP plant and electric battery storage.

USP/Highlight
The system is an integral part of the ambition to become grid independent on a campus housing 1 large academic building, an energy centre, a multi-storey car park and accommodation for 900 university students.

Project Scale	Individual site	**Planning Time**	<0.5 years
Development Type	Retrofitting	**Implementation Time**	0.5 - 1 years
Participation Model	Active participation	Students notified about the installations. Siemens will be carrying out behavioral change workshops with students.	

Stakeholder Analysis			
Owner	Pre-commissioning: Manchester City Council Post-commissioning: MMU	**Implementer**	Manchester City Council/subcontractor (HT Forrest)
Customer	Manchester Metropolitan University (MMU)	**Service Provider**	Subcontractors (HT Forrest)- 12 months/MMU- post

Implementation of UseCase

Supporting Factors			
Legal		Geographical	Located in close proximity to Corridor Manchester
Infrastructural	Structurally sound building preplanned for PV installations with electric and structural infrastructure. No additional cost to implement it. Sound electric grid in the neighborhood which facilitates easier integration.	Social	MMU one of the top sustainable campuses in UK, to showcase micro-grid and other technologies to demonstrate hybrid systems.
Financial	Government supporting energy efficient loans (0% finance) to public organizations - this provided MMU with match funding to maximize PV array	Partners	Existing relationship between MMU and Manchester City Council.
Other	Meeting Manchester's agreed 2020 and 2050 carbon emissions strategic target.		

Main Implementation Challenge
Informing an agreement from all relevant stakeholders was a challenge owing to the huge number stakeholders from the building. UK Regulatory requirements and approvals needed which took long time. Procurement / asset transfer complications due to recipient (MMU) not being budget holder to deliver the action

Lessons Learned
Ensure all stakeholders are on board and well informed right from the beginning
More feasible to have contracts and agreements with the end user instead of tri-party agreements (client is not end user).
Ensure building is structurally and technically (sufficient mechanical and electrical infrastructure available) viable

Financing Information

Initial Investment	50,000 -250,000	ROI	10-15 years
Scale of Investment	158kW installed PV panels, installation infrastructure and one year direct maintenance, warranties (PV Panel - 10 yrs. above 90% performance, inverter - 10yrs)		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	50%	Financial institutions	
Regional funds		End User	50%
Others			

Revenue Streams/ Monetized Value
Reduced energy bill(Reduced grid energy use, shaving peaks)

Project Details

Standard & Technical Details
158kW installed Solar PV over 978m2 area wired through 6 invertors to transform energy from DC to AC, warranties (PV Panel - 10 yrs. above 90% performance, inverter - 10yrs), Export/Generation Meter

Necessary Projects

Supporting Projects
Battery Storage, demand Side response, Grid-independent systems

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Reducing Operation Costs
Reducing GHG Emissions	Create new jobs
Increasing share of renewables	Improving Air Quality
Reducing energy Bill	Promoting sustainable behavior
Reduced reliance on grid	

Wider Benefits
Enabled larger installation of PV to be realized (originally MMU was not financing but they eventually paid for 50%)

Suggested Financing Options
Blending Government financed loans, EU funding and other funding sources to achieve innovative funding mechanism: (using existing budget, applying for government loans, EU funding, other loans), Using multiple sources to get best return on investment, European Investment Bank (0% loans for energy efficient)

Prospective Customers for future
Building owners, tenants (with agreement from landlords)

Contact for further Details
s.sheil@manchester.gov.uk

5.6.9 Corporate Electric car sharing for University (UC-331a)

Corporate Electric car sharing for University

General Information

City	Manchester	Sector	Mobility & Transport
Country	UK	Triangulum	Yes

Short Description

The aim was to reduce the staff using their own cars for university business and to increase the use of electric vehicles (EVs). Two electric cars (30kWh Nissan Leaf) were purchased and two additional charging points were installed at MMU. The sharing scheme is managed by a third party enterprise through an online booking system.

USP/Highlight

Online booking system and RFID cards used to access the vehicles which eliminates the need for transferring keys.

Project Scale	Individual site	Planning Time	<0.5 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Passive Participation	Consultation with staff and frequent car users	

Stakeholder Analysis

Owner	MMU	**Implementer**	MMU
Customer	University staff	**Service Provider**	MMU and Enterprise

Implementation of UseCase

Supporting Factors

Legal	City's climate change strategy goal aligns with increasing share of EVs. (reduce Co2)	Geographical	Staff travels mainly in Greater Manchester region-short distance(avg travel is 25 miles)
Infrastructural	Greater Manchester Electric Vehicle charging Network stimulated adding EV charging stations across the region which could be used by public. 26 charging base installed on campus as part of the scheme Extended range of EVs encouraged people to use them-reduced range anxiety. (Nissan Leaf from 24 to 30kWh)	Social	MMU prides to be a green university.
Financial	National Funds for hosting charging points, maintenance and the electricity use (100% by GMEV) . (75:25 funds share for installations)	Partners	Manchester Corridor Board, Worked with Nissan leaf before
Other	Existing experience with 2 electric car sharing. Efficient way of getting approval to drive the EV.		

Main Implementation Challenge

To encourage people to use the fleet over there own vehicles was a challenge. People did not have enough motivation to move to EVs as using own cars had several diverse fringe benefits attached to it.

Lessons Learned
Individual training sessions, and experiencing the use of Evs encourages more users to use them. Good to schedule half hour training sessions to encourage more users.
Investigate Telematics and monitoring options from the beginning. Additional telematics can be added as the car monitoring system that came with the cars has limitations for corporate use.
There was a time gap(4 days) between signing up and receiving a card to be able to use it. Additional RFID for charging station use needed. Finding the right parking spots takes some time and effort.

Financing Information

Initial Investment	50,000 -250,000	ROI	10-15 years
Scale of Investment	2 Nissan Leaf (30kWh), 2 charging points (7kW), monthly fee for operating the vehicle booking system (incl. Phone service, web-site, app, cleaning)		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Savings from reduced mileage claims from using private vehicles for work, savings from rental cars as a former alternative for the private vehicles

Project Details

Standard & Technical Details
Type-2 (7kW) chargers with two sockets per access points, equipped with RFID readers (managed by external company); 30kWh Nissan Leaf standard model, Enterprise booking system

Necessary Projects
Parking spots with good power connection

Supporting Projects
app to train electric vehicle drivers (360 deg)

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Reducing use of fossils
Improving personnel efficiency	Reducing GHG Emissions
Improving Air Quality	Reducing traffic congestion
Supporting environmental efficient transport	Improving Life Quality
Promoting sustainable behavior	Improving Parking
Promoting Electric Vehicles	Improving data availability
	Increasing transparency

Wider Benefits
positive staff experience with electric vehicles, used to promote green image of the University, after proof of concept an additional electric vehicle of the same make was purchased

Suggested Financing Options
existing market offers that allow pay-per-use schemes for electric vehicles, leasing models from car rental car companies or manufacturers,

Prospective Customers for future
any organization where staff uses vehicles for short/medium distance trips

Contact for further Details
a.m.taylor@mmu.ac.uk

5.6.10 Leasing electric vans for estate management (UC-331b)

Leasing electric vans for estate management

General Information

City	Manchester	Sector	Mobility & Transport
Country	UK	Triangulum	Yes

Short Description
7 diesel vans from the university estate management team were replaced with new electric leasing vans. The vans are used for delivering mail and operational services.

USP/Highlight
simple and high scale replacement of vehicles due to a leasing model

Project Scale	District level	Planning Time	<0.5 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	Nissan	**Implementer**	UniMan
Customer	Operational staff of the university	**Service Provider**	Nissan

Implementation of UseCase

Supporting Factors			
Legal	Target by the university to increase the number of electric fleet vehicles (from 4 in 1014/15 to 20 in 2022). University commitment to reduce carbon emissions.	Geographical	The campus stretches only over 5km and therefore the operation area of the vans is limited
Infrastructural	6 charging stations with 2 sockets each available already in place.	Social	
Financial	The gap between the leasing price of the diesel and electric vehicles is covered by EU project money.	Partners	the users of the vehicles are employed by the university leasing the vehicles
Other	experience from one electric pool car has already been gained		

Main Implementation Challenge
finding an efficient way to collect data on usage also for scientific purposes (manual data download necessary) - 7 different log-in details are needed for 7 vans that makes it very time consuming.

Lessons Learned
Looking at different (stand-alone) telematics systems that are Not locked into the vendor
Limit the accuracy of the GPS data to overcome privacy issues when tracking the movements of the employees. Handling tracking data is harder for the public sector than for the private sector.
Involving fleet managers from the beginning during the development of the business case/planning to ensure their commitment.

Financing Information

Initial Investment	50,000 -250,000	ROI	< 5 years
Scale of Investment	7 Nissan Tekna ENV 200		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	25%	Financial institutions	
Regional funds		End User	
Others	75%	University of Manchester	

Revenue Streams/ Monetized Value
Saving from reduced fuel costs of electricity vs. Diesel

Project Details

Standard & Technical Details

Necessary Projects
Existing charging infrastructure

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Reducing GHG Emissions
Reducing Operation Costs	Improving Life Quality
Improving Air Quality	Increasing transparency
Supporting environmental efficient transport	
Promoting sustainable behavior	
Promoting Electric Vehicles	
Improving data availability	

Wider Benefits
proof of concept to roll out electric vehicles on a bigger scale throughout the university, with the leading model (3year contract) it is easy to upgrade to newer (battery) technology

Suggested Financing Options

Prospective Customers for future
any user of fuel driven vans operating in short/medium distance only

Contact for further Details
julia.durkan@manchester.ac.uk

5.6.11 Electric Assist Cargo bikes (Pedelecs) for goods delivery (UC-332)

Electric Assist Cargo bikes (Pedelecs) for goods delivery

General Information

City	Manchester	Sector	Mobility & Transport
Country	UK	Triangulum	Yes

Short Description
The Use case is aimed at promoting the sustainable alternatives for local deliveries using electric Assist cargo bikes. The Municipality offers the use of 4 bikes leased from a fleet of different bikes owned by Manchester Bike Hire to any organization in Manchester who would like to use the bikes for end distribution. The bikes come with a tracking system which enables data collection on usage

USP/Highlight
Free to Use opportunity to try a variety of different types of models. Collecting data on usage of bikes by tracking the electric cargo bikes (provides insights on usage)

Project Scale	City Level	Planning Time	<0.5 years
Development Type	Greenfield Development	Implementation Time	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	Manchester City Council	**Implementer**	Manchester Bike Hire
Customer	University, SMEs, anyone with need for end delivery alternatives	**Service Provider**	Manchester Bike Hire

Implementation of UseCase

Supporting Factors			
Legal	Restriction on cars in the Corridor encourages use of bikes for end distribution Manchester city goals and target for reducing emissions and having bikes as 10% of transport share	Geographical	Existing congestion in Corridor encourage search for alternatives to reduce the number of cars
Infrastructural	Bike tracks- big enough to accommodate cargo bikes	Social	Only 2.5% commuters use bikes for commuting. Need for promoting bikes.
Financial		Partners	Manchester Bike hire is partner organisation with experience and expertise in cycle logistics, using cargo bikes to undertake last mile deliveries
Other			

Main Implementation Challenge
Attracting users for the Cargo bikes (behavioral change). Cultural view associated with use of bikes and safety

Lessons Learned
Health and safety e.g. rider considerations differ for different organizations. PPE (Personal Protective Equipment) needs to be supplied to riders - sharing helmets is Not desirable
Behavior change process - changing from vehicles to bikes takes time. Individual demonstrations and regular changes would provide incentives to encourage more users.
Cargo Bikes are not mass produced. Lead-in times can be long - electric assist cargo bikes are still manufactured in small batches, so it can take 3-4 months from order to delivery

Financing Information

Initial Investment	< 50,000 Euros	ROI	
Scale of Investment	leasing of 4 cargo bikes, associated management of the bikes		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Not business model but to promote to use of bikes. Potentially reduce car parking and fuel costs, improve delivery service efficiency

Project Details

Standard & Technical Details
Manchester Bike Hire has a fleet of different cargo bikes. The leasing model allows the Municipality to offer at any one time 4 of this fleet.

Necessary Projects
Space for storage,

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Reducing GHG Emissions
Reducing Operation Costs	Improving Life Quality
Improving personnel efficiency	
Improving Air Quality	
Supporting environmental efficient transport	
Reducing traffic congestion	
Promoting sustainable behavior	
Promoting Use of active modes	

Wider Benefits

Suggested Financing Options
Mainly for businesses to develop their own business model around it

Prospective Customers for future
University, SMEs, anyone with need for end delivery alternatives

Contact for further Details
m.tommis1@manchester.gov.uk

5.6.12 Data Curation & 342a Data Visualization Platform (UC-341)

Data Curation Service

General Information

City	Manchester	Sector	ICT
Country	UK	Triangulum	Yes

Short Description
It is a service that allows people (e.g. citizens or the city as a whole) to access real-time and historic data sets (mainly numeric data sets) and make informed choices. The data curation service improves and enhances data and gives benefits back to the data provider. It gives an opportunity to create innovation (The service is used for research, already)

USP/Highlight
brings together a diverse set of datasets from different stakeholders, "one stop shop", give access to historic data, improvement/enhancement of data, it is possible to develop services within the platform itself, data accessible via an API or a SDK, can cope with high speed data

Project Scale	City Level	Planning Time	0.5 - 1 years
Development Type	Technological Development	Implementation Time	< 2 years
Participation Model	Active participation	workshops regarding platform, mainly academics but facility managers too	

Stakeholder Analysis			
Owner	University of Manchester (UoM)	Implementer	UoM
Customer	city planners, building owners, app developers, innovators that want to use the data, citizens	Service Provider	UoM

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	University of Manchester runs data centres,receive support from IT services	Social	
Financial		Partners	partner that wanted to develop a data platform for Smart Cities (OSISoft)
Other	access to a wide set of data streams, confident that people will use the data		

Main Implementation Challenge
answer to the questions: "what is the business case? How do I get the money?", considerations of data governance (Who owns the data?), dealing with/managing all stakeholders (each stakeholder may have a different view), considering platform security

Lessons Learned
securing finance to invest in the infrastructure, operation and maintenance
getting a wide range of relevant stakeholders, that want to publish data, together and try to get all data on one platform
data provider should provide data for a long time (5y)

Financing Information

Initial Investment	250,000 - 500,000	ROI	
Scale of Investment	personnel costs, software licenses, servers that run the platform		

Financer (Contribution in Percentage)			
City		Private Sector	20%
National funds		Public Companies	20%
EU funds	60%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
city planners using infrastructure investment decisions, app , people who need enhanced data (data providers)

Project Details

Standard & Technical Details
PI platform is based on data repositories, a metadata server, comp. engine, APIs/SDKs and different interfaces that enable communication between different data sources and data repositories

Necessary Projects
availability of data sources with programmatic access

Supporting Projects
data visualization platform, data-enabled innovation challenges

Benefits

Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships	Create new jobs
Enabling new business opportunities	
Facilitating Citizen Engagement	
Improving data availability	
Increasing transparency	

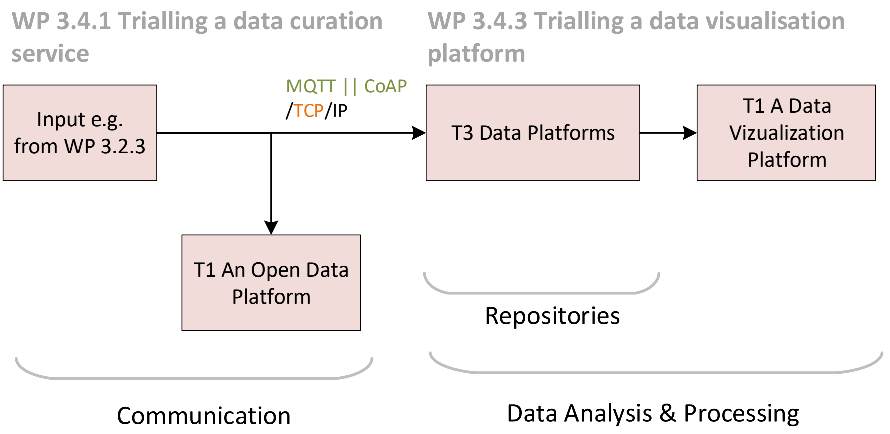
enhancement of data quality

Wider Benefits

Suggested Financing Options
consortium funding

Prospective Customers for future
city planners, building owners, app developers, innovators that want to use the data, citizens

Contact for further Details
ian.cotton@manchester.ac.uk



As UC-341a and 342s are closely interconnected and partially complement each other, they are regarded in union. The designations in grey describe the Triangulum WP and subtask in which the implemented modules can be found that fit to the current UC. The actual data comes from another module of the Triangulum project (i.e. the implemented energy controller from the module in subtask WP3 subtask 2.3). As the incoming data has already been recorded by sensors previously, no entity that could be mapped onto the data sources layer is available. Open data platforms keep track of metadata and their current storage location and thus by virtue of this enable efficient data transport and communication. Therefore the open data platform was assigned to the communication layer, in contrast to the actual data platforms or data hubs that actually will download the data and make it available for further processing and therefore fall into the repositories sublayer of the data analysis and processing layer. The assignment of the visualization platform onto the same layer is trivial, as good visualizations presuppose data analysis.

Relevant Standards: HyperCat Initiative, OKF CKAN, ISO 37120, UNE 178301:2015

5.6.13 Data Visualization Platform (UC-342)

Data Visualization Platform

General Information

City	Manchester	Sector	ICT
Country	UK	Triangulum	yes

Short Description
The data visualization platform is a collection of tools to visualize data from a range of sources in different ways (e.g. VR, AR, 2D maps).The data visualization platform enables users to engage with data in a user friendly way.

USP/Highlight
application of gaming technology (Unity) to real world problems

Project Scale	City Level	Planning Time	0.5 - 1 years
Development Type	Technological Development	Implementation Time	0.5 - 1 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	Clicks+Links	**Implementer**	Clicks+Links
Customer	urban planners, transport planners, citizens, engineering consultants, real estate developers, municipalities	**Service Provider**	Clicks+Links

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural		Social	
Financial		Partners	partners are willing to share data (sources of data)
Other			

Main Implementation Challenge
development of a use case - how to use this particular, new technology, changing people's mindset

Lessons Learned
find a use case sponsor (someone who wants to use this) and involve them from the beginning (design stage)
availability and accessibility of data is fundamental
curated data ('high quality' data) is needed, otherwise visualization is not meaningful

Financing Information

Initial Investment	50,000 -250,000	ROI	
Scale of Investment	development costs (personnel), ongoing operational costs including licenses		

Financer (Contribution in Percentage)			
City		Private Sector	40%
National funds		Public Companies	0%
EU funds	60%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
municipalities commissioning platform

Project Details

Standard & Technical Details
unity gaming environment

Necessary Projects
data sources

Supporting Projects
VR to train vehicle drivers, behavioral change app, vehicle charging app

Benefits

Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships	Facilitating Citizen Engagement
Enabling new business opportunities	
Improving data availability	
Increasing transparency	

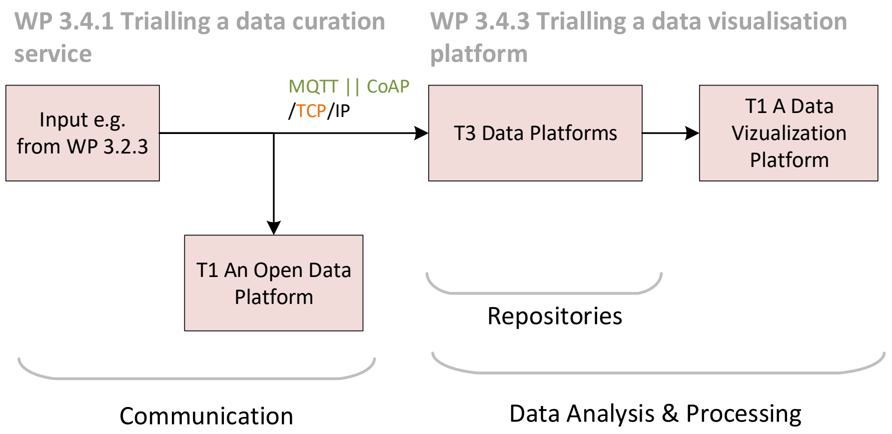
improving data accessibility and data visibility

Wider Benefits
participation of CityVerve

Suggested Financing Options

Prospective Customers for future
urban planners, transport planners, citizens, engineering consultants, real estate developers, municipalities

Contact for further Details
michael.king@clicksandlinks.com


WP 3.4.1 Trialling a data curation service
WP 3.4.3 Trialling a data visualisation platform
MQTT || CoAP
/TCP/IP
Input e.g. from WP 3.2.3
T3 Data Platforms
T1 A Data Vizualization Platform
T1 An Open Data Platform
Repositories
Communication
Data Analysis & Processing

5.6.14 Data-Enabled Innovation Challenges (UC-343a)

Data-Enabled Innovation Challenges

General Information

City	Manchester	Sector	ICT
Country	UK	Triangulum	Yes

Short Description
The data-enabled innovation challenges are about getting a wider group to engage with the data curation service and data visualisation platform and encouraging this group to make use of these tools and data. The goal is to encourage data enabled solutions i.e. solutions which make use of the data available by organising events such as hackathons. The best solutions proposed during the hackathon will get a 5000 Euro funding.

USP/Highlight
grass root approach to identify citizen challenges

Project Scale	City Level	Planning Time	0.5 - 1 years
Development Type	Technological Development	Implementation Time	<0.5 years
Participation Model	Active participation	press releases, social media, hackathons, grass root approach to identify challenges	

Stakeholder Analysis			
Owner	municipality	Implementer	Clicks & Links, UoM, MMU, Siemens
Customer	Municipality (the hackathon is aimed at improving livability using Open Data), participants	Service Provider	Clicks & Links, UoM, MMU, Siemens, MCC

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	data curation service, data visualization platform	Social	number of established technical groups, e.g. Manchester Digital
Financial		Partners	
Other			

Main Implementation Challenge
public procurement challenges (it is going through the municipality), IP related challenges

Lessons Learned
hackathons are too often focused on technology people and data and forget about citizen issues. It is important to identify the right challenges to work on.
Guide the participants by defining challenges and by providing examples.
Targeting the right participants through advertising to the right audience.

Financing Information

Initial Investment	50,000 -250,000	**ROI**	
Scale of Investment	prize money, equipments (including VR studio)		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
improving life quality of citizens, added value by enhancing data

Project Details

Standard & Technical Details

Necessary Projects
data curation service and data visualization platform

Supporting Projects
applications (see F,G,H)

Benefits

Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships	Create new jobs
Improving Life Quality	Enabling new business opportunities
Facilitating Citizen Engagement	

enhancing data use

Wider Benefits

Suggested Financing Options
any partner that may get (financial) benefits out of the results

Prospective Customers for future
anyone with data and challenges

Contact for further Details
vin.sumner@clicksandlinks.com

5.6.15 App to train electric vehicle drivers (UC-343b)

App to train electric vehicle drivers

General Information

City	Manchester	**Sector**	ICT
Country	UK	**Triangulum**	Yes

Short Description
It uses a series of 360 degree videos to educate UoM/MMU staff in how they use their fleet of electrical vehicles (booking, driving and charging). Typically, booking and using an EV can be quite complex, especially to those who have never done it before. This can create extra work for support staff, which this app aims to reduce.

USP/Highlight
360 degree videos are immersive, it complements the existing human based training, it encourages the use of EV

Project Scale	City Level	**Planning Time**	<0.5 years
Development Type	Technological Development	**Implementation Time**	<0.5 years
Participation Model	Active participation	co-developed with the fleet managers	

Stakeholder Analysis			
Owner	Clicks & Links	**Implementer**	Clicks & Links
Customer	EV fleet owners	**Service Provider**	Clicks & Links

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	having an EV fleet, charging stations, IT infrastructure in UoM/MMU	Social	people are used to e-learning courses
Financial		Partners	collaboration with the EV owners
Other			

Main Implementation Challenge
longevity, how often they have to change the processes and videos, file size of app, how to achieve interactivity within the app

Lessons Learned
to have a good relationship with the process owners (EV fleet owners)
think about how users will use the application

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	< 5 years
Scale of Investment	series of videos for fleet of two types of cars		

Financer (Contribution in Percentage)			
City		Private Sector	30%
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
reduced personnel costs, increased use of EV fleet

Project Details

Standard & Technical Details
developed in Unity, 360 degree videos

Necessary Projects
EV fleet available

Supporting Projects

Benefits

Primary Benefits	**Secondary Benefits**
Improving personnel efficiency Supporting environmental efficient transport Promoting Electric Vehicles	

Wider Benefits
promoting use of EV

Suggested Financing Options
customer would pay

Prospective Customers for future
EV fleet owners

Contact for further Details
vin.sumner@clicksandlinks.com

5.6.16 Behavioural change application for students (UC-343c)

Behavioral change application for students

General Information

City	Manchester	Sector	ICT
Country	UK	Triangulum	Yes

Short Description
It is an app to engage students in electricity demand reduction initiatives (Specifically during periods of high prices or during the times demand and response are required). The app could consist of different missions that aim to reduce electricity demand.

USP/Highlight
gamification in electricity demand reduction initiatives, aims to save money during periods of high prices, mechanism to understand the behavioral change

Project Scale	Individual site	Planning Time	0.5 - 1 years
Development Type	Technological Development	Implementation Time	0.5 - 1 years
Participation Model	Active participation	co-developed with energy managers and academics	

Stakeholder Analysis			
Owner	Clicks & Links	**Implementer**	Clicks & Links
Customer	energy managers	**Service Provider**	Clicks & Links

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	availability of smart meters makes it more viable	Social	
Financial	opportunity to reduce energy costs owing to time of use pricing	Partners	
Other			

Main Implementation Challenge
ethical signoffs are needed (What information can be captured?), ability to validate the quality of data (e.g. data from smart meter), need for iOS app and android app, push messages, sustain interest

Lessons Learned
should capture data at different stages in order to validate processes
use insights received through the app to improve the process

Financing Information

Initial Investment	50,000 -250,000	**ROI**	< 5 years
Scale of Investment	creation of an app and mission platform		

Financer (Contribution in Percentage)			
City		Private Sector	30%
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
reduced energy bills

Project Details

Standard & Technical Details
iOS and android app, bespoke mission platform

Necessary Projects
smart meters

Supporting Projects
link to central controller or projects where energy use reduction is desirable

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Facilitating Citizen Engagement
Shaving peak Energy Demand	
Reducing energy Bill	
Promoting sustainable behavior	

helping to understand behavioral change

Wider Benefits

Suggested Financing Options
building owners

Prospective Customers for future
building owners

Contact for further Details
vin.sumner@clicksandlinks.com

5.6.17 Vehicle charging Application (UC-343d)

Vehicle charging Application

General Information

City	Manchester	Sector	ICT
Country	UK	Triangulum	Yes

Short Description
It is an app that maps where the current charging stations are and where there is capacity to charge within the time that you want. It is facilitating the use of EV by managing the grid. The app shows the viable charging stations through green color on a map.

USP/Highlight
facilitating use of EV, supporting grid management

Project Scale	City Level	Planning Time	<0.5 years
Development Type	Technological Development	Implementation Time	<0.5 years
Participation Model	Active participation	co-developed with the fleet managers	

Stakeholder Analysis			
Owner	Clicks & Links	Implementer	Clicks & Links
Customer	fleet managers or potentially grid managers	Service Provider	Clicks & Links

Implementation of UseCase

Supporting Factors			
Legal		Geographical	location of the charging stations
Infrastructural	having an EV fleet, charging stations, data from charging stations, data from the grid	Social	
Financial		Partners	collaboration with grid owners
Other	users with smart phones		

Main Implementation Challenge
getting the data from charging stations and the grid, dealing with privacy issues (e.g. tracking of users)

Lessons Learned
use Google's routing service
app depends on internet connection

Financing Information

Initial Investment	50,000 -250,000	**ROI**	< 5 years
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	30%
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
may avoid grid reinforcements (larger cables), peak shavings

Project Details

Standard & Technical Details
IOS and android app that report preferred locations

Necessary Projects
EV fleets, charging stations, grid status, predicted demands

Supporting Projects
link to central controller

Benefits

Primary Benefits	**Secondary Benefits**
Shaving peak Energy Demand	Reducing Operation Costs
Enhances Grid Stability	
Promoting Electric Vehicles	
geographical distribution of EV loads maximizes capability of the electricity network	

Wider Benefits
avoid digging up roads

Suggested Financing Options
grid owners

Prospective Customers for future
grid owners, EV fleet owners

Contact for further Details
vin.sumner@clicksandlinks.com

5.6.18 Sustainable Energy Supply by Soil Sanitation (UC-421)

Sustainable Energy Supply by Soil Sanitation

General Information

City	Eindhoven	Sector	Energy
Country	Netherlands	Triangulum	Yes

Short Description
It is a low cost system which aims at purifying soil in combination with extracting energy from ground water using heat pumps. It is an open system which directly pumps water into the soil. 2.7Mm3/yr. being pumped. The system works for VOCs (fluorides & chlorides)-water soluble.

USP/Highlight
System can extract energy while purifying soil. It is much cheaper than removing soil. (5-10 times less expensive)

Project Scale	Neighborhood	Planning Time	0.5 - 1 years
Development Type	Brownfield Development	Implementation Time	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis

Owner	Park Strijp Energy (Volker wessels and Municipality - PPP)	**Implementer**	iCity (Volker Wessels daughter company)
Customer	Building Developers & Pollution Owners	**Service Provider**	Park Strijp Energy (Volker wessels and Municipality - PPP)

Implementation of UseCase

Supporting Factors

Legal	Dutch law to clean soil and ground water before constructing on site and also using heat pumps. Polluter of the soil is the one responsible for purifying the area Dutch Regulation: (Energy labels)EPC standard 0.3 Regulation: to extract balanced heating and cooling from the ground	Geographical	Solid temperature gradient is high
Infrastructural	Industrial areas from the city are being converted to residential areas. Polluted soil is present in such cases. Demand for heating and cooling both nearby (Business or houses who have demand)	Social	
Financial	Energy costs of the area	Partners	
Other	Availability of customers to use the produced energy		

Main Implementation Challenge
Strong regulation of the electricity market (generation and sale)-pricing is monitored: so difficult to develop a business case around it. Regulations in handling of groundwater wells with regards to the built environment above. Lot of planning needed. External factors influencing underground water flows.

Lessons Learned
Extraction of pollutants more efficient than expected
The groundwater system in the whole area should be studied before designing the system. Public companies should manage/influence the groundwater systems in the whole region to reduce the conflicts in the neighboring systems.

Financing Information

Initial Investment	> 5,000,000	ROI	> 15 years
Scale of Investment	one site of 68 acres (6 Million)		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	10%	Financial institutions	
Regional funds		End User	
Others	90%	Park strijp (PPP between municipality and volker Wessels)	

Revenue Streams/ Monetized Value
Selling Energy, fee from polluter, increased real estate value

Project Details

Standard & Technical Details
SANERGY system, 12 groundwater wells drilled over 68 acres, 8 Heat exchangers, 8kms of piping connection to supply energy to buildings

Necessary Projects
Customers to use the Energy produced. (Possibly through a building plan of area)

Supporting Projects
Connecting to sewage treatment plants

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Improving Air Quality
Reducing water pollution	Reducing GHG Emissions
Supporting the sustainable use of land	Increasing share of renewables
	Improving Energy Supply Efficiency

Purifying soil, less time to reuse a polluted area

Wider Benefits

Suggested Financing Options
From the sold energy

Prospective Customers for future
Industrial site owners who pollute the areas, Municipality

Contact for further Details
tvdieren@volkerwessels.com

5.6.19 Switching from steam based to water based heating systems powered by biomass (UC-422)

Switching from steam based to water based heating systems powered by biomass

General Information

City	Eindhoven	**Sector**	Energy
Country	Netherlands	**Triangulum**	Yes

Short Description

Changing steam pipes to district heating based on water as energy transmitter. The power is supplied via a biomass power plant owned by the municipality.

USP/Highlight

Pipes can be used with any other water based heat production system. The biomass power plant is fueled by the waste of public green spaces.

Project Scale	District level	**Planning Time**	<0.5 years
Development Type	Upgrading	**Implementation Time**	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis

Owner	municipality (power plant), strijp-s Ontwikkeling	**Implementer**	strijp-s Ontwikkeling
Customer	building owners, inhabitants	**Service Provider**	Park Strijp Energy

Implementation of UseCase

Supporting Factors

Legal	Dutch Regulation: (Energy labels)EPC standard 0.3	Geographical	lot of biomass produced in the city
Infrastructural	built on a site of a former CHP-plant that was replaced with this system, highly functioning waste collection system for pruned green	Social	
Financial	Energy costs in the area, public subsidies (from EU: SDE) for the biomass power plant	Partners	good relationship to the energy company that built the plant
Other	goal of the municipality to become carbon neutral and self-sustaining		

Main Implementation Challenge

Lessons Learned
An agreement between the private sector and municipality regarding sustainability goals and compensation is necessary
The process of collecting and providing the garbage to the biomass power plant needs significant improvement
The process of transforming the plant is highly complicated as there are only a few suppliers of the biomass plant existing in the market

Financing Information

Initial Investment	> 5,000,000	**ROI**	5 - 10 years
Scale of Investment	one plant + 2.5km of piping		

Financer (Contribution in Percentage)			
City	97%	Private Sector	
National funds		Public Companies	
EU funds	3%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
continuous subsidy for each GJ produced (5-19EUR/GJ) as a subsidy from the EU, selling energy

Project Details

Standard & Technical Details
2.5km of piping, 8.2 MW heat and 1.6 MW of electricity biomass plant

Necessary Projects
existing district heating system pipes (towards the city center) to which the system was connected

Supporting Projects
possible other heat water production systems (e.g. solar based heat)

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Reducing Operation Costs
Reducing GHG Emissions	Improving personnel efficiency
Increasing share of renewables	Enabling new business opportunities
	Improving Component Efficiency
	Improving Energy Supply Efficiency
	Increasing (primary)resource efficiency
increased autonomy with regards to energy supply/self-sufficiency	

Wider Benefits

Suggested Financing Options
EU subsidy (based on production)

Prospective Customers for future
Municipalities, energy companies, energy cooperatives

Contact for further Details
tvdieren@volkerwessels.com

5.6.20 Smart Control of individual rooms in existing buildings (UC-423a)

Smart Control of individual rooms in existing buildings

General Information

City	Eindhoven	**Sector**	Energy
Country	Netherlands	**Triangulum**	Yes

Short Description

The system allows interactive monitoring and control of heating, ventilation and lighting through a mobile application of individuals rooms independently. The system works on predictive control algorithm to automatically adjust the room to its user when needed. The system monitors window openings, temperature and occupancy. It gives users insights into energy use and promotes sustainable behavior. (e.g.. receive message when you open window in winter but want higher indoor temp)

USP/Highlight

Predictive control algorithm used to independently control rooms in a building. The system can be used to setup a room before the user arrives. Encourages sustainable behavior through developing a sense of competition between users

Project Scale	Individual site	**Planning Time**	<0.5 years
Development Type	Upgrading	**Implementation Time**	<0.5 years
Participation Model	Active participation	app used by Volerwessel employees too. So constant feedback received from end user. Feedbacks from other potential users was taken into account.	

Stakeholder Analysis

Owner	Volker Wessel (icity) and OpenRemote	**Implementer**	OpenRemote
Customer	Tenants and occupants of a building, building owners,	**Service Provider**	heating service providers

Implementation of UseCase

Supporting Factors

Legal	EPC Ratings (Energy labels) to be maintained for each building (regulation)	Geographical	
Infrastructural		Social	
Financial	Strong financial benefit foreseen as heating service provider charges occupants fixed fee.	Partners	
Other	Energy usage in old buildings is high		

Main Implementation Challenge

The Use case did Not provide the expected end results due to:

1. The existing HVAC infrastructure did Not allow individual room control and installing new room controls was too expensive. High ROI period
2. The heat losses form the connecting pipes to radiator are too high. hence, enough energy Not saved.
3. Air conditioning system able to only control per wing and Not per room.

Lessons Learned
Important to have well functioning hardware(technology) as failure during piloting can lead to reduced trust on the technology.
Promotion is needed to encourage use of the App as a change in behavior is expected.

Financing Information

Initial Investment	< 50,000 Euros	ROI	< 5 years
Scale of Investment	12 offices on one floor of a building		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	
Others	100%	Volker Wessel (icity)	

Revenue Streams/ Monetized Value
reduced energy bills, energy use, optimized maintenance and cleaning services

Project Details

Standard & Technical Details
Predictive control algorithm, Mobile app and Management monitoring dashboard

Necessary Projects
Network

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Improving Energy Supply Efficiency
Improving personnel efficiency	Improving Life Quality
Improving Air Quality	Promoting sustainable behavior
Decreasing energy consumption in buildings	Improving data availability
Improving Energy Usage Efficiency	
Shaving peak Energy Demand	
Reducing energy Bill	

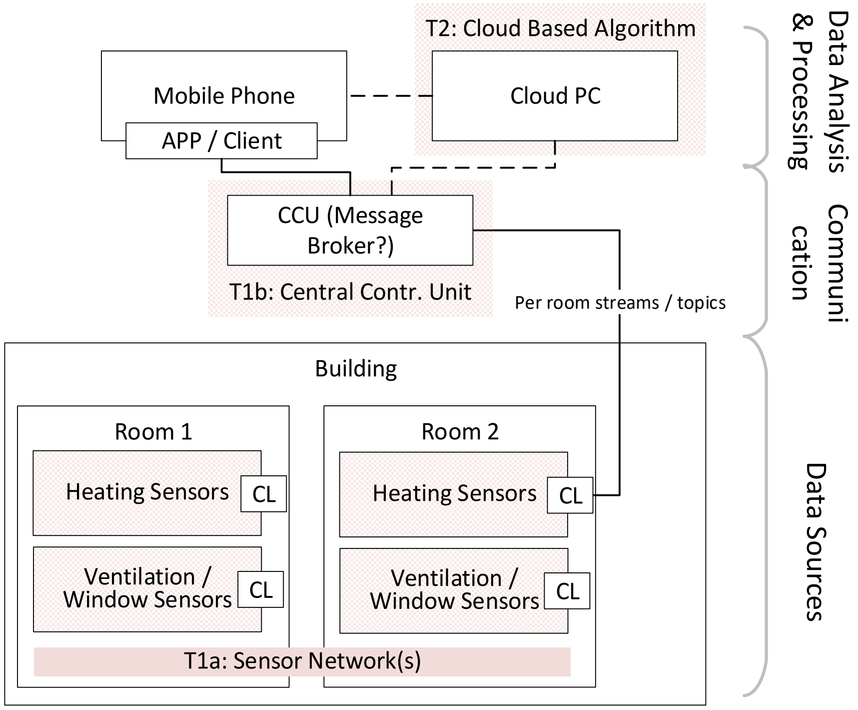
increases comfort, can improve safety in emergency situations as occupancy is monitored, cleaning and maintenance facilities can be more efficient

Wider Benefits

Suggested Financing Options
EU funding for improving energy efficiency in buildings

Prospective Customers for future
Heating Service providers, building owners, households, commercial buildings

Contact for further Details
tvdieren@volkerwessels.com



The technical system behind UC-423a overlaps to a great degree with solutions and Use Cases of the energy sector in Stavanger (UC-521a-c). Sensors and actuators act majorly as data sources but also have a message broker client attached that is necessary for communication. The messaging system on the communication layer allows different data processing entities, implementing different algorithms (i.e. mobile phones or computers in the cloud) to interface with those sensors and actuators.

Relevant Standards: RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.21 Smart control of individual floors in existing buildings (UC-423b)

Smart control of individual floors in existing buildings

General Information

City	Eindhoven	Sector	Energy
Country	Netherlands	Triangulum	Yes

Short Description
Based on challenges expected on individual room control, the system was designed on floor level. This does not lead to most optimized scenarios but reduces energy consumption to some extent. The system allows interactive monitoring and control of (heated) ventilation through a application for separate floors in a building independently. The system works on predictive control algorithm to automatically adjust the floor to its user when needed. The system monitors temperature, CO2 level and occupancy.

USP/Highlight
Predictive control algorithm used to independently control floors in a building.

Project Scale	Individual site	Planning Time	<0.5 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Active participation	app used by Volkerwessels employees too. So constant feedback received from end user. Feedbacks from other potential users was taken into account.	

Stakeholder Analysis			
Owner	Volker Wessels (icity)	**Implementer**	
Customer	Tenants and occupants of a building, building owners,	**Service Provider**	heating service providers

Implementation of UseCase

Supporting Factors			
Legal	EPC Ratings (Energy labels) to be maintained for each building (regulation)	Geographical	
Infrastructural		Social	
Financial	Strong financial benefit foreseen as heating service provider charges occupants fixed fee.	Partners	
Other	Energy usage in old buildings is high		

Main Implementation Challenge

Lessons Learned
Important to strike a balance between maintaining good indoor air quality and energy efficiency

Financing Information

Initial Investment	50,000 -250,000	**ROI**	5 - 10 years
Scale of Investment	One building- 7 floors		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	
Others	100%	Volker Wessels (icity)	

Revenue Streams/ Monetized Value
reduced energy bills, energy use

Project Details

Standard & Technical Details
Predictive control algorithm, Management monitoring dashboard Monitoring of Temperature & CO2: room Level System control: floor level

Necessary Projects
Network

Supporting Projects

Benefits

Primary Benefits	**Secondary Benefits**
Reducing Operation Costs	Improving Energy Supply Efficiency
Improving personnel efficiency	Improving Life Quality
Improving Air Quality	Promoting sustainable behavior
Decreasing energy consumption in buildings	Improving data availability
Improving Energy Usage Efficiency	
Shaving peak Energy Demand	
Reducing energy Bill	

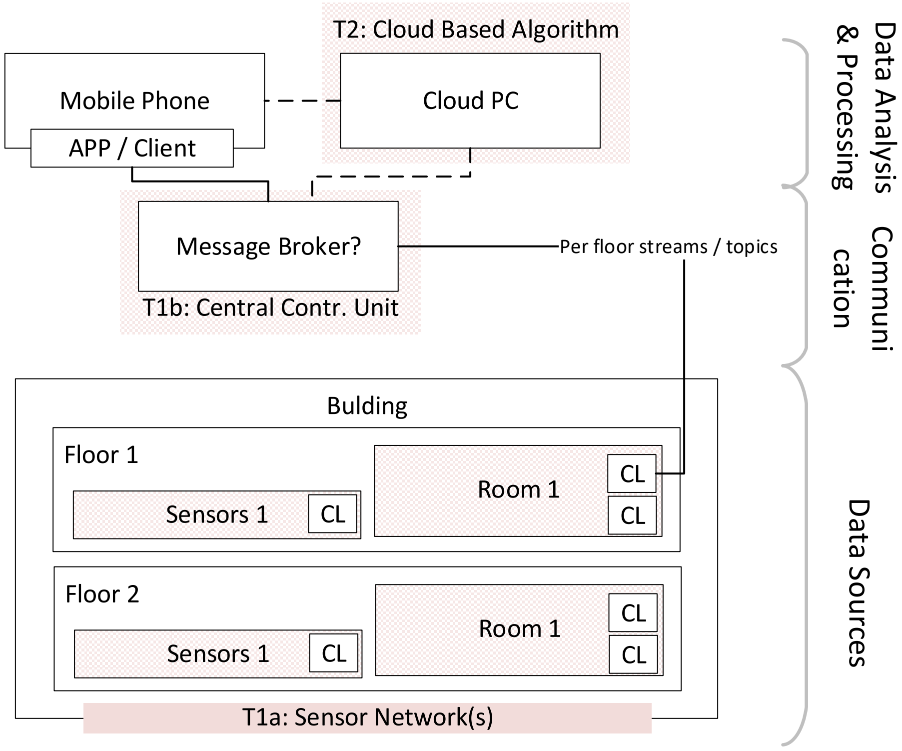
increases comfort, can improve safety in emergency situations as occupancy is monitored, cleaning and maintenance facilities can be more efficient

Wider Benefits

Suggested Financing Options
EU funding for improving energy efficiency in buildings

Prospective Customers for future
Heating Service providers, building owners, households, commercial buildings

Contact for further Details
tvdieren@volkerwessels.com



The mark-up of UC-423b is identical to that of UC-423a, only the subdivision of the space in which the different sensors and actuators can be found has been changed. Therefore no new entities have to be mapped on the RA.

Relevant Standards: ANSI/ASHRAE Standards 135-2016 (BacNet), RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.22 Renovation of Semi-attached homes of housing association using woonconnect tool (UC-424a)

Renovation of Semi-attached homes of housing association using woonconnect tool

General Information

City	Eindhoven	**Sector**	Energy
Country	Netherlands	**Triangulum**	Yes

Short Description

The project aims to involve tenants into the process of renovating and maintaining homes owned by the social housing association Woonbedrijf. It enables tenants to make informed decisions on what pre-defined renovation options they want to realize. The digital 3D-tool WoonConnect allows tenants to see the influence of their behavior (i.e. showering, heating) and the expected results of the renovation.

USP/Highlight

The tool creates a new sense of influencing power and was accompanied by several direct interactions to capture preferences of the tenants. The tool provides direct feedback on the web-application what the influence of several renovation options are.

Project Scale	Neighborhood	**Planning Time**	2-5 years
Development Type	Retrofitting	**Implementation Time**	<0.5 years
Participation Model	Active participation		started with direct kitchen table interviews in 200 homes prepared the renovation plan on the basis of the outcome enter the renovation plans into the WoonConnect tool (prepare the tool for the tenant) guided process/introduction of the tenants using the WoonConnect tool to make informed decisions on renovation options possible: using the tool for monitoring of the efficiency of the renovation and behavioral changes

Stakeholder Analysis

Owner	Woonbedrijf owns implementation	**Implementer**	Woonbedrijf
Customer	house owner (institutional)	**Service Provider**	WoonConnect (2SNoeken) in cooperation with KPN

Implementation of UseCase

Supporting Factors

Legal	Housing association bound by law to maintain and improve the houses. Agreement to improve the average social house to energy label B. Official regulation to have an energy label on each home.	Geographical	
Infrastructural		Social	Generally high usage of new technology / however Not in several important tenant groups
Financial		Partners	
Other	The type of houses is present 1 Mio. Times in the whole of The Netherlands (high scaling up opportunities). Closer interaction being triggered between the involved private and public partners.		

Main Implementation Challenge

PRIVACY // Creating enough trust for the data to be collected through the WoonConnect tool. Many partners involved interested in many different kinds of data and therefore tenants became afraid of the type of questions asked and the possible uses of the data.

Lessons Learned
Not all tenants prefer digital interaction (via the tool) or interaction in general. Main influencing factors are age, trust in private and public authorities.
Data privacy in the homes is perceived much more pressing than in other digital areas (such as social media)
The direct and personal interaction at kitchen-tables was highly important for the success of the project - therefore the process was redesigned to use WoonConnect as a self-service and as a guided experience. Know your customer: is the digital tool right for the user. Design a customer journey before you begin

Financing Information

Initial Investment	> 5,000,000	ROI	> 15 years
Scale of Investment	250 semi-attached homes		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	8%	Financial institutions	
Regional funds		End User	
Others	92%	Woonbedrijf	

Revenue Streams/ Monetized Value
rent, reduced energy bill for tenant, increased real estate value, contract fee for WoonConnect,

Project Details

Standard & Technical Details
renovation options available: new insulated of roof, exchange of single-glazing to double-glazing, new ventilation system based on a C02 sensor, new layout of homes (i.e. bigger bathroom), PV panels for the roof

Necessary Projects

Supporting Projects
community building (get in touch with your neighbor by renovating together of using the tool together)

Benefits

Primary Benefits	Secondary Benefits
Decreasing energy consumption in buildings	Reducing use of fossils
Improving Energy Usage Efficiency	Reducing Operation Costs
Reducing energy Bill	Improving personnel efficiency
Improving social integration	Improving Air Quality
Improving Life Quality	Reducing GHG Emissions
	Increasing share of renewables
	Promoting sustainable behavior
	Facilitating Citizen Engagement
	Increasing transparency

The renovation allows the housing association to directly interact with the tenants, renovation is now possible on an individual household level, improved living conditions for tenants

Wider Benefits

Suggested Financing Options

Prospective Customers for future
all kinds of home owners with multiple homes - especially institutional ones

Contact for further Details
m.vandenwijngaard@woonbedrijf.com

5.6.23 Renovation of Semi-attached homes of privately owned apartments using woonconnect tool (UC-424b)

Renovation of Semi-attached homes of privately owned apartments using woonconnect tool

General Information

City	Eindhoven	Sector	Energy
Country	Netherlands	Triangulum	Yes

Short Description

The digital 3D-tool WoonConnect allows the housing association and apartment owners to improve their apartments and see the influence of their behavior (i.e. showering, heating) and the expected results of the renovation. It shows the different renovation options available through different suppliers via a two-sided platform approach that even allows direct contracting. Decision making is collective

USP/Highlight

The tool provides direct feedback on the web-application what the influence of renovation is. A homeowner can directly receive an offer for a renovation option.

Project Scale	Individual site	Planning Time	
Development Type	Upgrading	Implementation Time	
Participation Model			

Stakeholder Analysis

Owner	WoonConnect (2SNoeken) in cooperation with KPN	**Implementer**	WoonConnect (2SNoeken) with Municipality as a facilitator
Customer	house owners and contractors	**Service Provider**	WoonConnect (2SNoeken) in cooperation with KPN

Implementation of UseCase

Supporting Factors

Legal		Geographical	
Infrastructural		Social	Generally high usage of new technology / however Not in several important tenant groups
Financial		Partners	
Other	The type of houses is present 1 Mio. Times in the whole of The Netherlands (high scaling up opportunities). Closer interaction being triggered between the involved private and public partners.		

Main Implementation Challenge

Decision making is a challenge as collective process. MARKETING and helping the customers through the process. Trust Issue with who the contractors are in the list. Finding the right offer for the apartment building

Lessons Learned
Know your customer: is the digital tool right for the user.

Financing Information

Initial Investment		ROI	
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	
Others	100%	KPN	

Revenue Streams/ Monetized Value
reduced energy bill for home owners, Contractors: new business opportunities WoonConnect: from the contractors

Project Details

Standard & Technical Details
All renovation options for upgrading the house

Necessary Projects

Supporting Projects
community building (get in touch with your neighbor through the tool) Building digital archive/history of building which can help while selling it

Benefits

Primary Benefits	Secondary Benefits
Decreasing energy consumption in buildings	Reducing use of fossils
Improving Energy Usage Efficiency	Reducing Operation Costs
Reducing energy Bill	Improving personnel efficiency
Improving social integration	Improving Air Quality
Improving Life Quality	Reducing GHG Emissions
	Increasing share of renewables
	Promoting sustainable behavior
	Facilitating Citizen Engagement
	Increasing transparency

Wider Benefits

Suggested Financing Options
National/local/regional Subsidies and loans for retrofitting measures.

Prospective Customers for future
all kinds of apartment owners and housing associations/co-operatives

Contact for further Details
roel.willemsen@kpn.com

5.6.24 Renovation of Semi-attached homes of privately owned houses using woonconnect tool (UC-424c)

Renovation of Semi-attached homes of privately owned houses using woonconnect tool

General Information

City	Eindhoven	Sector	Energy
Country	Netherlands	Triangulum	Yes

Short Description
The digital 3D-tool WoonConnect allows the home owners to improve their homes and see the influence of their behavior (i.e. showering, heating) and the expected results of the renovation. It shows the different renovation options available through different suppliers via a two-sided platform approach that even allows direct contracting.

USP/Highlight
The tool provides direct feedback on the web-application what the influence of renovation is. A homeowner can directly receive an offer for a renovation option.

Project Scale	Individual site	Planning Time	2-5 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Active participation	Input taken for scenario development. Qualitative research to couple with quantitative data from municipality	

Stakeholder Analysis			
Owner	WoonConnect (2SNoeken) in cooperation with KPN	**Implementer**	WoonConnect (2SNoeken) with Municipality as a facilitator
Customer	house owners and contractors	**Service Provider**	WoonConnect (2SNoeken) in cooperation with KPN

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural		Social	Generally high usage of new technology / however Not in several important tenant groups
Financial		Partners	
Other	The type of houses is present 1 Mio. Times in the whole of The Netherlands (high scaling up opportunities). Closer interaction being triggered between the involved private and public partners.		

Main Implementation Challenge
to get in touch with the private home owner. MARKETING and helping the customers through the process. Who do you address for the decision making in the house. Trust Issue with who the contractors are in the list

Lessons Learned
main factor for implementation is the reduction in energy bill. Know your customer: is the digital tool right for the user.
Finding right scenarios important to encourage users. Complete self-service tool is difficult. Need some help for getting started
don't start with Energy use. Luring them in is a challenge. Important to start with someone who knows the neighborhood well. Spreading message through social groups. Privacy of Data: Who will use the information? Who sends the message /In Eindhoven letter sent by Mayor

Financing Information

Initial Investment	500,000 - 1,000,000	ROI	5 - 10 years
Scale of Investment	Investment to fill tool with data (250/house) for 4000 houses		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	
Others	100%	KPN	

Revenue Streams/ Monetized Value
reduced energy bill for home owners, Contractors: new business opportunities WoonConnect: from the contractors

Project Details

Standard & Technical Details
All renovation options for upgrading the house

Necessary Projects

Supporting Projects
community building (get in touch with your neighbor through the tool) Getting approval/permits from Municipality for renovation Building digital archive/history of house which can help while selling it

Benefits

Primary Benefits	Secondary Benefits
Decreasing energy consumption in buildings	Reducing use of fossils
Improving Energy Usage Efficiency	Reducing Operation Costs
Reducing energy Bill	Improving personnel efficiency
Improving social integration	Improving Air Quality
Improving Life Quality	Reducing GHG Emissions
	Increasing share of renewables
	Promoting sustainable behavior
	Facilitating Citizen Engagement
	Increasing transparency

Wider Benefits

Suggested Financing Options
National/local/regional Subsidies and loans for retrofitting measures.

Prospective Customers for future
all kinds of home owners

Contact for further Details
roel.willemsen@kpn.com

5.6.25 Solar Smart Grid for apartment buildings with private home owners (UC-425a)

Solar Smart Grid for apartment buildings with private home owners

General Information

City	Eindhoven	Sector	Energy
Country	Netherlands	Triangulum	Yes

Short Description

It is a smart grid system which enables effective and flexible distribution of roof-top solar energy produced. It allows the individual house owners to opt in/out of the system by investing in solar panel system. The energy produced by the system is distributed to the home owners based on their investment share. It includes a web application through which the energy system can be monitored, the house owners can trade energy among each other and also smartly control their energy bills.

USP/Highlight

Home owners have a choice to opt in or out of the system

Project Scale	Individual site	Planning Time	0.5 - 1 years
Development Type	Retrofitting	Implementation Time	<0.5 years
Participation Model	Active participation	Layered participation model: Communicate with the Housing Association, have general meeting with home owners and have individual sessions with home owners to develop a suitable model	

Stakeholder Analysis

Owner	Municipality of Eindhoven, Onze Stroomfabriek	**Implementer**	Onze Stroomfabriek and contractors
Customer	Apartment building home owners, Housing Co-operatives/Association	**Service Provider**	Onze Stroomfabriek

Implementation of UseCase

Supporting Factors

Legal	Roof and other common areas are owned by the Housing Association in Netherlands. Collective decision made to install in this. Home owners are a part of the Housing Associations as soon as they buy the apartment.	Geographical	
Infrastructural	High strength Roof to install panels. Available open space on the roofs.	Social	Enthusiastic social groups are present across the city to encourage use of RE. Bottom up approach as people are more inclined to sustainable behavior.
Financial	Tax concession (21%) on Solar PV available in Netherlands Special loan agreements from Municipality for investing in sustainable energy production. Strong ROI(5-6 yrs.) owing to the financial subsidies High energy prices in city would support	Partners	
Other	Currently low share of local Renewable Energy in the electricity mix(4.5%). Future high RE goals. So political encouragement.		

Main Implementation Challenge

Convincing individual home owners (apartment buildings) to participate in the process. Takes a lot of time to convince.
Implementation in apartment building occupancy by a mix of tenants and owners is a challenge owing to different interests
Convincing people to invest in Solar panels and make them aware of the benefits

Lessons Learned
Important to make an analysis of the ownership and occupancy model, decision making structure of building to offer an interesting solution
Analyze the building structure to know the technical suitability of building. Building orientation should be suitable for solar PV installations

Financing Information

Initial Investment	250,000 - 500,000	**ROI**	5 - 10 years
Scale of Investment	For 4 apartment building with 540 kW (peak), with 20-25% participation		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	30%	Financial institutions	
Regional funds		End User	70%
Others			

Revenue Streams/ Monetized Value
Reduced electricity bill, energy trading when Not used

Project Details

Standard & Technical Details
Solar PV Panels, Smart Distribution System (distribution box(with hardware and software) in each house), Web portal

Necessary Projects

Supporting Projects
Energy production from different renewable sources, Possible addition of energy storage, Additional services and functions on the open web portal, Integration of WoonConnect on the system

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Enabling new business opportunities
Reducing GHG Emissions	Improving social integration
Increasing share of renewables	Improving Life Quality
Improving Energy Usage Efficiency	Promoting sustainable behavior
Reducing energy Bill	Facilitating Citizen Engagement
	Increasing transparency

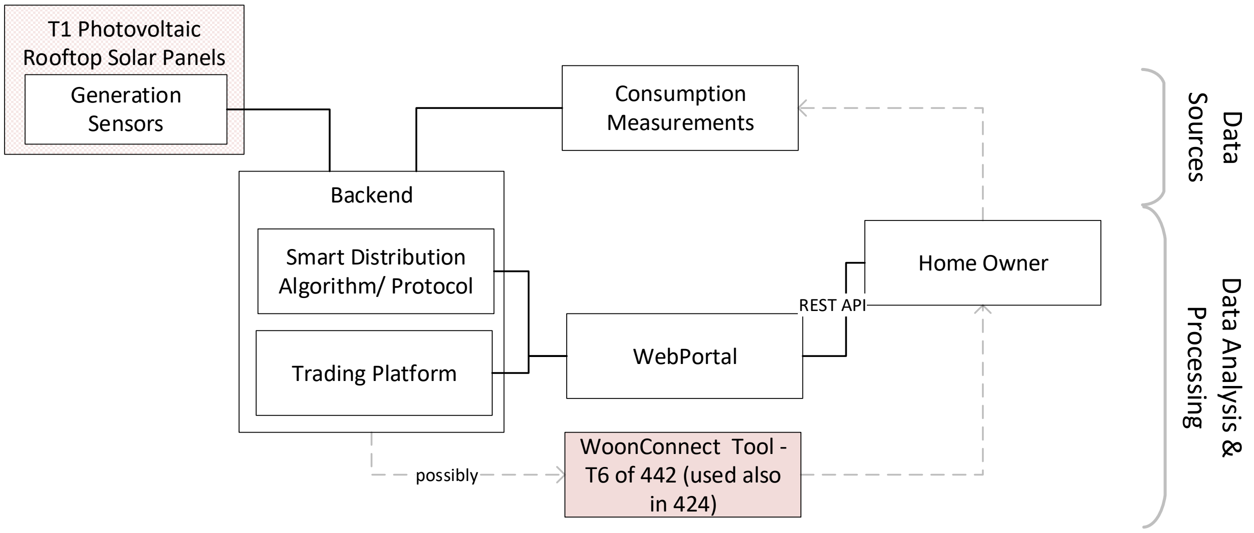
Gives better sense of ownership, democratizing energy production

Wider Benefits
Connecting WoonConnect to the Web Portal to make both the systems more beneficial

Suggested Financing Options
National/EU subsidies

Prospective Customers for future
Housing Associations- Apartment Buildings

Contact for further Details
d.mitcan@eindhoven.nl



Generation/consumption meters were assigned to the data sources layer by virtue of their sensing function. Direct communication pathways exist between the meters and the backend and therefore no single entity had to/could be mapped onto the communications layer. The backend, the trading platform both are responsible for data processing and can be accessed by the home owners' PC through a web portal. Furthermore data can be transmitted to and integrated with other data through the woonconnect tool. All these tools therefore belong onto the data processing and analysis layer.

Relevant Standards: RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.26 Wind energy for common areas of apartment building (UC-425b)

Wind energy for common areas of apartment building

General Information

City	Eindhoven	**Sector**	Energy
Country	Netherlands	**Triangulum**	Yes

Short Description
Closed Wind turbine produced by IBIS installed on top of a apartment building. The energy produced is used to light the common areas in the building. The regular wind flow was not suitable for regular wind turbines. Hence, the closed wind turbine design uses effectively the wind flow along the façade along with the regular wind flow. Closed system: visually more appealing and more acceptable for city

USP/Highlight

Project Scale	Individual site	**Planning Time**	
Development Type	Technological Development	**Implementation Time**	
Participation Model	Passive Participation	The housing association had planned to discuss with the tenants and association about the	

Stakeholder Analysis			
Owner	IBIS Power NL	**Implementer**	IBIS Power NL
Customer	Housing Association	**Service Provider**	

Implementation of UseCase

Supporting Factors			
Legal	Housing Association National Law- They can't earn money other than rent. So cannot sell electricity generated by the turbines	Geographical	Not enough wind in the city, so a new technology which also uses wind from façade
Infrastructural	Dense neighborhood with social housing. Tall buildings	Social	More socially acceptable solution owing to the visual appeal and less Noise.
Financial	Reduced rent and service costs as wind energy was used to light common areas.	Partners	Start-up from the TU/e Innovation Lab. so strong relations
Other			

Main Implementation Challenge
Not a proved technology when planned to be implemented. So the initial results were much more optimistic

Lessons Learned
Have a completely independent bureau to analyze the feasibility of system in urban areas. Also get a second opinion on the feasibility of the system. Analyzing wind resource
Technical solution might Not be the only challenge, but also dealing with start-ups as a trust worthy solid business partner.
Better to use the energy in common areas and neighboring areas than sell it to avoid legal burden accompanying with being an energy provider.

Financing Information

Initial Investment	50,000 -250,000	**ROI**	
Scale of Investment	2 wind turbine systems		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	30%	Financial institutions	
Regional funds		End User	70%
Others			

Revenue Streams/ Monetized Value
Reduced Energy bill

Project Details

Standard & Technical Details
Closed wind turbine systems

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	
Reducing GHG Emissions	
Increasing share of renewables	
Reducing energy Bill	

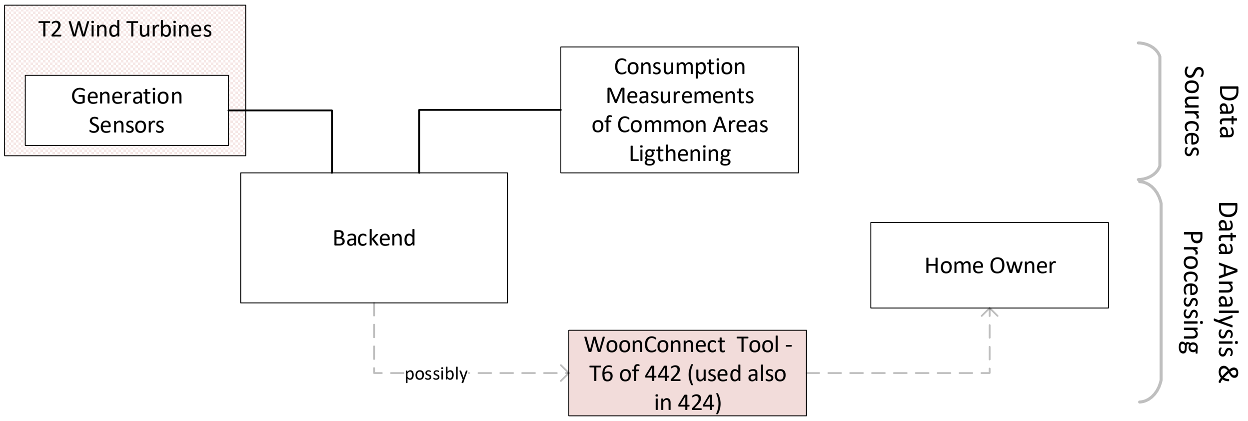
Tenants benefit with reduced electricity bill in common areas

Wider Benefits
Huge marketing value for city (Power nests on high rise buildings)

Suggested Financing Options
National, European subsidies

Prospective Customers for future
Housing Associations

Contact for further Details
m.vandenwijngaard@woonbedrijf.com



UC-425b closely resembles a simplified version of UC-425a. Changes include the type of sensors used (here energy consumption measurements by lightening solutions) as well as the dropping of the trading platform and the separate web portal, whose functions are entirely taken over by the WoonConnect tool.

Relevant Standards: ANSI/ASHRAE Standards 135-2016 (BacNet), RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

UC-425b has not been installed as part of Triangulum as it did not pass the financial feasibility test of a corresponding scientific study. Throughout the process the considerable learning was captured and can be used in an identical way as successful implementation projects.

5.6.27 Public Charging Infrastructure (UC-431a)

Public Charging Infrastructure

General Information

City	Eindhoven	Sector	Mobility & Transport
Country	Netherlands	Triangulum	Yes

Short Description
6 Type-2 AC chargers (2 access points) in Strijp-S with two charging points. One located in a parking garage and two in open parking lots. Planned app shall trigger the user to unplug the car once it is readily charged. Also one DC/fast charger have been implemented

USP/Highlight
Peak load management system/charging management system included. Enabled for smart grid usage.

Project Scale	District level	Planning Time	0.5 - 1 years
Development Type	Upgrading	Implementation Time	0.5 - 1 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	Volker Wessels iCity	**Implementer**	Ecotap (Charging station), Homij (power connection)
Customer	residents, visitors, workers	**Service Provider**	Ecotap

Implementation of UseCase

Supporting Factors			
Legal	European standards for plugs and communication (charging pole - car) Now available	Geographical	
Infrastructural		Social	
Financial	Several subsidies for electric vehicles and charging stations from the Dutch national government.	Partners	
Other	Political push towards electric vehicles.		

Main Implementation Challenge
Charging points are connected to the real estate and Not directly to the public grid. Billing between the building and the charging station owner is necessary.

Lessons Learned
Takes a lot of effort if there is a shared electricity access point.
Additional meter at access point to the real estate grid had to be installed.
Maximum available capacity is a bottleneck in already in use buildings.

Financing Information

Initial Investment	50,000 -250,000	ROI	5 - 10 years
Scale of Investment	7 charging stations (incl. connection to electricity grid and data backbone) and one app		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others	30%	Volker Wessels iCity	

Revenue Streams/ Monetized Value
fee for the usage of the charging stations (kWh based) in addition to the Normal parking fee

Project Details

Standard & Technical Details
charging stations have up to 22kW per charging point

Necessary Projects

Supporting Projects
Parking Management System

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Improving Life Quality
Improving Air Quality	
Reducing GHG Emissions	
Supporting environmental efficient transport	
Promoting sustainable behavior	
Promoting Electric Vehicles	

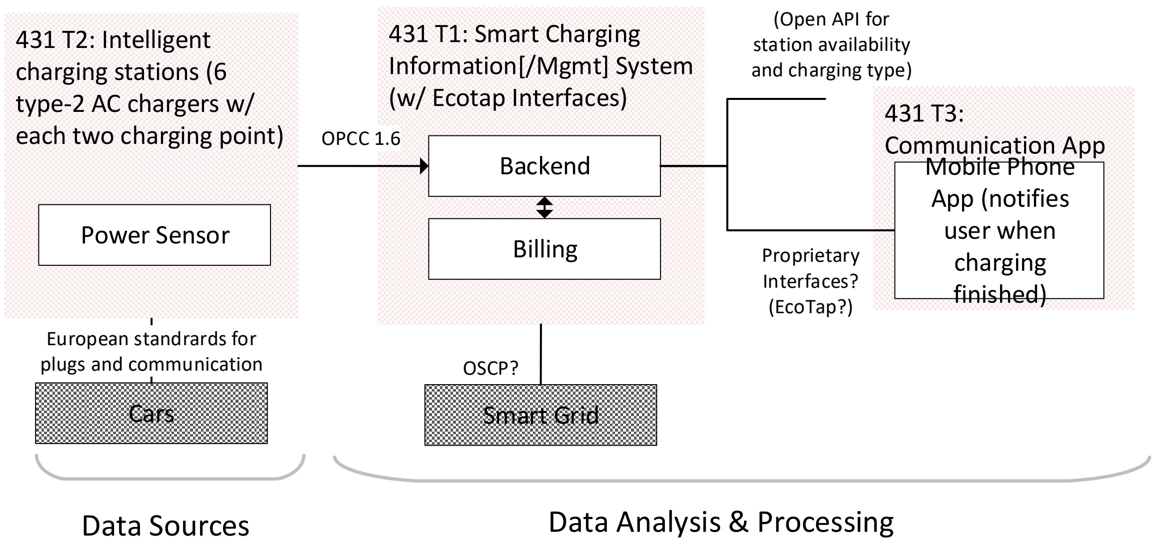
more efficient use of charging infrastructure

Wider Benefits

Suggested Financing Options
public funding often available, leasing models with Charge Point Operators (CPOs) and manufacturers available

Prospective Customers for future
real estate owner, municipality, industrial site owners, airports, hospitals, shopping malls

Contact for further Details
tvdieren@volkerwessels.com



UC-431a has about the same structure as UC-432b-c. In contrast, charging stations and charging points were collapsed into a single abstraction. Furthermore, a mobile app for enabling notifications of the user when the charging has finished, has been added to the data processing and analysis layer.

Relevant Standards: OCCP, Open Smart Charging Protocol 1.0, IEC 61851-24 (DC Charger), RFID

5.6.28 Parking Management System (UC-432a)

Parking Management System

General Information

City	Eindhoven	Sector	Mobility & Transport
Country	Netherlands	Triangulum	Yes

Short Description

A mobility management system which guides motorized transport using 3 large LED display sites, online and via an app. The system will recognize cars using visual license plate recognition and other modes of transport via a smartphone app. Occupancy of parking lots is increased. The most suitable parking lot is recommended and displayed to the user via the screens. If no personalized information are available, general occupancy information are displayed. The system will be able to recognize patterns and adopt the mode of operation. For cyclists and bikes three wayfinders (multidirectional LED screen with route information) were installed

USP/Highlight

The wayfinder screen can accommodate other relevant information such as weather forecast. Parking lots can be rented out when not needed (airbnb for parking). It collects information from several sources (e.g. cameras and barriers.)

Project Scale	District level	Planning Time	< 2 years
Development Type	Technological Development	Implementation Time	0.5 - 1 years
Participation Model	Passive Participation	Interviews and Questionnaires with customers	

Stakeholder Analysis

Owner	Parkres (Software), Mobility S(front end)	**Implementer**	Volker Wessels iCity and Parkres
Customer	End User: Offices, visitors, residential	**Service Provider**	Mobility S

Implementation of UseCase

Supporting Factors

Legal	A deal with the municipality allowed the developer to decrease the number of parking spaces that would have been required in a mixed use area by law - by developing a smart management system. It makes existing analogue hardware digitally controllable.	Geographical	
Infrastructural	Parking garages with management systems that needed replacement.	Social	
Financial		Partners	Mobility S as a parking reservation service provider through permits. Data collected like license plates provided to Mobility S. Real estate company has a major share in the management company.
Other			

Main Implementation Challenge

Several vendors operate the different parking spots (system integration is necessary, proprietary APIs). Existing parking management system with existing infrastructure and hardware.
Digital infrastructure to connect the parking hardware to fibre optic infrastructure. (e.g.. payment system, cameras etc.)
Maintaining privacy has been a challenge.

Lessons Learned
Important to get detailed existing information(hardware, software, infrastructure) with all the vendors and parking systems in the area.
Understand who the end-user is(residential users/office goers) and what they expect from the management system. What changes are expected in the near future w.r.t service needed in future.
Useful to have a system which can work with different vendors as it makes it easier to replicate in different regions

Financing Information

Initial Investment	250,000 - 500,000	ROI	5 - 10 years
Scale of Investment	park management system for 2 parking garages and 5 open parking lots, 3 screen sites		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others	30%	Volker Wessels iCity	

Revenue Streams/ Monetized Value
reservation of parking, increased real estate value, service fees, less parking spots needed, better use of personnel (higher degree of automation)

Project Details

Standard & Technical Details
Visual Recognition through camera used by the portal to identify number plates of the cars.

Necessary Projects

Supporting Projects
Fibre Optic Infrastructure, electric vehicle charging

Benefits

Primary Benefits	Secondary Benefits
Improving Air Quality	Reducing Operation Costs
Reducing traffic congestion	Improving personnel efficiency
Improving Parking	Enabling new business opportunities
Supporting the sustainable use of land	Reducing GHG Emissions
	Improving Life Quality
	Improving data availability

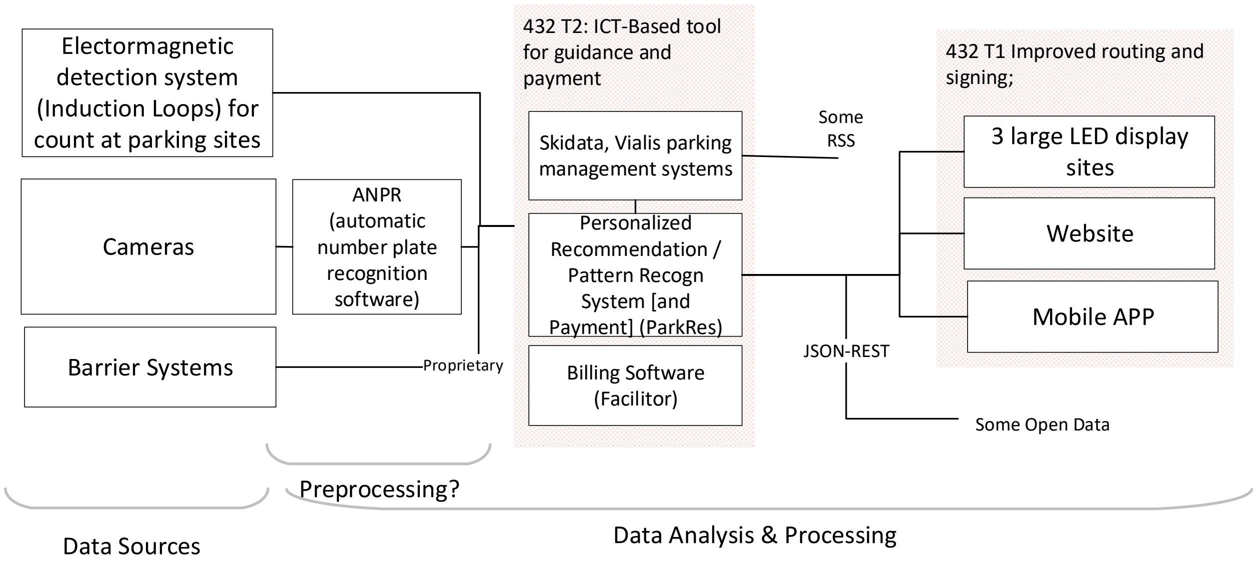
reduced park searching time, extend lifetime of existing hardware, more efficient use of parking space

Wider Benefits

Suggested Financing Options
direct investment by implementer

Prospective Customers for future
real estate owner, municipality, industrial site owners, airports, hospitals, shopping malls

Contact for further Details
tvdieren@volkerwessels.com



Multiple types of data sources (cameras, sensors on barrier systems and an electromagnetic car detection system) collect car movement and parking related data The automatic number plate recognition system takes over predominantly processing tasks and therefore already counts as first entity on the data analytics and processing layer, which encompasses a multitude of further technologies (i.e. ICT-based tools for guidance and payment as well as the improved routing and signing system that serve mainly as interfaces to users).

Relevant Standards: ISO/IEC 13249, ISO/IEC 27040, ISO/IEC 27017, ISO/IEC 27018, CWA 16871-1, ITU-T Y.3600, ISO/IEC 10746, ISO/TR 9007:1987, ITU-T X.1601, RFC 7252 (CoAP), MQTT, RFC 7159 JSON

5.6.29 Station bound district car sharing (UC-432b)

Station bound district car sharing

General Information

City	Eindhoven	Sector	Mobility & Transport
Country	Netherlands	Triangulum	Yes

Short Description
3-5 sharing cars that are operated by several contractors. Several membership and pay-as-you-go options are available to customer. Greenwheel, free2go and another provider have stations in Strijp-S. Strijp-S provides the parking space and provide local marketing.

USP/Highlight
Multiple providers are enabled at the same site.

Project Scale	District level	Planning Time	< 2 years
Development Type	Upgrading	Implementation Time	0.5 - 1 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	Greenwheels, free2go and the other provider	**Implementer**	Greenwheels, free2go and the other provider (cars), Mobility S (infrastructure, parking)
Customer	residents, visitors, workers	**Service Provider**	Greenwheels, free2go and the other provider (cars)

Implementation of UseCase

Supporting Factors			
Legal	Less parking spaces needed if car sharing is implemented in an area.	Geographical	
Infrastructural	big parking areas available	Social	
Financial		Partners	Municipal ambition to decrease CO2 emissions and increase use of green mobility.
Other			

Main Implementation Challenge
Existing car sharing providers and locked with specific vehicles (as they most often are OEMs) - this decreases flexibility and possibilities of close cooperation. Even independent vendors are inflexible.

Lessons Learned
Behavioral change of people (Not owning an own car) takes time

Financing Information

Initial Investment	50,000 -250,000	**ROI**	
Scale of Investment	3-5 cars including the necessary parking spots		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others	30%	Volker Wessels (X%); Greenwheels, free2go and the other provider (X%)	

Revenue Streams/ Monetized Value
direct income from the user, less parking spots needed (less investment for developer)

Project Details

Standard & Technical Details

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Improving public transport	Improving Air Quality
Improving Parking	Reducing GHG Emissions
	Supporting environmental efficient transport

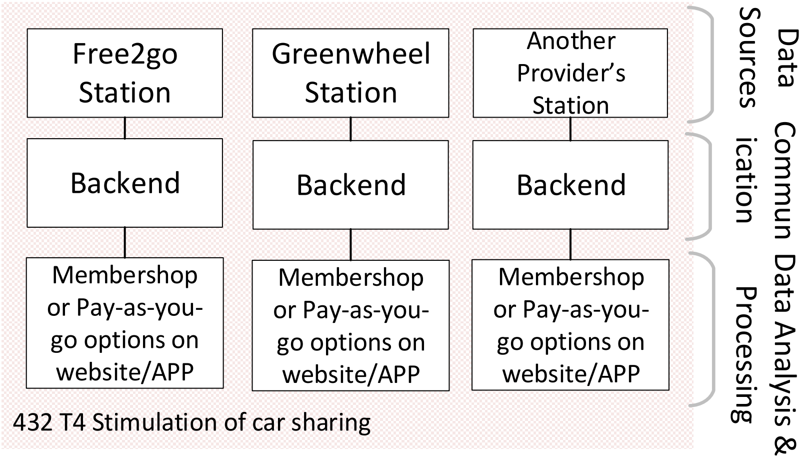
less cars needed, increased mobility options,

Wider Benefits

Suggested Financing Options
mainly financed by the service provider, real estate developer

Prospective Customers for future
real estate owner, municipality, industrial site owners, airports, hospitals, shopping malls

Contact for further Details
tvdieren@volkerwessels.com



Sensors and NFC items make up the data sources that can be found locally at the car sharing stations. Communication goes through backend systems. The data analytics layer encompasses the registration, authentication and billing logic, and provides interfaces to them via APPs and websites. The underlying subdivision likely encompasses a business logic server, website server and mobile phones.

Relevant Standards: RFID, TLS, 95/46/EG, EC 45/2001

5.6.30 Single base bike sharing (UC-432c)

Single base bike sharing

General Information

City	Eindhoven	Sector	Mobility & Transport
Country	Netherlands	Triangulum	Yes

Short Description
12 bikes operated locally by Mobility S as a service for visitors, workers and inhabitants. A mixture of ebikes and normal bikes is offered in a station bound bike sharing system located at one of the entrances of Strijp S. Bookings are done via a smartphone app, via the website and in an office located at the station.

USP/Highlight
Different types of bikes are available (e.g. electric). Special offer from the district for the district.

Project Scale	District level	Planning Time	0.5 - 1 years
Development Type	Upgrading	Implementation Time	< 2 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	Mobility S	**Implementer**	Mobility S
Customer	residents, visitors, workers	**Service Provider**	Mobility S

Implementation of UseCase

Supporting Factors			
Legal		Geographical	very flat area
Infrastructural	good bike lanes available in the district and beyond	Social	strong biking community
Financial		Partners	direct interaction as the office of the operator is located on-site
Other			

Main Implementation Challenge
Find suitable locations that are easily accessible via other transport modes - those are in areas where floor space is scarce and expensive

Lessons Learned
People own their own bikes and therefore No real need for sharing. Sharing mainly for tourists.
New mobility options need to be incentivized to create a user base.
The bike sharing has to fit to mobility needs in a suitable way - a significant use case is needed.

Financing Information

Initial Investment	< 50,000 Euros	ROI	5 - 10 years
Scale of Investment	20 bikes and one central sharing station		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others	30%	Mobility S (X%), Volker Wessels iCity (X%)	

Revenue Streams/ Monetized Value
rental fees from the user, increased brand value through advertisements

Project Details

Standard & Technical Details
Axa locks, 7 shift gear box,

Necessary Projects

Supporting Projects
mobility management system

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Improving Life Quality
Improving Air Quality	
Reducing GHG Emissions	
Supporting environmental efficient transport	
Reducing traffic congestion	
Promoting sustainable behavior	
Improving public transport	
Promoting Use of active modes	

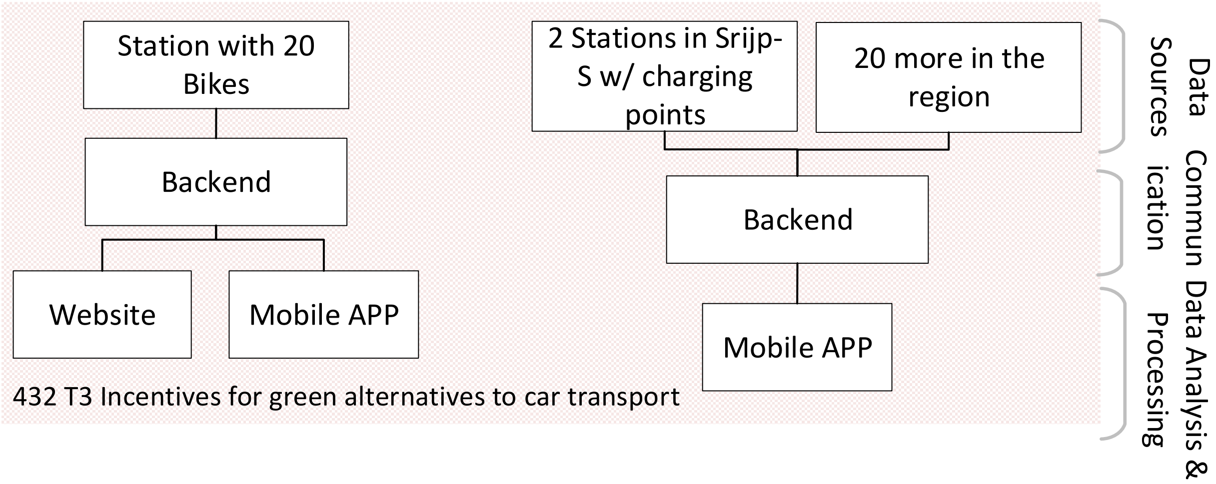
new job opportunities for people distant to the labor market (maintenance of bikes), marketing exposure (through branding of the bikes)

Wider Benefits

Suggested Financing Options
leasing options (e.g. from bike companies), self-financed, municipal public transport budget

Prospective Customers for future
municipality, real estate owners, hotels, recreational parks

Contact for further Details
tvdieren@volkerwessels.com



Instead of enabling car sharing (cf. UC-431b), UC-431c and UC-431d target bicycles. The underlying layout of the solution remains identical, alas security and authentication measures may be less powerful.

Relevant Standards: RFID, TLS, 95/46/EG, EC 45/2001

5.6.31 Point-to-point station bound bike sharing (UC-432d)

Point-to-point station bound bike sharing

General Information

City	Eindhoven	Sector	Mobility & Transport
Country	Netherlands	Triangulum	Yes

Short Description
16 bikes operated by HopperPoint as a service for visitors, workers and inhabitants of the whole region. A mixture of ebikes and Normal bikes is offered in 2 locations in Strijp-S and several more in the region (20+). Bookings are done via a smartphone app.

USP/Highlight
Regional offer integrating several areas in the region. Can be picked-up and dropped-off at different stations.

Project Scale	Beyond City Level	Planning Time	< 2 years
Development Type	Upgrading	Implementation Time	< 2 years
Participation Model	Passive Participation	on-street interviews as information and for publicity	

Stakeholder Analysis			
Owner	HopperPoint	**Implementer**	HopperPoint
Customer	residents, visitors, workers	**Service Provider**	HopperPoint

Implementation of UseCase

Supporting Factors			
Legal		Geographical	very flat area
Infrastructural	good bikelanes available in the district and beyond	Social	strong biking community
Financial		Partners	existing community and good connection go local stakeholders as it is a regional product
Other			

Main Implementation Challenge
Find suitable locations that are easily accessible via other transport modes - those are in areas where floor space is scarce and expensive

Lessons Learned
People own their own bikes and therefore No real need for sharing. Sharing mainly for tourists. Minimum number of stations needed for critical added value.
New mobility options need to be incentivized to create a user base.
The bike sharing has to fit to mobility needs in a suitable way - a significant use case is needed.

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	5 - 10 years
Scale of Investment	two sharing stations in Strijp-S (approx. 20 more in the region) - the 16 bikes have been paid by HopperPoint		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others	30%	Volker Wessels iCity (X%)	

Revenue Streams/ Monetized Value
None for Volker Wessels

Project Details

Standard & Technical Details

Necessary Projects

Supporting Projects

Benefits

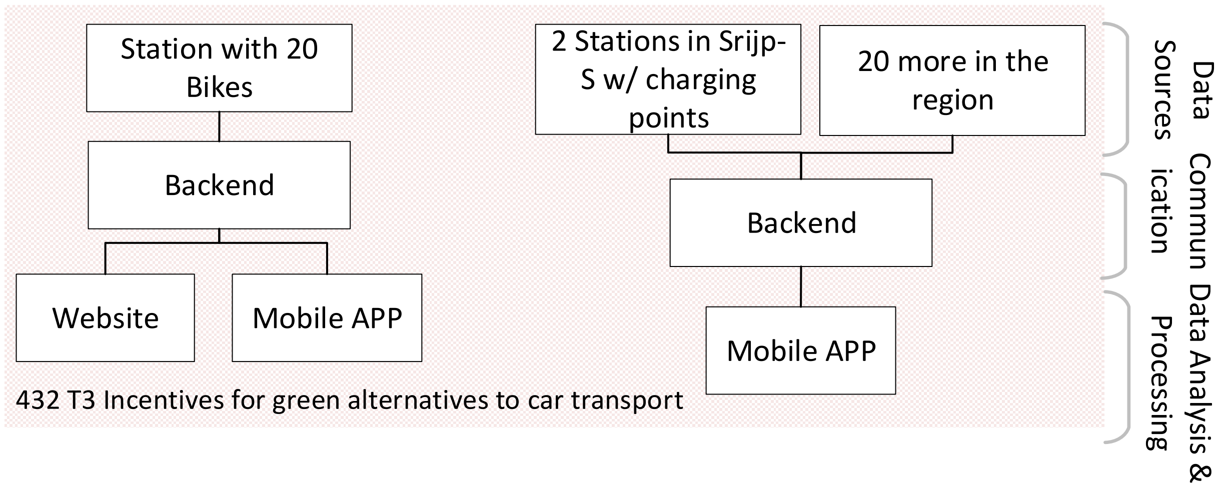
Primary Benefits	Secondary Benefits
Reducing use of fossils	Improving Life Quality
Improving Air Quality	
Reducing GHG Emissions	
Supporting environmental efficient transport	
Reducing traffic congestion	
Promoting sustainable behavior	
Improving public transport	
Promoting Use of active modes	

Wider Benefits

Suggested Financing Options
self-financed

Prospective Customers for future
municipality

Contact for further Details
tvdieren@volkerwessels.com



Instead of enabling car sharing (cf. UC-432b), UC-432c and UC-432d target bicycles. The underlying layout of the solution remains identical, alas security and authentication measures may be less powerful.

Relevant Standards: RFID, TLS, 95/46/EG, EC 45/2001

5.6.32 Eindhoven Open Data Portal (UC-441a)

Eindhoven Open Data Portal

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	Yes

Short Description

A data portal of the City of Eindhoven to upload, share, use, analyze and visualize public data sets. After a market consultation and testing to build and operate an own data portal, the city of Eindhoven decided to choose for a commercially available platform from Open Data Soft.

USP/Highlight

Very low barrier to use the portal to make it highly user friendly. Simple basic visualizations (e.g. tables geo-data) are available. Discussion functionalities on data set level is available to facilitate interaction between data owners and users.

Project Scale	City Level	Planning Time	< 2 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Active participation	Discussion round tables with data related businesses in the area to define (on a high level) the requirements on the data portal	

Stakeholder Analysis

Owner	Municipality of Eindhoven	**Implementer**	Open Data Soft
Customer	citizens, data driven businesses, start-ups, SMEs, students from local universities, researchers	**Service Provider**	Open Data Soft

Implementation of UseCase

Supporting Factors

Legal	Strict but clear information on privacy regulations.	Geographical	
Infrastructural	Increasing number of (real time) data sets available in the city.	Social	
Financial		Partners	
Other	Municipality of Eindhoven decided to be a frontrunner in the topic and therefore supports open data. Data sources are developed parallel to the portal. A total number and brief explanation of all available data sets in the municipality has been published on the platform (Not only those available openly).		

Main Implementation Challenge

Decision and process towards making data available from the municipality. Migrating existing data from an old platform to the open data portal was challenging.

Lessons Learned
There is a shift from just having an open data portal, to a portal incorporated in a wider vision to create a smarter society.
The focus should be on the usage of the data usage via the platform and Not on the portal and the storage on it.
Important to understand data ownership. Metadata of all municipal datasets are available publicly. A decision tree is available to decide on which data to make available.

Financing Information

Initial Investment	< 50,000 Euros	ROI	
Scale of Investment	Building URL, to add data, personnel training (Software as a Service- pay according to use)		

Financer (Contribution in Percentage)			
City	100%	Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
More involved citizens, Additional Business opportunities,

Project Details

Standard & Technical Details
Software as A Service, Cloud based portal, CKAN based

Necessary Projects

Supporting Projects
Data based Services, IOT devices, Sensor data based solutions

Benefits

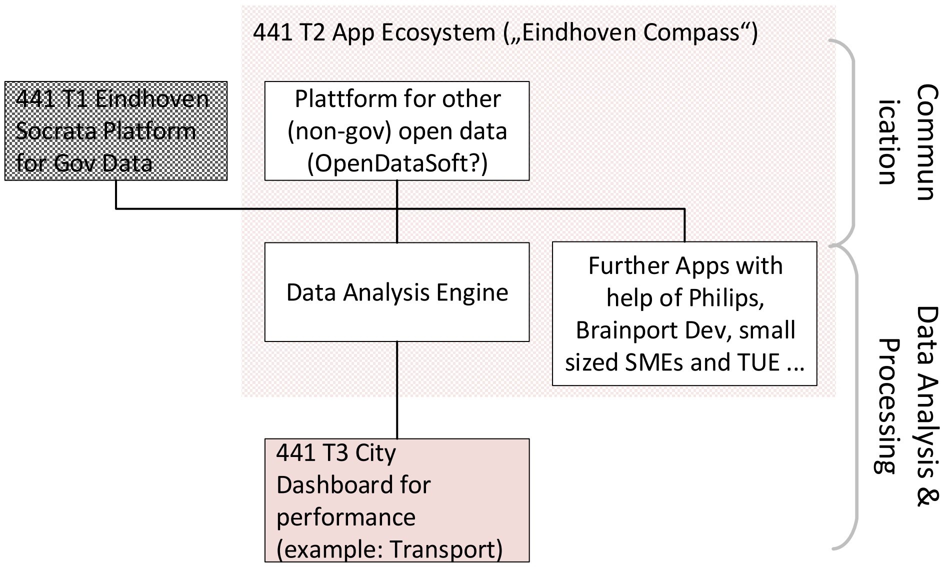
Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships Facilitating Citizen Engagement Improving data availability Increasing transparency	Improving personnel efficiency Enabling new business opportunities

Wider Benefits

Suggested Financing Options
Municipality budget

Prospective Customers for future
citizens, data driven businesses, start-ups, SMEs, students from local universities, researchers

Contact for further Details
d.mitcan@eindhoven.nl



As already stated in some previous Use Cases, Open Data platforms that store metadata and thereby enable efficient data finding and transfer – Socrata and the OpenDataSoft platform belong into this category - are mapped onto the communications layer. Visualization, including dashboards) and processing tools, such as apps, belong instead onto the Data Processing and Analysis layer.

Relevant Standards: HyperCat Initiative, OKF CKAN, ISO 37120, UNE 178301:2015

5.6.33 Public Sound Sensor Safety Project in Stratumseind (UC-442a)

Public Sound Sensor Safety Project in Stratumseind

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	No

Short Description

Sound sensors in the public space that are attached to the smart light poles enabled to detect specific sounds such as fighting and sound levels in bars and cafes in the main bar street in Eindhoven. The idea is to prevent incidents from happening.

USP/Highlight

The sensor is able to find out the exact position of a sound source. Safety features are enabled without continuously perceived intrusive monitoring via cameras. Trained law enforcement agents from the municipality are informed about any events directly on their phone. Light can be adjusted (color and intensity) also based on incidents.

Project Scale	Neighborhood	Planning Time	0.5 - 1 years
Development Type	Technological Development	Implementation Time	<0.5 years
Participation Model	Active participation	involvement of the bar owners and residents of the area	

Stakeholder Analysis

Owner		**Implementer**	Sorama (Tech-Start-up), Open Remote
Customer	municipality, safety related services, event/crowd managers, police	**Service Provider**	Sorama (Tech-Start-up)

Implementation of UseCase

Supporting Factors

Legal		Geographical	The area is closed to motorized traffic during the time the system is mainly used. Therefore less Noise occurs. The area is the main bar street in the area and therefore fights occur naturally,
Infrastructural	Fibre Optic Infrastructure	Social	
Financial		Partners	Close cooperation with the bar owners (the paid for part of the installation).
Other			

Main Implementation Challenge

Tuning of the sensor needs to be specific to the surrounding and is therefore time-consuming. Combination of sensing and acting via the smart lights is Not trivial.

Lessons Learned
Sensors work very well in combination with video surveillance systems to add additional information to the case.

Financing Information

Initial Investment	50,000 -250,000	ROI	
Scale of Investment	About 20 sound sensors installed with a few of them able to detect sounds at higher quality, includes a user interface		

Financer (Contribution in Percentage)			
City	30%	Private Sector	
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Reduced need for personnel in the safety area, reduced insurance fees, through increased safety property value increases, increased revenue for local shop owners

Project Details

Standard & Technical Details
64 sound sensors per unit,

Necessary Projects
Fibre Optic Infrastructure

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Improving personnel efficiency	Encouraging digital entrepreneurships
Improving Life Quality	Enabling new business opportunities
Increasing Safety	

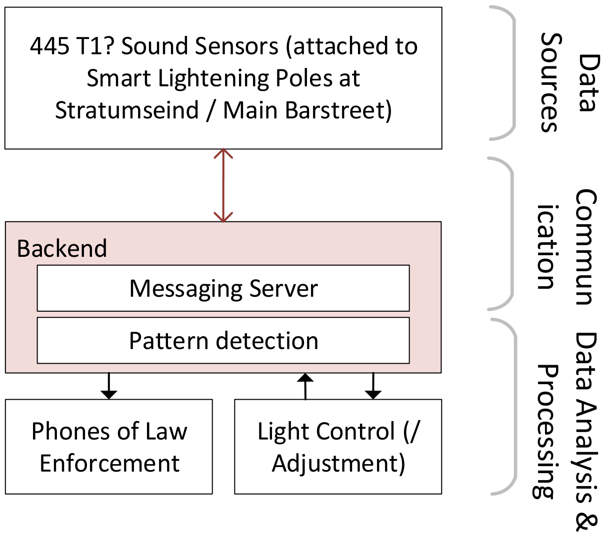
customized sound analytics enabled (e.g. detection of cries for help)

Wider Benefits

Suggested Financing Options
safety budget of public entities and real estate developers, local shop/bar owners,

Prospective Customers for future
municipalities, real estate developers, (industrial) site owners

Contact for further Details
d.mitcan@eindhoven.nl



Sensors are counted by default to the Data Sources layer. Notably certain data anonymization steps can already be taken here, which would count as data pre-processing. The back-end in this case acts similar as a messaging system server by relaying data and control commands but also does applies some kind of pattern detection algorithm to extract unusual events and consequently notifies law enforcement agents. Therefore, a part of the back-end belongs onto the communications layer and the other onto the data processing and analysis layer. On the data processing layer, we find the phones of the law enforcement agents that are notified upon and visualize location and type of event, as well as the light control system responds to changes in loudness level according to a certain logic.

Relevant Standards: TLS, 95/46/EG, EC 45/2001, RFC 7252 (CoAP), MQTT, RFC 7159 JSON

5.6.34 Sensor based citizen initiative for environmental monitoring (UC-442b)

Sensor based citizen initiative for environmental monitoring

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	No

Short Description
Collecting environmental data to monitor air quality focused on particulate matter. A heat map of air quality is published to put pressure on traffic regulations in the area. Historical data starting from 2015, daily curves and analyses are available on the web. The data are provided to the local open data portal.

USP/Highlight
The initiative is driven by the citizens and Not subsidized by the public sector.

Project Scale	City Level	Planning Time	0.5 - 1 years
Development Type	Stakeholder Engagement	Implementation Time	<0.5 years
Participation Model	Active participation	Citizens Initiative	

Stakeholder Analysis			
Owner	AIREAS (citizen group)	**Implementer**	
Customer		**Service Provider**	

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	open data portal to publish the data is available on a city level	Social	environmental aware citizens
Financial		Partners	
Other	At the time of installation there were No environmental sensors available in the city.		

Main Implementation Challenge

Lessons Learned

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	
Scale of Investment	33 sensors installed throughout the city incl. operation of the website		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	100%
Others			

Revenue Streams/ Monetized Value

Project Details

Standard & Technical Details

Necessary Projects

Supporting Projects
open data portal

Benefits

Primary Benefits	Secondary Benefits
Promoting sustainable behavior Improving data availability Increasing transparency	

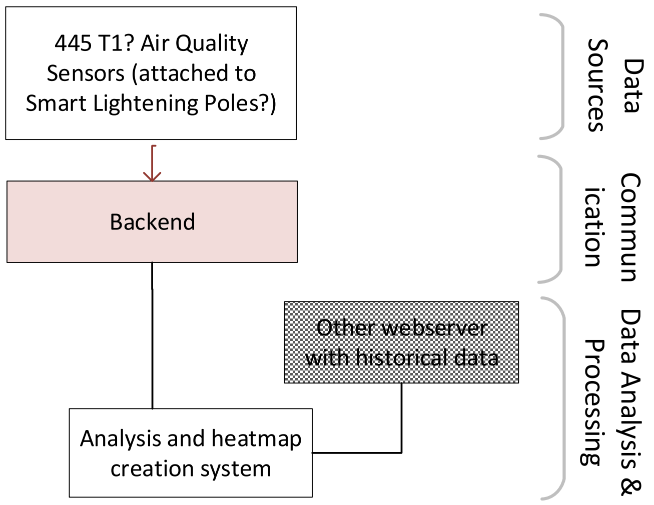
pressuring towards more sustainable behavior

Wider Benefits
push of the open data portal as real time data are provided by the sensors to the public

Suggested Financing Options

Prospective Customers for future
municipalities, public transport providers

Contact for further Details
d.mitcan@eindhoven.nl



Similarly to UC-442b, the sensors in 442c are assigned to the Data Sources layer. In contrast to that, the backend in UC-442c only takes over a communicative task and lacks processing capabilities, as data analysis is entirely taken over by the analysis and heat map creation system on the data processing and analysis layer. This system also takes historical data points as input. This data is stored on a webserver that belong onto the repositories sublayer of the data processing and analysis layer.

Relevant Standards: TLS, 95/46/EG, EC 45/2001, RFC 7252 (CoAP), MQTT, RFC 7159 JSON

5.6.35 Camera based crowd management in the Eindhoven city centre (UC-442c)

Camera based crowd management in the Eindhoven city center

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	No

Short Description
Several cameras are installed on the main bar street in Eindhoven (Stratumseind). The cameras have in-built software to recognize pedestrians an cyclists. The data are used to manage crowds in the city center. The system has an in-built decision system and informs e.g. law enforcement if necessary.

USP/Highlight
The cameras do Not transmit images but only counts of pedestrians and cyclists (privacy by design). Therefore also smaller data transmission rates are needed.

Project Scale	Neighborhood	Planning Time	0.5 - 1 years
Development Type	Technological Development	Implementation Time	<0.5 years
Participation Model	Active participation	involvement of the bar owners and residents of the area	

Stakeholder Analysis			
Owner	Dutch Institute of Technology (DITs)	**Implementer**	
Customer	municipality, law enforcement,	**Service Provider**	Open Remote, ViNotion

Implementation of UseCase

Supporting Factors			
Legal		Geographical	Narrow and closed area that is easily crowded during evening hours.
Infrastructural		Social	
Financial		Partners	
Other			

Main Implementation Challenge

Lessons Learned

Financing Information

Initial Investment		ROI	
Scale of Investment	5 cameras, a physical cockpit and a dashboard		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value

Project Details

Standard & Technical Details

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Improving personnel efficiency	
Increasing Safety	
Improving data availability	

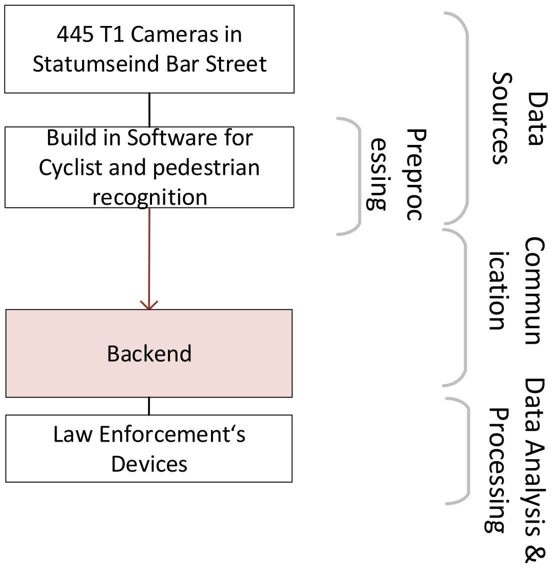
better crowd control

Wider Benefits

Suggested Financing Options

Prospective Customers for future

Contact for further Details
d.mitcan@eindhoven.nl



Cameras give rise to new data streams and therefore belong onto the data sources layer. Some processing happens already on-site at the cameras and thereby reduces the amount of data that needs to be transferred. As this can still be considered a pre-processing step at the data source itself, it was mapped to the data sources layer. The backend does not take over any further processing tasks and thus belongs in its entirety onto the communication layer. Data visualization happens on the law enforcement personnel's phone, which is hence part of the data processing and analysis layer.

Relevant Standards: H.246, RTP, SIP, TLS, 95/46/EG, EC 45/2001

5.6.36 Fibre Optic Infrastructure in Strijp-S (UC-443a)

Fibre Optic Infrastructure

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	Yes

Short Description

500km of Fibre Optic(Backbone) cables have been installed in ducts in the Strijp S district (68 acres) for improving connectivity in the area. The Fibre Optic network acts as a Backbone for additional data related services in Strijp-S. 227 smart light poles are directly connected to the fibre - 400 poles in total through gateways in the other poles.

USP/Highlight

Very high number of connection points per ???. Cables were included in construction works requiring digging anyway. Additional length and capacity of fibre is provided. The infrastructure can be easily accessed via a Smart City Hub - which is n access point to the control of the infrastructure.

Project Scale	District level	Planning Time	0.5 - 1 years
Development Type	Brownfield Development	Implementation Time	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis

Owner	partly Strijp-S Ontwikkeling (PPP of municipality and Volker Wessels) and Volker Wessels iCity	Implementer	Volker Wessels iCity
Customer	directly to owners and businesses in the area, providers, own use for value added services (e.g. maintenance)	Service Provider	Volker Wessels iCity

Implementation of UseCase

Supporting Factors

Legal		Geographical	densely populated area with many different small companies
Infrastructural		Social	
Financial		Partners	implemented through a PPP with the local municipality that allowed shorter processes
Other	area built as a smart data driven area and therefore in need for a strong data backbone. Huge variety of different data related services expected in the area.		

Main Implementation Challenge

Defining the future usage patterns and requirements together with a wide variety of potential users. Receiving the permits in time (connection to local poles, digging permit).

Lessons Learned
Combine the installation of the fibre optic infrastructure with other ground works required.
As much communication as possible with potential partner (e.g. providers to have several access points to prevent vendor lock-ins, city council to provide permits and investment money, responsible persons in the city administration)
Capacity will grow due Technological developments in fibre - meaning ducts with the same size will carry more capacity.

Financing Information

Initial Investment	50,000 -250,000	ROI	5 - 10 years
Scale of Investment	whole district of Strijp-S with 68 acres, 500km of fibre in 4-5km of ducts		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others	30%	Strijp-S Ontwikkeling	

Revenue Streams/ Monetized Value
If the fibre is Not implemented and owned by a provider, multi-provider offers are possible by renting out the infrastructure to providers which allows additional income; inhabitants and businesses in the area, direct exploitation with television services or similar

Project Details

Standard & Technical Details
Phase 1: 163.5 km of Fibre optic cables Phase 2: 337 km single mode network, 4-5km of ducts

Necessary Projects

Supporting Projects
sensor network, smart lighting in Strijp-S, Smart City Hub,

Benefits

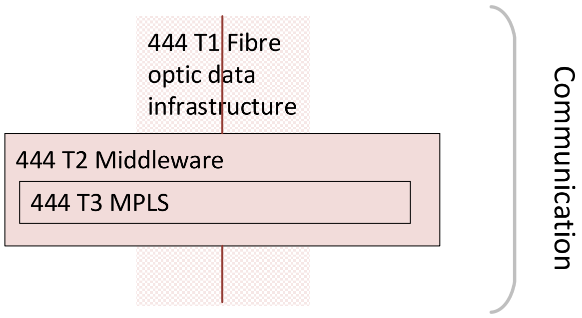
Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships	Reducing Operation Costs
Enabling new business opportunities	Improving personnel efficiency
Improving data availability	
enabling many kinds of new services, less latency in transmission (high transmission speed)	

Wider Benefits
new use of fibre in multiple wave-length from a big mobile phone provider switching from 4G-5G

Suggested Financing Options
financing options for added infrastructure like Wi-Fi available on EU level, specifically targeting remote areas

Prospective Customers for future
Normal network providers supported by public money from the municipality

Contact for further Details
tvdieren@volkerwessels.com



As UC-443a instantiates a network backbone out of glass fibre cables and furthermore enables efficient switching between different communication protocols by multi-protocol label switching, all of its entities fit well onto the communications layer.

Relevant Standards: -

5.6.37 Public Wi-Fi (UC-443b)

Public Wi-Fi

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	Yes

Short Description
Providing open and free Wi-Fi to inhabitants and visitors of Strijp-S. 18 hot-spots are planned.

USP/Highlight
Direct access to the site-related internet services is enabled. Inhabitants use the same access in public space as they use at home.

Project Scale	District level	Planning Time	<0.5 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	Volker Wessels iCity	**Implementer**	Cisco
Customer	event organizers, inhabitants, visitors	**Service Provider**	Cisco

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	Fibre Optic Infrastructure	Social	
Financial		Partners	
Other	Owner of the fibre backbone owns and operated the Wi-Fi		

Main Implementation Challenge
To link all the different hot-spots (indoor and outdoor) to a seamless network

Lessons Learned
Privacy regulations have to be taken into account.

Financing Information

Initial Investment	50,000 -250,000	**ROI**	5 - 10 years
Scale of Investment	68 acres with 18 public hot-spots		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others	30%	Volker Wessels iCity	

Revenue Streams/ Monetized Value
network/service providers, local business (e.g. retail) for advertisements, inhabitants in combination with their private hot-spots

Project Details

Standard & Technical Details

Necessary Projects
Fibre Optic Infrastructure

Supporting Projects
Sensors Not directly connected to the fibre backbone

Benefits

Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships	Enabling new business opportunities
Improving Life Quality	
Improving data availability	
simplifying connectivity to the internet, extension of backbone	

Wider Benefits

Suggested Financing Options
municipal budget for public connectivity, EU funds

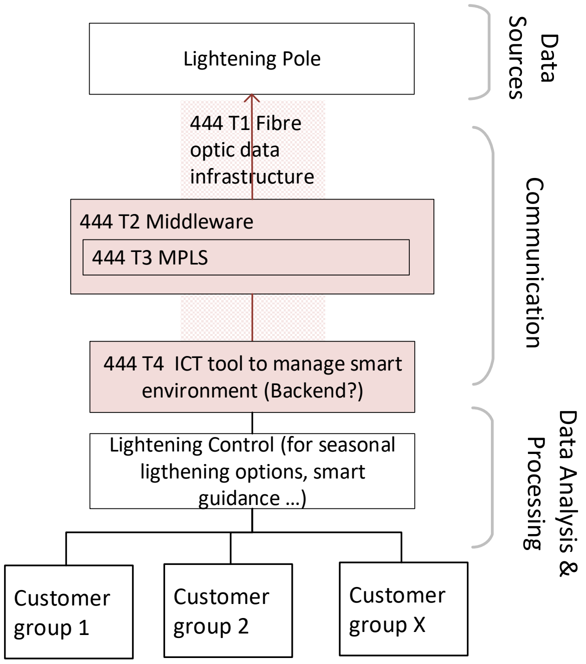
Prospective Customers for future
real estate owners, municipalities

Contact for further Details
tvdieren@volkerwessels.com

UC-443b foresees the equipment of the lightening poles from UC-444b and/or UC-444c with Wi-Fi-devices. As Wi-Fi devices enable access to the internet and thus enables communication, it belongs onto the communication layer.

Relevant Standards: -

5.6.38 Smart Lighting in Strijp-S (UC-444a)



In UC-444a, the lightening poles act again as Data Sources. Both backend and middleware take over communicative task (cf. UC-443a for a more detailed explanation). The lightening control system integrates and conducts computations in top of the communicated data and hence belongs onto the data processing and analysis layer. This processing logic and can altered/managed according to the desire of different customer groups.

Relevant Standards: RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.39 Public Sound Sensor Safety Project (UC-444b)

Public Sound Sensor Safety Project

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	Yes

Short Description
Sound sensors in the public space that are attached to the smart light poles enabled to detect specific sounds such as gunshots, car alarms and screams.

USP/Highlight
The sensor is able to find out the exact position of a sound source. Safety features are enabled without continuously perceived intrusive monitoring via cameras. The neighborhood watch receives access to relevant safety information via an app.

Project Scale	Neighborhood	Planning Time	0.5 - 1 years
Development Type	Technological Development	Implementation Time	<0.5 years
Participation Model	Active participation	involvement of the neighborhood watch in defining the need for the system	

Stakeholder Analysis			
Owner	Volker Wessels iCity	Implementer	Sorama (Tech-Start-up), Volker Wessels iCity
Customer	municipality, event managers, service developers, safety related services	Service Provider	Sorama (Tech-Start-up)

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	Fibre Optic Infrastructure	Social	In the early stages of the district redevelopment safety has been a concern.
Financial		Partners	Local Community that provided feedback on the needs of the area (neighborhood watch)
Other			

Main Implementation Challenge
Tuning of the sensor needs to be specific to the surrounding and is therefore time-consuming. Combination of sensing and acting via the smart lights is Not trivial.

Lessons Learned
Safety issues are less pressing in the area and therefore the push towards implementation lower
Interaction with other systems should be taken into account early. Getting the app accepted takes more time than expected.
Sensors work very well in combination with video surveillance systems to add additional information to the case.

Financing Information

Initial Investment	50,000 -250,000	**ROI**	
Scale of Investment	6 sound sensors installed		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	70%	Financial institutions	
Regional funds		End User	
Others	30%	Volker Wessels iCity	

Revenue Streams/ Monetized Value
Reduced need for personnel in the safety area, reduced insurance fees, though increased safety property value increases

Project Details

Standard & Technical Details
64 sound sensors per unit,

Necessary Projects
Fibre Optic Infrastructure

Supporting Projects
Smart Lighting Poles in Strijp-S

Benefits

Primary Benefits	Secondary Benefits
Improving personnel efficiency	Encouraging digital entrepreneurships
Improving Life Quality	Enabling new business opportunities
Increasing Safety	

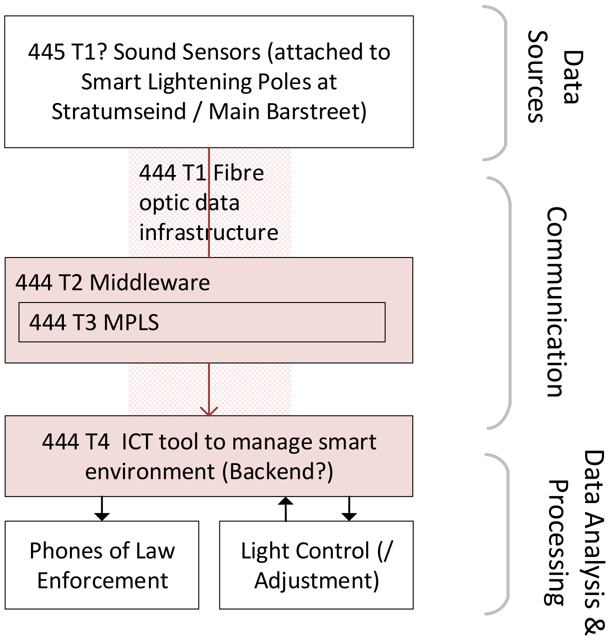
customized sound analytics enabled (e.g. detection of cries for help)

Wider Benefits

Suggested Financing Options
safety budget of public entities and real estate developers

Prospective Customers for future
municipalities, real estate developers, (industrial) site owners

Contact for further Details
tvdieren@volkerwessels.com



The mapping of UC-444c closely mirrors that of UC-442b, with the sole difference being that UC-444c also incorporated the communication backbone defined in UC-444a.

Relevant Standards: TLS, 95/46/EG, EC 45/2001, RFC 7252 (CoAP), MQTT, RFC 7159 JSON

5.6.40 IOT Security Systems (UC-446a)

IOT Security Systems

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	Yes (Demonstrator funded by Triangulum)

Short Description
It is plug-in software which ensures IOT Security. It is installed in the communication platform to avoid hacking of the IOT devices installed across the platform. The software is provided by a company called Bit Sensor. It ensures safety & security in smart city technology systems

USP/Highlight
Internet security in smart city is neglected. The solution tackles this challenge. It shortens time for the company to find leaks in their security systems. (Currently, it takes on avg. 9 months for a company to find out that they are hacked)

Project Scale	District level	Planning Time	<0.5 years
Development Type	Technological Development	Implementation Time	<0.5 years
Participation Model	Active participation	Discussions with Volker Wessels iCity to understand the need and choosing an alternative which suits their needs.	

Stakeholder Analysis			
Owner	Bit Sensor	**Implementer**	Bit Sensor
Customer	Volker Wessels iCity	**Service Provider**	Bit Sensor

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	Works with regular internet	Social	People are willing to try out this system and have trust in the company. So are ready to let them handle the security
Financial		Partners	Strong partnership with TU/e and Strijp S. Opportunity to try out their system. Easy to get right talent at TU/e
Other			

Main Implementation Challenge
Start-up company: earning trust from the customers is a struggle. Attracting more customers is a challenge Internet Security is a new topic. It is hard to explain it to Non-technical people.

Lessons Learned
Important to have mediators who can communicate with the technical and Non-technical people.
Higher investments would make the implementation process faster and easier

Financing Information

Initial Investment	< 50,000 Euros	ROI	
Scale of Investment	The communication platform in StrijpS (68 acres land)		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
preventing hacking attempts (works like an insurance and security system). Depends on case: If hacking prevented: very high ROI

Project Details

Standard & Technical Details
plug-in software, IOT devices in bulk which are connected to platform can be monitored through the software

Necessary Projects
Communication platform (Smart devices)

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Encouraging digital entrepreneurships
Increasing Safety	Enabling new business opportunities
Improving data availability	Enhances Grid Stability
Increasing transparency	Improving Life Quality

Ensures safety and security of Hardware components connected to household

Wider Benefits
Social Security in city is highly dependent on function of devices like Street lights. Ensuring security of these leads to much higher level of safety and security.

Suggested Financing Options
EU funds, Good business model. (paid by end user)

Prospective Customers for future
Municipality, district management, Real-Estate company, Event Management Companies

Contact for further Details
m.g.d.m.cox@tue.nl

5.6.41 High-End solar E-bike sharing system (UC-446b)

High-End solar E-bike sharing system

General Information

City	Eindhoven	**Sector**	ICT
Country	Netherlands	**Triangulum**	Yes (Demonstrator funded by Triangulum)

Short Description
It is a high-end, station bound electric bike sharing system which is based in a hotel. It is mainly meant for visitors in StrijpS. The bikes part of the system are good quality bikes which encourage more users to use the system with pride. The bikes are powered by flexible PV cells integrated in the bikes. Bikes also have installed sensors to gather data for city(light, temperature, CO_2, fine dust).

USP/Highlight
Encourages the concept of bike sharing to a new customer base and also promotes the region and cycling. It makes the experience of cycling much better.

Project Scale	District level	**Planning Time**	<0.5 years
Development Type	Upgrading	**Implementation Time**	<0.5 years
Participation Model	Active participation	Discussion between Abby & Volker Wessels iCity. The e-bikes were tested at TU/e and TU/twente with 240 people who got to use the bikes for 1 week.	

Stakeholder Analysis

Owner	Abby	**Implementer**	Abby with Volker Wessels iCity
Customer	Volker Wessels iCity, Hotel End-user: Visitors	**Service Provider**	

Implementation of UseCase

Supporting Factors

Legal		Geographical	
Infrastructural	Dedicated bike lanes	Social	Existing Biking culture
Financial	E-bikes receive Tax subsidies (in Netherlands all bikes get subsidy, In Belgium E-bikes get extra subsidy)	Partners	
Other			

Main Implementation Challenge
Getting the required flexible solar cells for the integration. The solar cells were specially designed for the product

Lessons Learned
Electric biking use also encourage elderly people to cycle
High end bikes encourage people to use them better and also encourage people to use it more

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	< 5 years
Scale of Investment	20000 euros for 4 bikes		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
End Users, Provided as service by hotels ,

Project Details

Standard & Technical Details
Electric Bikes charged by integrated flexible solar cells

Necessary Projects

Supporting Projects
Data collected from bikes can be used to build services (e.g.. Where to put salt on road in winter)

Benefits

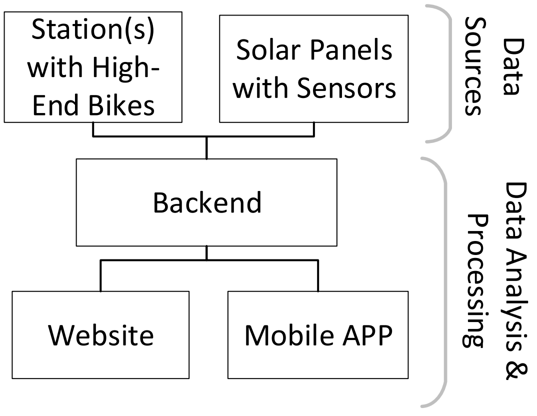
Primary Benefits	Secondary Benefits
Improving Air Quality	Reducing use of fossils
Supporting environmental efficient transport	Encouraging digital entrepreneurships
Improving social integration	Reducing GHG Emissions
Improving Life Quality	Increasing share of renewables
Improving Health Care	Reducing energy Bill
Promoting sustainable behavior	Reducing traffic congestion
Promoting Use of active modes	Improving Elderly Care
	Promoting Electric Vehicles
	Improving Parking
	Improving data availability

Wider Benefits
Elderly people are more active and social with E-bikes

Suggested Financing Options
Provincial funds available to promote E-bikes

Prospective Customers for future
Hotels, Companies, campuses, industrial areas

Contact for further Details
m.g.d.m.cox@tue.nl



UC-446b consist out of the same entities that also can be found in UC-431b+c. Solar panels were added onto the data sources layer as they deliver information about the energy produces that is then used to power the local rental station backend.

Relevant Standards: RFID, TLS, 95/46/EG, EC 45/2001

5.6.42 Navigation device for visually impaired people in Smart Cities (UC-446c)

Navigation device for Visually impaired in Smart Cities

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	Yes (Demonstrator funded by Triangulum)

Short Description
Small and inexpensive navigation device for helping visually impaired and blind people to safely reach their destination. The system helps them navigate through the crowded cities using vibrations on the device. It is a navigation device which is seen as extension on the google navigation system.

USP/Highlight
The accuracy and reliability of GPS systems is Not good enough for navigation systems for visually blinded people. The system uses UWB to ensure smoother navigation and accurate location determination indoors & outdoors

Project Scale	Neighborhood	Planning Time	<0.5 years
Development Type	Technological Development	Implementation Time	<0.5 years
Participation Model	Active participation	Co-creation with the visually impaired by understanding what they actually need.	

Stakeholder Analysis			
Owner	Cats, TU/e, StrijpS	**Implementer**	TU/e & Strijp S
Customer	Visually Impaired and blind people	**Service Provider**	TU/e & Strijp S

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	City Beacons (High accuracy location information provider - UWB)	Social	
Financial	Various Funds available for the technical solution (MIT fund/HTSM)	Partners	Royal Institute for Blind People partner in project, TU/e and StrijpS strong collaboration for demonstrating projects
Other			

Main Implementation Challenge
Lack of experienced leadership to ensure effective progress of project.

Lessons Learned
Hearing is critical for blind people and should Not be used for navigation as they need it for their own safety.
System improves hospitality of the system. The business model is more to improve quality of life for all people. A region which supports all kinds of people
Easier to understand what the actual customer need. Bottom-up approach important in design.

Financing Information

Initial Investment	< 50,000 Euros	ROI	
Scale of Investment	Implemented 500m long & 50 m wide area (5 receivers and 33 special beacons)		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Improved Safety and security, Integration

Project Details

Standard & Technical Details
Navigation device connected by Bluetooth to the smart phone. The device is also connected

Necessary Projects

Supporting Projects
Currently device vibration: can be connected to other parts of body]

Benefits

Primary Benefits	Secondary Benefits
Improving social integration	Promoting Use of active modes
Improving Life Quality	
Increasing Safety	

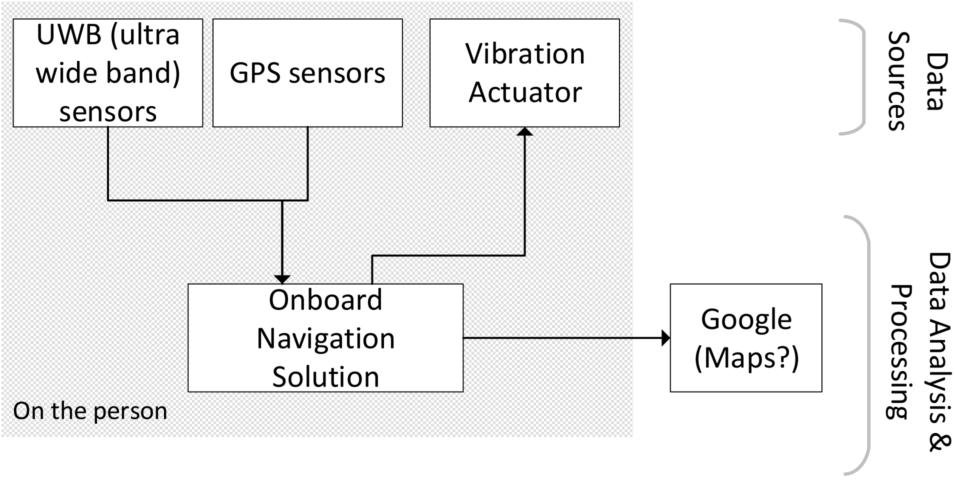
Social integration for visually impaired and blind

Wider Benefits
Blind people are more comfortable with Navigation. Also promotes region as more accessible for all sectors of society

Suggested Financing Options
Various funds available for development

Prospective Customers for future
Visually Impaired and blind people

Contact for further Details
m.g.d.m.cox@tue.nl



All the entities of UC-446c, aside of the web server that delivers the map data are found directly on the body of the visually impaired person. Different kinds of sensors (GPS and Ultra Wide Band) ascertain the position of the person in space, actuators that also lie on the data sources layer indicate the target movement direction by vibrations on different body parts/locations. These are controlled by an on-board navigation solution, which integrates positional data with map data gathered from an online server. Both of these latter items thus belong onto the data processing and analysis layer.

Relevant Standards: Zigbee, RFC 7252 (CoAP), RFC 7159 JSON

5.6.43 Preference based work space finder for Flex buildings (UC-446d)

Preference based work space finder for Flex buildings

General Information

City	Eindhoven	**Sector**	ICT
Country	Netherlands	**Triangulum**	Yes (Demonstrator funded by Triangulum)

Short Description
Web based platform that recommends suitable working space based on individual preferences in an open and flexible office concept. It smartly monitors internal and external climatic factors of a building and finds unusual patterns and informs users and building maintenance team about it. The platform has a BIM model of the office building which gives an overview of the building to the operator to ensure effective maintenance.

USP/Highlight
Individual preference based location which improves comfort level of users, enhances their productivity and reduced building energy consumption simultaneously. The system improves comfort level in buildings which are traditionally designed for fix case scenarios.

Project Scale	Individual site	**Planning Time**	<0.5 years
Development Type	Upgrading	**Implementation Time**	<0.5 years
Participation Model	Active participation	Designed with tenants in the building (Discussion, phone calls, meetings)	

Stakeholder Analysis			
Owner	Octo	**Implementer**	Octo
Customer	Building Operators, Real Estate, HR Dept., Municipality	**Service Provider**	Octo

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	Open and flexible office: where occupancy is varying, Network Connectivity (Regular internet)	Social	Mostly tenant occupied office buildings
Financial		Partners	
Other			

Main Implementation Challenge
The system only works when you have a complete flex building. So it does Not work with buildings where people have their own desks. Financial Constraints owing to small budget.

Lessons Learned
Commercial Benefit for building maintenance team

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	< 5 years
Scale of Investment	9 rooms in a building, sensors, BIM Model, Web based application		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Rent for platform and sensor, reduce electricity bill, reduces operation costs, improve real estate value, increased productivity of occupants

Project Details

Standard & Technical Details
3D Interactive BIM Model, sensors(temperature, CO2, Humidity, Light, Sound), Web Application

Necessary Projects
Network available (Optic Fibre or any other)

Supporting Projects
Additional sensors can be added to provide added services, can be used for cleaning, higher safety(fire),

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Reducing use of fossils
Improving personnel efficiency	Improving Air Quality
Decreasing energy consumption in buildings	
Improving Energy Usage Efficiency	
Reducing energy Bill	
Improving Life Quality	

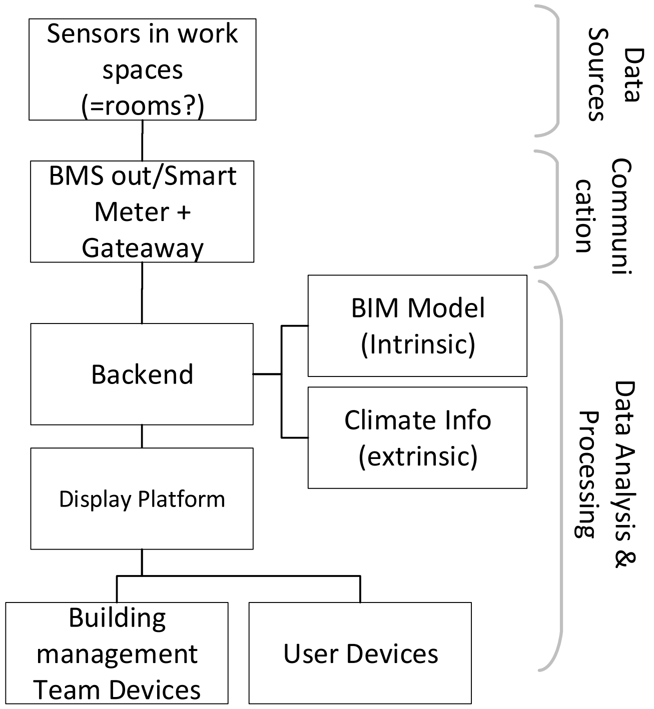
Increases comfort level and productivity of occupants. Easy to expand by adding additional sensors

Wider Benefits
Encourages Open office concept, Brings creative people together, Higher productivity in occupants

Suggested Financing Options
End user has to pay: Business model, Not very high investment

Prospective Customers for future
Building Operators, Real Estate, HR Dept., Municipality, Universities

Contact for further Details
m.g.d.m.cox@tue.nl



The backend stores certain externally provided information (i.e the BIM model and a data set on climate info) and furthermore includes a lot of processing logic, and hence was mapped onto the data processing layer. The BMS system provides the necessary communication between the sensors on the data sources layer and the aforementioned backend. Interface devices that visualize the data also belong onto the data processing and analysis layer.

Relevant Standards: -

5.6.44 Interactive neighbourhood screen for development projects (UC-446e)

Interactive neighborhood screen for development projects

General Information

City	Eindhoven	**Sector**	ICT
Country	Netherlands	**Triangulum**	Yes

Short Description

A visual representation of Strijp-S including interaction capabilities. Citizens can provide their opinion about ongoing developments through the system. It can run on a touchscreen which is located in public space.

USP/Highlight

A Non-static and direct interaction point with the local community for real estate/urban planning projects.

Project Scale	Individual site	**Planning Time**	<0.5 years
Development Type	Technological Development	**Implementation Time**	<0.5 years
Participation Model	Active participation	The system is designed to allow gathering public feedback on the screen	

Stakeholder Analysis

Owner	municipality of Eindhoven	**Implementer**	Tom Veeger Atelier
Customer	inhabitants, local companies, visitors	**Service Provider**	Tom Veeger Atelier

Implementation of UseCase

Supporting Factors

Legal		Geographical	
Infrastructural	The tender specified that the existing infrastructure in Strijp-S needed to be used	Social	The competition stated that the initiative should bring add to the quality of life
Financial	20k EUR support by the iCity tender (the initiative won a competition)	Partners	Close tie to the main developer (co-writing the tender)
Other			

Main Implementation Challenge

Avoiding damage to a large touchscreen implementation in public space. Actually triggering people to make use of the system.

Lessons Learned

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	5 - 10 years
Scale of Investment	one screen including a beta-version of the corresponding software		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
improved public support for the development project, less chances projects are delayed

Project Details

Standard & Technical Details
1 large scale touchscreen

Necessary Projects
internet connectivity, corresponding development project

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Improving social integration	
Facilitating Citizen Engagement	
Increasing transparency	

increased acceptance and support for building projects

Wider Benefits

Suggested Financing Options
marketing budget of developers, public funds

Prospective Customers for future
real estate developers, municipalities, construction companies

Contact for further Details
m.g.d.m.cox@tue.nl

5.6.45 Self-sufficient modular plant-panels (UC-446f)

Self-sufficient modular plant-panels

General Information

City	Eindhoven	Sector	Building
Country	Netherlands	Triangulum	Yes

Short Description

Modular plant panels to be installed vertically or horizontally on buildings mainly designed for the construction phase. It includes an automated watering system.

USP/Highlight

The panels collect dust of construction works, improve esthetics and bind CO2. The system also absorbs Noise. As the system also includes power supply, different sensors can be included easily.

Project Scale	Individual site	Planning Time	<0.5 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis

Owner	municipality of Eindhoven	**Implementer**	5D Solutions
Customer	building developers, construction companies, all kinds of home owners	**Service Provider**	5D Solutions

Implementation of UseCase

Supporting Factors

Legal	Dust and Noise regulations require mitigation measures during demolition and construction.	Geographical	
Infrastructural	The tender specified that the existing infrastructure in Strijp-S needed to be used	Social	The competition stated that the initiative should bring add to the quality of life
Financial	20k EUR support by the iCity tender (the initiative won a competition)	Partners	Close tie to the main developer (co-writing the tender)
Other			

Main Implementation Challenge

Installing water supply to the panels (either through continuous running water supply or a dedicated water tank). Security for the panels in public space might be an issue.

Lessons Learned
Not an infinite amount of panels can be connected to one another using the same water piping.
Plans had to be adjusted due to site-specific requirements.

Financing Information

Initial Investment	< 50,000 Euros	ROI	> 15 years
Scale of Investment	One pilot location with multiple panels which cover 40m2		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
improved real estate value

Project Details

Standard & Technical Details
panel size: 120cmx40cm (other sizes possible), water and power supply modular in ducts that can be connected to other panels

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Improving Air Quality	Reducing GHG Emissions
Improving Life Quality	
improved aesthetics of building sites	

Wider Benefits

Suggested Financing Options
marketing budget of developers, public funds, construction budget

Prospective Customers for future
real estate developers, municipalities, all kinds of real estate owners

Contact for further Details
m.g.d.m.cox@tue.nl

5.6.46 Smart City Data Platform of Platforms (UC-446g)

Smart City Data Platform of Platforms

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	

Short Description
A central data hosting and distribution platform for real time data. Private persons, businesses and municipalities can add data on the platform, use the API generation service and market their data in a platform approach.

USP/Highlight
The system automatically creates APIs for stand-alone and combines data streams to be used by the platform users. Only uses open source software and protocols.

Project Scale	Beyond City Level	Planning Time	<0.5 years
Development Type	Technological Development	Implementation Time	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	municipality of Eindhoven (architecture of the platform), data are owned by the data providing individual/institutions	**Implementer**	Omines
Customer	data owners, data users (e.g. data driven businesses)	**Service Provider**	Omines

Implementation of UseCase

Supporting Factors			
Legal	Privacy regulations of the EU	Geographical	
Infrastructural	The tender specified that the existing infrastructure in Strijp-S needed to be used (strong fibre backbone)	Social	The competition stated that the initiative should bring add to the quality of life.
Financial	20k EUR support by the iCity tender (the initiative won a competition)	Partners	
Other	Strong need for a system of systems / platform of platforms to integrate data sources.		

Main Implementation Challenge
Growing the number of data streams to create a sufficient user base. Providing the right granularity of data taking into account the limited capacity of the platform and the differing needs for (raw) data.

Lessons Learned
Strong and constant connection to the data streams (connected APIs) is required

Financing Information

Initial Investment	< 50,000 Euros		ROI	5 - 10 years
Scale of Investment	highly scalable system architecture based on open source components currently using the data from Strijp-S			

Financer (Contribution in Percentage)				
City			Private Sector	
National funds			Public Companies	
EU funds	100%		Financial institutions	
Regional funds			End User	
Others				

Revenue Streams/ Monetized Value
platform approach to receive a share of the revenue sold via the system

Project Details

Standard & Technical Details

Necessary Projects

Supporting Projects

Benefits

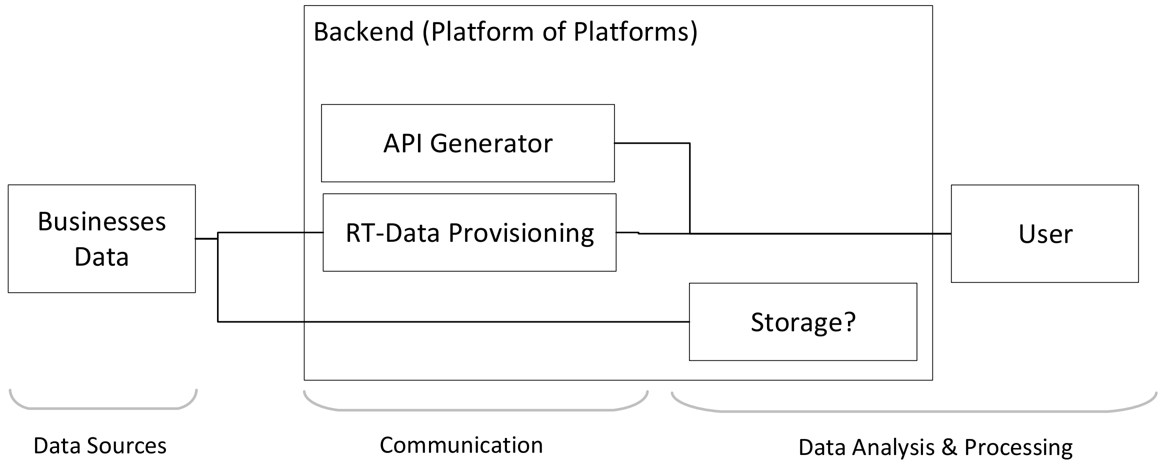
Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships	
Enabling new business opportunities	
Improving data availability	
Increasing transparency	

Wider Benefits
easier service development through combines data availability, monetizes data streams/ownership

Suggested Financing Options
EU funds, own strong business case, Venture Capitalists

Prospective Customers for future
combination of public and private entities

Contact for further Details
m.g.d.m.cox@tue.nl



The mapping of entities from UC-446g is straightforward: Business data is collected from different data sources (i.e. input forms or stream generation entities). API Generation and real-time data provisioning are required so that the data arrives at the target data storage and processing system to be used in further applications and therefore are mapped onto the communication layer. Storage systems fall onto the repositories sublayer of the data processing and analysis layer.

Relevant Standards: ISO/IEC 13249, ISO/IEC 27040, ISO/IEC 27017, ISO/IEC 27018, CWA 16871-1, ITU-T Y.3600, ISO/IEC 10746, ISO/TR 9007:1987, ITU-T X.1601, HyperCat Initiative, OKF CKAN, ISO 37120, UNE 178301:2015

5.6.47 Non-intrusive camera based vehicle recognition system (UC-446h)

Non-intrusive camera based vehicle recognition system

General Information

City	Eindhoven	**Sector**	ICT
Country	Netherlands	**Triangulum**	Yes

Short Description
A video camera system able to recognize vehicle types without scanning the license plate. The algorithm recognizes shape and color of the car and compares this with e.g. a database of stolen vehicles. The system can then be linked to an existing Automated Number Plate Recognition System (ANPR) to confirm the match.

USP/Highlight
Vehicle recognition works without scanning the license plate (Non-intrusive).

Project Scale	Individual site	**Planning Time**	2-5 years
Development Type	Technological Development	**Implementation Time**	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	municipality of Eindhoven	**Implementer**	ViNotion (algorithm), Bosch (camera)
Customer	real estate owners, municipalities	**Service Provider**	ViNotion (algorithm), Bosch (camera)

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	The tender specified that the existing infrastructure in Strijp-S needed to be used (strong fibre backbone)	Social	The competition stated that the initiative should bring add to the quality of life.
Financial	20k EUR support by the iCity tender (the initiative won a competition)	Partners	
Other	Privacy concerns with different stakeholders.		

Main Implementation Challenge
The system currently has a 90% accuracy rate - which is continuously improved. Locating the cameras is highly important.

Lessons Learned
Multi-directional traffic needs different and more sophisticated recognition algorithms.
High quality cameras (maybe including infrared vision) are needed for visual night-time recognition

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	> 15 years
Scale of Investment	one camera with corresponding algorithm and corresponding user interface		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
increased real estate value, highly scalable system with many value added services enabled through it

Project Details

Standard & Technical Details
full-HD camera, data transmission directly via fibre (5MB/s data stream)

Necessary Projects
Fibre Optic Infrastructure

Supporting Projects
parking management system, monitoring of traffic streams

Benefits

Primary Benefits	Secondary Benefits
Increasing Safety	Improving data availability

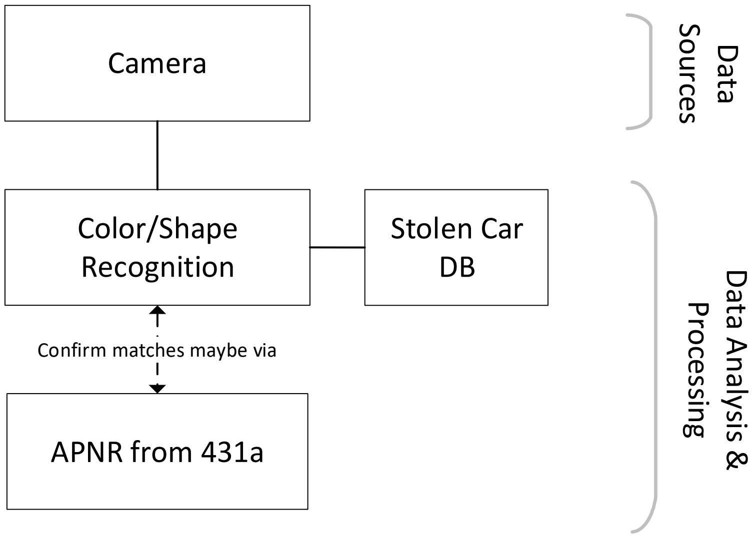
analytics results of visual data can be used for multiple purposes (e.g. detection of available parking lots, traffic counts)

Wider Benefits
enables many different additional services

Suggested Financing Options
through operation budget of entities, real estate developers

Prospective Customers for future
real estate developers, municipalities, traffic management entities, infrastructure management entities

Contact for further Details
m.g.d.m.cox@tue.nl



UC-446h resembles to a subset of UC-431a. Cameras are found on the data sources layer. Certain characteristic features (excluding number plate) of the car are extracted by machine learning and compared to a database that incorporates the same data about stolen vehicles. If a match has been found it is confirmed via the number plate recognition from UC-431a. These latter steps all belong onto the data processing and analysis layer.

Relevant Standards: H.246, RTP, SIP, TLS, 95/46/EG, EC 45/2001

5.6.48 Sound Sensor for Vehicle operation safety (UC-446i)

Sound Sensor for Vehicle operation safety

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	Yes

Short Description
Highly accurate array of sound sensors to detect problematic sounds from vehicles passing the site. The cameras recognizes problems such as brakes that need replacements or damaged wheels of trains. The system is piloted on buses and trains.

USP/Highlight
The system enables monitoring of the vehicles during operations and therefore reduces costs and maintenance time of vehicles.

Project Scale	Individual site	Planning Time	0.5 - 1 years
Development Type	Technological Development	Implementation Time	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	municipality of Eindhoven	**Implementer**	Sorama (Tech-Start-up), Volker Wessels iCity
Customer	municipality, bus companies, railway companies, vehicle fleet operators	**Service Provider**	Sorama (Tech-Start-up)

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	The tender specified that the existing infrastructure in Strijp-S needed to be used (strong fibre backbone)	Social	The competition stated that the initiative should bring add to the quality of life.
Financial	20k EUR support by the iCity tender (the initiative won a competition)	Partners	
Other			

Main Implementation Challenge
Tuning of the sensor needs to be specific to the surrounding and is therefore time-consuming.

Lessons Learned
Sounds are partly vehicle specific. Buses have different sounds depending on their engine and brake systems.
Train sounds are quite similar and do Not need specific tuning as the system focuses only on the sound of the wheels.

Financing Information

Initial Investment	< 50,000 Euros	ROI	5 - 10 years
Scale of Investment	2 sound sensors on both sides of a bus route, including a user interface		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Reduced need for personnel for the maintenance, reduced insurance fees, better data on maintenance and malfunction of vehicle components

Project Details

Standard & Technical Details
64 sound sensors per unit,

Necessary Projects
Fibre Optic Infrastructure, Strong Wi-Fi infrastructure

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Improving data availability
Improving personnel efficiency	
Increasing Safety	
Improving public transport	

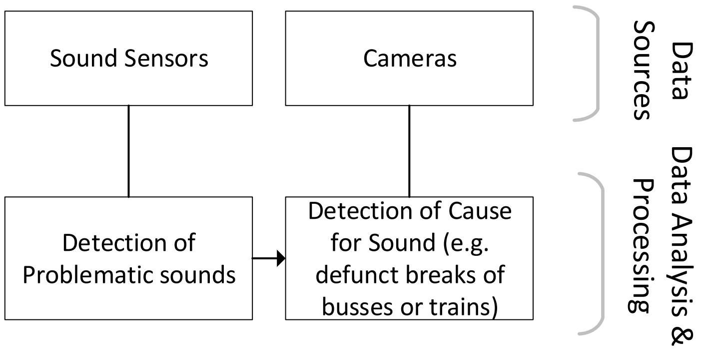
customized sound analytics enabled (e.g. detection of cries for help)

Wider Benefits
enables additional services based on sound recognition

Suggested Financing Options
operation and maintenance budget of customers

Prospective Customers for future
municipality, bus companies, railway companies, vehicle fleet operators

Contact for further Details
m.g.d.m.cox@tue.nl



Both sound sensors and cameras collect data about passing vehicles, and therefore count as entities in the data sources layer. Problematic sounds are detected by appropriate processing algorithms and the cause for it discovered by the camera on the data processing and analysis layer. This data is saved to allow for alleviation of the problem on own busses or trains.

Relevant Standards: 95/46/EG, EC 45/2001, ISO/IEC 29182

5.6.49 Smart Interactive floor light for walking and running in Eckart (UC-446j)

Smart Interactive floor light for walking and running in Eckart

General Information

City	Eindhoven	Sector	ICT
Country	Netherlands	Triangulum	Yes

Short Description
To encourage walkers, joggers and runners lights are embedded in a foot walk around two ponds in Eckart. People can trigger the system via panels at several different locations around the ponds and choose a walking/running speed. The floor embedded 4-coloured lights follow users in the speed they have decided on. The solar powered tiles are embedded every 20m. The lights stimulate social interactions and enhance usability of the public space.

USP/Highlight
First system of its kind making the environment interact and coach the people. The system was designed jointly with the inhabitants. New services can be added in an open living lab approach.

Project Scale	District level	Planning Time	< 2 years
Development Type	Brownfield Development	Implementation Time	<0.5 years
Participation Model	Active participation	Co-creation/design thinking process with the local community. 25 sessions (incl. 5 interviews, 10 observation session)with the local community over 4 month.	

Stakeholder Analysis			
Owner	Municipality of Eindhoven	**Implementer**	Led Mark ITS (solar powered tiles), University (app and Bluetooth sensors), Energiebureau (design)
Customer	local citizens, Technical University (for scientific purposes)	**Service Provider**	Municipality of Eindhoven

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	walking path was partly already existing however underutilized	Social	Local responsible municipal employee with close ties to the local community.
Financial		Partners	The social housing cooperation mainly responsible for the area and the municipality have close ties
Other	municipal intention to improve the area and make it more livable		

Main Implementation Challenge
The walking path needed to be completed to form a full round around the pond. The piles in the floor have Not been tested over long periods before (storage and energy provision might be problematic).

Lessons Learned
A close tie to the local community and a joint design process building on it is highly recommended. However do Not expect everyone to show up (an outcome of 4% from invitations is Normal)
Use an area with high and constant solar power provision (less shadow) to make sure enough energy for the light is produced.
Not all citizen groups are joining the design sessions, there will most likely be "usual suspects" joining. For involving specific groups (like students) additional efforts are needed. Bring different kinds of project related personnel to get in touch with the citizens in the sessions.

Financing Information

Initial Investment	50,000 -250,000	ROI	
Scale of Investment	2.5 km with tiles every 20m around two ponds. 3 gateways for connecting the components also providing public Wi-Fi. The backend system. Additional solar panels for energy provision. Two upgraded pedestrian crossing (with lights) for safe runner crossing.		

Financer (Contribution in Percentage)			
City	5%	Private Sector	
National funds		Public Companies	
EU funds	95%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
new valuable insights through University research

Project Details

Standard & Technical Details

Necessary Projects

Supporting Projects
unidirectional lighting, CO2 sensors, pollution sensors, Running Smartphone Apps

Benefits

Primary Benefits	Secondary Benefits
Improving social integration	Encouraging digital entrepreneurships
Improving Life Quality	Enabling new business opportunities
Increasing Safety	Supporting environmental efficient transport
Promoting Use of active modes	Promoting sustainable behavior
	Facilitating Citizen Engagement
	Improving data availability

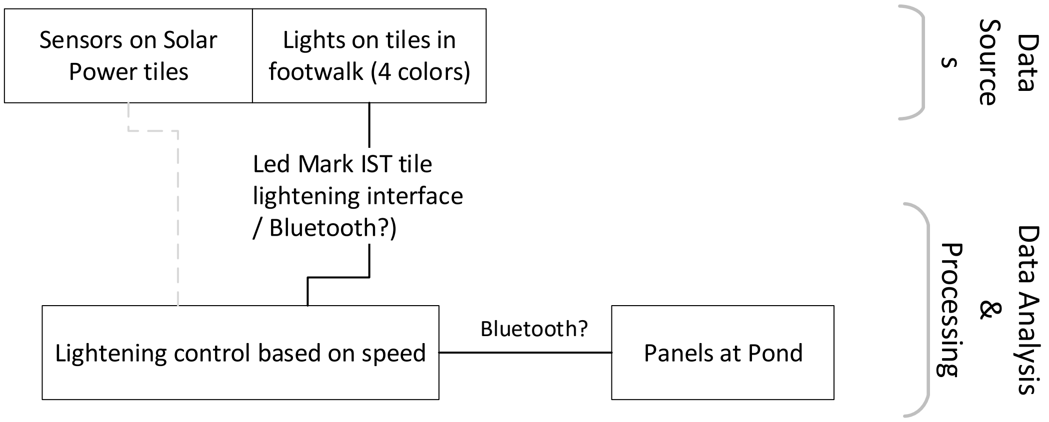
increased district pride

Wider Benefits
sense of pride for the area,

Suggested Financing Options
municipal budget, different public funding programs due to the wide range of benefits

Prospective Customers for future
sports associations, health centers, schools,

Contact for further Details
d.mitcan@eindhoven.nl



Sensors in the ground act as data sources and sense both the generated energy by the solar panels as well as movements on the walkway. According to this different control systems can regulate the lightening of the tiles, which happens on the data processing and analysis layer.

Relevant Standards: Zigbee, RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.50 Unidirectional functional lighting in Eckart (UC-446k)

Unidirectional functional lighting in Eckart

General Information

City	Eindhoven	Sector	Energy
Country	Netherlands	Triangulum	Yes

Short Description
Unidirectional functional lighting on a walking path at a pond in Eckart. The special types of lights only shine towards the path and Not on the pond to Not disturb the local fauna. 10 of the 30 poles are equipped with sensors that dim the light according to the usage of the path.

USP/Highlight
The special kind of lighting only points into one direction. Great futuristic design and highly energy efficient. Lighting is adopted to allow for a natural moon-light effect. Citizens have been involved in the design of the system.

Project Scale	Neighborhood	Planning Time	< 2 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Active participation	Co-creation/design thinking process with the local community. 25 sessions (incl. 5 interviews, 10 observation session)with the local community over 4 month.	

Stakeholder Analysis			
Owner	Municipality of Eindhoven	**Implementer**	Philips (light pole), Heijmans (installation), Energiebureau (design)
Customer	local citizens	**Service Provider**	Municipality of Eindhoven

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural	Wide Wi-Fi network as a communication backbone for the sensors.	Social	safety concerns in the area - very good innovation ecosystem that support efficient implementation
Financial		Partners	Strong tie to relevant partners (municipality, lighting companies) Strong political support in the city council (elderman) to support against opponents of the implementation
Other	the local fauna was Not allowed to be affected by the lighting - therefore the lights cannot point towards the pond.		

Main Implementation Challenge
Positioning the motion sensor out of the reach of pedestrians. Activating the light in a meaningful intensity without flashing the pedestrian. Lighting is Normally Not installed in parks to Not create the perception of safety if Now safety measures are being done at the same time.

Lessons Learned
Invite a wide variety of creative institutions and people to get a good product.
There are always people against this kind of projects / the project will Not be able to please all agendas / try your best but learn to go on
Additional services such as open Wi-Fi are sometimes seen critical. Link the implementation of new poles with the end of lifetime of old poles.

Financing Information

Initial Investment	< 50,000 Euros	ROI	< 5 years
Scale of Investment	30 light poles of which 10 are equipped with sensors and dimmable around one pond in Eckart, 3 gateways with Wi-Fi for connecting the components and offering public Wi-Fi		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
reduced energy consumption by light poles, increased safety in the area, marketing value for the city

Project Details

Standard & Technical Details

Necessary Projects

Supporting Projects
Smart Interactive floor light for walking and running in Eckart

Benefits

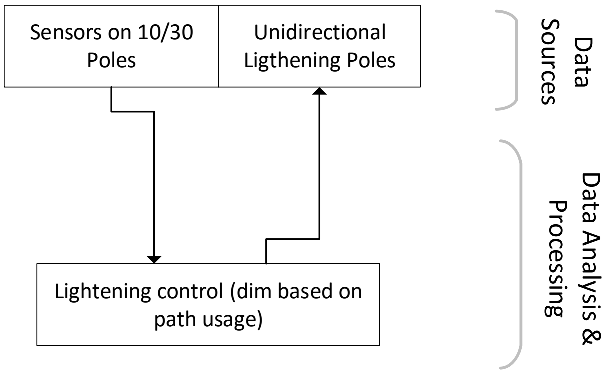
Primary Benefits	Secondary Benefits
Improving Life Quality	Reducing Operation Costs
Increasing Safety	Improving Component Efficiency
Promoting Use of active modes	Improving Energy Usage Efficiency
	Reducing energy Bill
	Promoting sustainable behavior
	Improving data availability

Wider Benefits
better community building and feeling, part of the roadmap Smart Lighting and being the first use case to be shown to the inhabitants of the city

Suggested Financing Options
municipal budget, different public funding programs due to the wide range of benefits

Prospective Customers for future
municipalities, real estate developers

Contact for further Details
d.mitcan@eindhoven.nl



Sensors and actuators can again be found on the data sources layer. The control logic is located on the data processing and analysis layer.

Relevant Standards: Zigbee, RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.51 Smart Gateway for homes (UC-521a)

Smart Gateway for homes

General Information

City	Stavanger	Sector	Energy
Country	Norway	Triangulum	Yes

Short Description
It enables supplier and user of energy to control and reduce consumption effectively. It is connected to a Smart Meter. It can provide added automation services like controlling heating/cooling and light control through the application. The implementation is for 100 homes as part of Triangulum and 60,000 homes in total

USP/Highlight
The gateway functions as a central brain and enabler of the smart home

Project Scale	Neighborhood	Planning Time	<0.5 years
Development Type	Retrofitting	Implementation Time	<0.5 years
Participation Model	Passive Participation	Feedback obtained from users through initial testing is being used to improve the system	

Stakeholder Analysis			
Owner	Lyse	**Implementer**	Lyse
Customer	Family (specially with school children and high energy demand), preferable for home owners	**Service Provider**	Sensio

Implementation of UseCase

Supporting Factors			
Legal	Government mandate to have a Smart Meter by end of 2018	Geographical	
Infrastructural	Good Fibre Infrastructure available in the city. Electricity used for most services at home including heating	Social	Lyse is trust worthy brand in region. Most people own their homes
Financial	Effect based Tariffs foreseen (will be introduced shortly)	Partners	Strong co-operation with Municipality and Lyse exists
Other	Implementation of smart meters and gateways simultaneously reduced labor costs.		

Main Implementation Challenge
Recruiting the demo-homes and retaining them through the pilot stage.

Lessons Learned
To make it beneficial for the users and communicating its benefits to them effectively
As the customer base is wide, they have different expectations. Difficult to retain them over long periods. Important to show the direct benefits clearly.(educate)
Ensure the effective functioning of the technology before scaled roll-outs

Financing Information

Initial Investment	50,000 -250,000	ROI	< 5 years
Scale of Investment	100 homes		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	30%
EU funds	70%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Grid Operator: Postpone additional investments in grid, reduced peak demands and possibly reduced man power leading to cost savings Home Owner: Reduce Energy Bill (Information service is free but automation service charged)

Project Details

Standard & Technical Details
Smart Gateway & AMS(Smart Meter) Optional Home Automation Systems

Necessary Projects

Supporting Projects
Home Automation System, Security(Alarm Systems), Air Quality Control, EV Charging, Decision Support Service

Benefits

Primary Benefits	Secondary Benefits
Decreasing energy consumption in buildings	Reducing Operation Costs
Improving Energy Usage Efficiency	Improving personnel efficiency
Shaving peak Energy Demand	Encouraging digital entrepreneurships
Reducing energy Bill	Enabling new business opportunities
Improving Life Quality	Enhances Grid Stability
Increasing Safety	Promoting sustainable behavior
	Improving data availability
	Increasing transparency

For Grid Operator: reduced peak loads

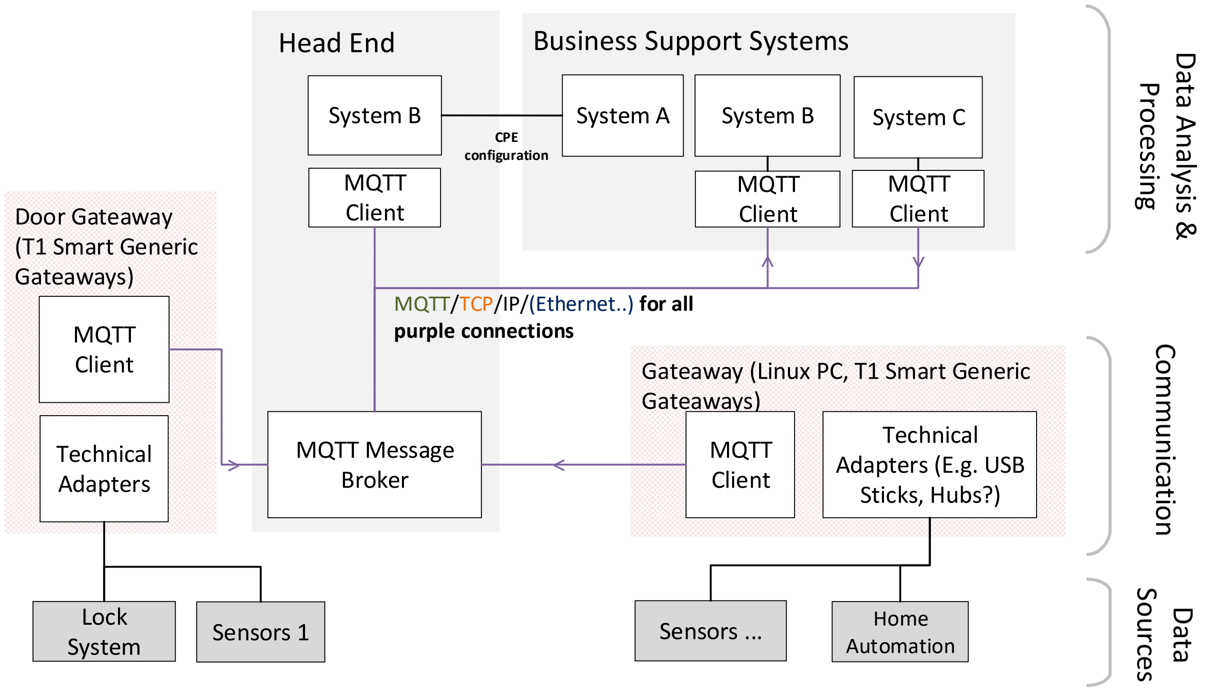
Wider Benefits
Other Triangulum partners have shown interest. Expanded to 60000 homes beyond the Triangulum 100 homes. Home Automation Services like security, fire alarm etc. can be built on it. Lyse adjusted the business model for smart home automation based on learning from the experience. Smart Gateways for schools was identified as an additional application

Suggested Financing Options
Monthly home automation service subscription by homes. Opportunity to build financial model with electricity providers. Energy Efficiency Improvement funds

Prospective Customers for future
Family (specially with school children and high energy demand), preferable for home owners

Contact for further Details
PerErling.Fjeld@lyse.no

WP 5.2.1 Smart gateway introduction and energy management (interface details excluded)



Smart Gateways usually connect technical systems including sensors and actuators of various kinds (i.e. home automation or door lock systems) with higher order processing systems such as business support systems. They usually enable this by acting as message broker clients providing the data read by the sensors as message streams and consuming a stream of commands from the higher order processing and control systems. This activity may involve a degree of pre-processing but as the major focus of the gateways lies on establishing a connection between technical systems on the data sources layer and higher order processing systems from the data analytics and processing layer, it can be regarded as a crucial part of the communication layer.

Relevant Standards: RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182, 95/46/EG, EC 45/2001

5.6.52 Smart Gateway for nursing homes (UC-521b)

Smart Gateway for nursing homes

General Information

City	Stavanger	Sector	Energy
Country	Norway	Triangulum	Yes

Short Description
The smart Gateway enables independent control of lighting and heating systems in each room by the patients and the nurses. As part of Triangulum it is done in 8 rooms in the nursing home Bergåstjernet. It reduces the time spent by nurses in doing mundane tasks enabling them to provide better care for patients.

USP/Highlight
Lighting & Heating control can be tailored for each room in building. It improves the quality of the health-care service

Project Scale	Individual site	Planning Time	<0.5 years
Development Type	Retrofitting	Implementation Time	<0.5 years
Participation Model	Passive Participation	Feedback obtained from users through initial testing is being used to improve the system	

Stakeholder Analysis			
Owner	Lyse	**Implementer**	Lyse
Customer	Health Care Providers, Private Homes with Special care needs	**Service Provider**	Sensio

Implementation of UseCase

Supporting Factors			
Legal	Government mandate to have a Smart Meter by end of 2018	Geographical	
Infrastructural	Good Fibre Infrastructure. Electricity used for most services including heating	Social	
Financial	Effect based Tariffs foreseen (introduced shortly)	Partners	Municipality has co-ownership of the company. Lyse is part of the Norwegian Smart Care Cluster
Other			

Main Implementation Challenge
Communication of benefits with owners, working personnel and the patients. (Human Factor key)

Lessons Learned
The communication of benefits to the end users and health care personnel needs to be given primary importance
With home care features added, home based care technology part has good potential

Financing Information

Initial Investment	< 50,000 Euros	ROI	< 5 years
Scale of Investment	8 rooms		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	30%
EU funds	70%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Incomes via peak shaving and reduced energy bill Nursing Home: Improved Service Quality and potentially reduced labor costs

Project Details

Standard & Technical Details
Smart Gateway & AMS(Smart Meter)

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
1	Encouraging digital entrepreneurships
Reducing Operation Costs	Enabling new business opportunities
Improving personnel efficiency	Decreasing energy consumption in buildings
Improving Life Quality	Improving Energy Usage Efficiency
Increasing Safety	Shaving peak Energy Demand
	Reducing energy Bill
	Enhances Grid Stability
	Promoting sustainable behavior
	Improving data availability
	Increasing transparency

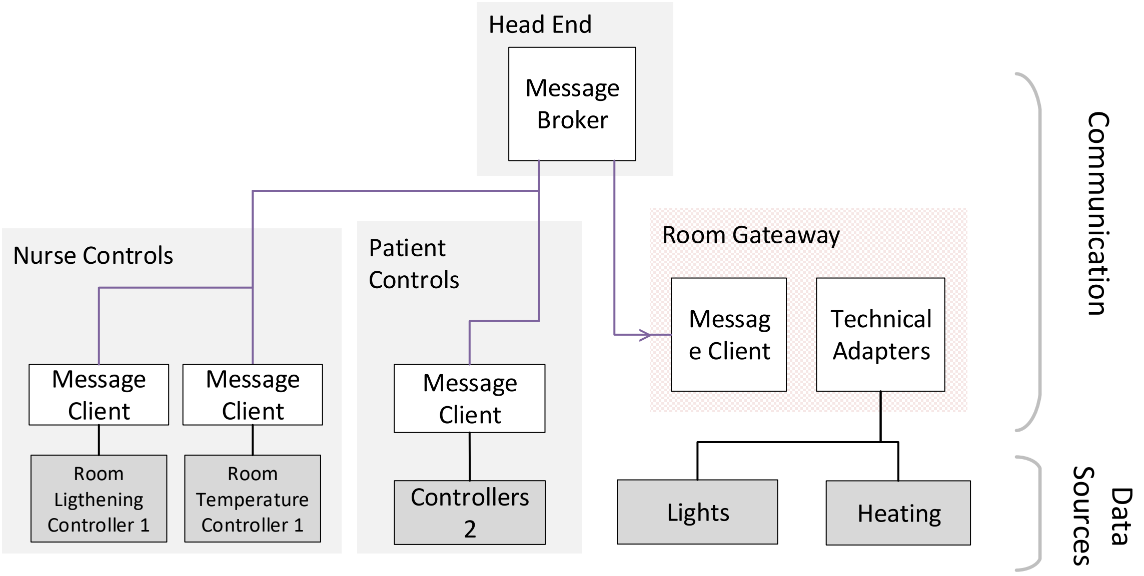
More efficient care (less routine work for the personnel)

Wider Benefits
Norwegian Smart Care Cluster interested in project. Prague highly interested in the project.

Suggested Financing Options
Health care provider and the earnings from the man power efficiency gain. Public funds available for improved health care

Prospective Customers for future
Health Care Providers, Private Homes with Special care needs

Contact for further Details
PerErling.Fjeld@lyse.no



As the information/data of UC-521b is merely relayed and its processing (choice of lightening status and heating level according to personal needs) is done by human beings (either a nurse, a doctor or the patient himself), no single technical entity is assigned to the data processing and analysis layer. The rest of the component assignment mirrors closely that of UC-521a: Controllers and sensors lie on the data sources layer, message broker clients and server lie on the communication layer. To become a really smart solution, certain processing systems may be incorporated as messaging system clients to bestow especially automated functionalities.

Relevant Standards: RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.53 Smart Gateway for Schools (UC-521c)

Smart Gateway for schools

General Information

City	Stavanger	Sector	Energy
Country	Norway	Triangulum	No

Short Description
The smart gateway enables Air Quality Control in the school gyms and thus enhancing the health of the students.

USP/Highlight

Project Scale	Individual site	Planning Time	<0.5 years
Development Type	Retrofitting	Implementation Time	<0.5 years
Participation Model	Passive Participation	Feedback obtained from users through initial testing is being used to improve the system	

Stakeholder Analysis			
Owner	Lyse	**Implementer**	Lyse
Customer	School Management	**Service Provider**	Sensio

Implementation of UseCase

Supporting Factors			
Legal	Government mandate to have a Smart Meter by end of 2018	Geographical	
Infrastructural	Good Fibre Infrastructure	Social	
Financial	Effect based Tariffs foreseen (introduced shortly)	Partners	Municipality co-ownership of the company
Other			

Main Implementation Challenge

Lessons Learned
Communicating benefits to the users is key

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	< 5 years
Scale of Investment	1 school		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	30%
EU funds	70%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Incomes via peak shaving and reduced energy bill
Better school brand as pupil health is given primary importance

Project Details

Standard & Technical Details
Smart Gateway & AMS(Smart Meter)

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Improving Life Quality	Improving personnel efficiency
Increasing Safety	Encouraging digital entrepreneurships
Income/Revenue Stream	Enabling new business opportunities
	Promoting sustainable behavior
	Improving data availability
	Increasing transparency

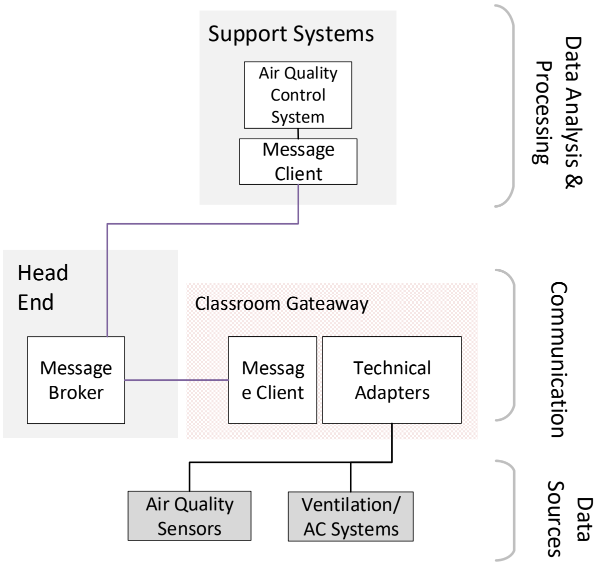
Better health for pupils

Wider Benefits
Project was a Spin-off from the home gateway system from Triangulum. Experience could be used for implementation in different kinds of public buildings to improve indoor air quality

Suggested Financing Options
Owners of public buildings (different financing models possible). National/Regional funds available for improving public buildings

Prospective Customers for future
Owners of public buildings

Contact for further Details
PerErling.Fjeld@lyse.no



Similarly to UC-521a and UC-521b, the system around the Smart Gateway for school possesses both messaging technologies as well as sensors and actuators (here for air quality and ventilation/air condition systems). In addition, an automated air quality control system is connected to the message broker consumes sensed data about air quality and calculates the appropriate parameter for ventilation and air condition regulation in order to improve the air quality situation accordingly. Therefore it falls onto the data analysis and processing layer.

Relevant Standards: RFC 7252 (CoAP), RFC 4944-6Lowpan, RFC 7159 JSON, MQTT, IEEE 802.15.4, ISO/IEC 29182

5.6.54 Sewage heat pump system (UC-522a)

Sewage heat pump system

General Information

City	Stavanger	Sector	Energy
Country	Norway	Triangulum	Yes

Short Description
A thermal energy plant which supplies the base load by utilizing the waste heat from sewage systems using heat pumps.

USP/Highlight
System can be used for both heating and cooling

Project Scale	Neighborhood	Planning Time	0.5 - 1 years
Development Type	Retrofitting	Implementation Time	0.5 - 1 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	Stavanger Municipality	**Implementer**	Stavanger Municipality
Customer	Municipality	**Service Provider**	Stavanger Municipality

Implementation of UseCase

Supporting Factors			
Legal	-	Geographical	High Rainfall in the region ensures that high amount of water is present in the tunnel
Infrastructural	Existence of a big Sewage and Waste Water Tunnel (3.3m) near the building	Social	
Financial		Partners	Municipality owns the sewage tunnel so it avoided ownership problems
Other			

Main Implementation Challenge
There was monopoly in market by the Drilling and Heat Exchanger suppliers. Piping connection(access to installation point) from Sewage plant to building through rocky terrain was a challenge. Cleaning the tunnel before installing the Heat Exchanger was also a challenge. Safety challenges for servicing personnel working inside the tunnel.

Lessons Learned
Start earlier with suppliers to get better deals. Dedicated team from the starting who stay with the project. Good planning and Risk management for each of the steps
Ownership Model of Sewage system can be concern. Business model needs to be developed to facilitate when private parties involved
Limited potential of sewage can be used due to cooling of the sewage. (bacteria present creates a challenge)

Financing Information

Initial Investment	1,000,000 - 5,000,000	**ROI**	10-15 years
Scale of Investment	Cleaning the tunnel, Piping connections, ground work, heat exchangers		

Financer (Contribution in Percentage)			
City	60%	Private Sector	
National funds		Public Companies	
EU funds	40%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Energy Bill savings

Project Details

Standard & Technical Details
Industrial Heat pumps(usually used for offshore systems) improve effectiveness. (Not done for buildings)

Necessary Projects

Supporting Projects
Biogas Peak Load System, Solar Heating System(Planned), Grey Water Recovery(Planned)

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Reducing energy Bill
Improving Air Quality	Enhances Grid Stability
Reducing GHG Emissions	
Increasing share of renewables	
Increasing (primary)resource efficiency	

Wider Benefits
Replaced an existing cooling system which was not foreseen.

Suggested Financing Options
Special Norwegian Grant for energy savings (CEP) (ENOVA funding)
Self financed by Implementer
City Municipality
City gives concessions to private owners switching to greener systems
Implementer/User pays at least 50%

Prospective Customers for future
Municipalities (who own sewage system, want to reduce GHG Emissions)
Big buildings or group of buildings (critical consumption mass/agglomeration of users)
Public Private Partnerships
Buildings close to sewage plant

Contact for further Details
ernst.olsen@stavanger.kommune.no

5.6.55 Public Transport with battery electric busses (UC-531a)

Public Transport with battery electric busses

General Information

City	Stavanger	**Sector**	Mobility & Transport
Country	Norway	**Triangulum**	Yes

Short Description
Introduction of Battery buses into public transport as first step towards an emission free bus network. Project Included buying the bus through public tendering, operation and maintenance, charging infrastructure installations and training personnel. Of the 5 buses, 3 buses, each 12m long were bought through Triangulum. On line monitoring system for analyzing the Electric bus performance was provided by Ebusco

USP/Highlight
Electric buses introduced in existing diesel bus routes. Design competition organized in the Municipality schools to create awareness about the E-bus.

Project Scale	City Level	**Planning Time**	0.5 - 1 years
Development Type	Upgrading	**Implementation Time**	< 2 years
Participation Model	Active participation	The bus design was finalized through an open design competition where students from county council run schools participated. The bus with this design was inaugurated in public.	

Stakeholder Analysis

Owner	Kolumbus (owned by Rogaland)	**Implementer**	Kolumbus (owned by Rogaland)
Customer	Citizens	**Service Provider**	Norgesbuss

Implementation of UseCase

Supporting Factors

Legal	Norwegian National Transportation Plan states all City buses have to be emission free by 2025; Decision from Stavanger County council that the buses on BRTS operating from 2021-22 will be battery electric.	Geographical	
Infrastructural	Uses existing inner-city roads dedicated to public transport (and electric vehicles)	Social	
Financial	Existing agreement between local, regional and state authorities on how to finance transportation infrastructure; VAT waiver on battery electric buses (VAT : 25%); Electricity in Norway comparatively cheap.	Partners	
Other			

Main Implementation Challenge
Public tendering process in combination with the unexperienced provider of the busses lead to major delay in delivery.

Lessons Learned
Customer focuses on comfort and services(punctuality) and not on technology (EV or not doesn't matter)
Mixed fleets are more complicated to operate (e.g. different ranges and maintenance patterns): continuous learning processes needed
Bus drivers are positive (more comfortable with driving EV buses);No range-problems detected yet (planning is different but possible if done proactively) Limited amount of experts for maintenance and repairing of electric buses.

Financing Information

Initial Investment	1,000,000 - 5,000,000	ROI	5 - 10 years
Scale of Investment	3 buses		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	60%	Financial institutions	
Regional funds	40%	End User	
Others			

Revenue Streams/ Monetized Value
Piloting of E-bus to scale up to more than 60 buses in the region. Return on investment through decreased operating costs and reduced pollution.

Project Details

Standard & Technical Details
300kWh electrical storage, 5 hour charging time from 0-100%

Necessary Projects

Supporting Projects
E-BRTS: Learnings from project used while planning the new project

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Enhances Grid Stability
Improving Air Quality	Limiting Urban Sprawl
Reducing GHG Emissions	
Supporting environmental efficient transport	
Promoting Electric Vehicles	
Improving public transport	

Wider Benefits
Bus producer is a company in the Eindhoven Brainport Region, used for scaling up to 60 buses in the region

Suggested Financing Options
At least partly national funds need to be available.

Prospective Customers for future
Public transport providers, tour bus operators, private and public bus operators

Contact for further Details
Joachim.Weisser@rogfk.no

5.6.56 Electric vehicle private home charging infrastructure (UC-532b)

Electric vehicle private home charging infrastructure

General Information

City	Stavanger	Sector	Mobility & Transport
Country	Norway	Triangulum	Yes

Short Description
The infrastructure enables EV users to charge their cars at home at their own convenience with high safety features. It is a charging box with Type 2 socket. As against regular charging of 3.7kW it provides it at 7-11 kW (AC Charging) (22 homes are equipped out of which 10 are in Triangulum)

USP/Highlight
Safe way for charging vehicles and can enable faster charging

Project Scale	Individual site	Planning Time	<0.5 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	Household	**Implementer**	Lyse
Customer	EV Owners with homes	**Service Provider**	Local Electricians

Implementation of UseCase

Supporting Factors			
Legal	Huge Tax benefits for EV owners in Norway. Priority road ways and privileges for use also exist	Geographical	
Infrastructural	Most Norwegians own Parking Spots which enables installation of dedicated electric circuit for the charging station. There is usually enough capacity of the home electric circuit and the Electric Grid also has sufficient capacity in most areas.	Social	
Financial	Relatively low electricity costs, Effect based tariffs(Peak Tariffs)	Partners	
Other	Updated smart home charging increase value of property		

Main Implementation Challenge
To showcase benefits of individual charging infrastructure at homes.

Lessons Learned
50% want to pay one time installation and others wanted EMIs(Monthly payments over period of time) Financing scheme should be planned taking this into account
Placing of the charging station at home (how they park the vehicles while charging -front or rear)
Instead of attached cable, use Sockets (flexible)

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	
Scale of Investment	10 homes		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	30%
EU funds	70%	Financial institutions	
Regional funds		End User	0%
Others			

Revenue Streams/ Monetized Value

Project Details

Standard & Technical Details
Type 2 Plugs, 3 Phase Electric supply, Type B RCCD ensures AC(power) not back to grid from car

Necessary Projects

Supporting Projects
Solar Panels, Batteries and DC Charging from Home Batteries

Benefits

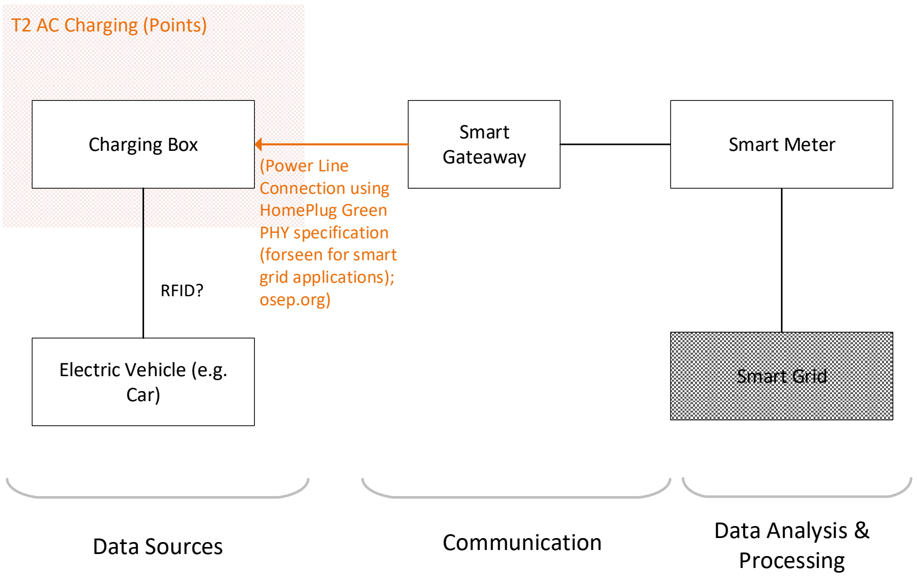
Primary Benefits	Secondary Benefits
Reducing use of fossils	Create new jobs
Supporting environmental efficient transport	Shaving peak Energy Demand
Improving Energy Usage Efficiency	Enhances Grid Stability
Promoting sustainable behavior	Increasing Safety
Promoting Electric Vehicles	

Wider Benefits
12 additional home chargers installed in another project. Expected additional charging installations in other projects (INVADE)

Suggested Financing Options
End-Users and home owners pay. National funds promoting EVs. Sharing costs with other EV users

Prospective Customers for future
EV Users in private homes with garage/parking spot.

Contact for further Details
PerErling.Fjeld@lyse.no



There are two major differences between the implementation of UC-532a and UC-532b. Instead of multiple industry grade charging points, a home charging infrastructure usually only encompasses a single somewhat less powerful charging box. The communication part is taken over by a Smart Gateway that makes the charging data (usually only how much energy is consumed but not the cars identity) available to the smart meter that integrated this with data coming from the smart grid and thus can be seen as responsible for data processing.

Relevant Standards: Powerline, HomePlug Green specification, Open Smart Charging Protocol 1.0

5.6.57 Electric vehicle apartment building charging infrastructure (UC-532c)

Electric vehicle apartment building charging infrastructure

General Information

City	Stavanger	Sector	Mobility & Transport
Country	Norway	Triangulum	Yes

Short Description
Enabling owners of EVs to charge vehicles at apartment buildings at their convenience. A continuous cable infrastructure installed in the parking making it easier for new users to join into the system with individual meters. As against regular charging of 3.7kW it enables at 7-11 kW (AC Charging) (No Triangulum, 1 system installed with 5 chargers). RFID can be used to access the charging stations for security.

USP/Highlight
Continuous cabling around the parking garage enabling additional users to join at any point

Project Scale	Individual site	Planning Time	<0.5 years
Development Type	Upgrading	Implementation Time	<0.5 years
Participation Model	Passive Participation	Feedback from the Housing Association was taken into account during design stage	

Stakeholder Analysis			
Owner	Housing Association (basic infrastructure) Apartment Owner (Charging station)	Implementer	Lyse
Customer	Housing Association	Service Provider	Local Electricians

Implementation of UseCase

Supporting Factors			
Legal	Huge Tax benefits for EV owners. Priority road ways and privileges for use also exist	Geographical	
Infrastructural	Most Norwegians own Parking Spots which enables installation of dedicated electric circuit for the charging station. There is usually enough capacity of the home electric circuit and the Electric Grid also has sufficient capacity in most areas.	Social	Early adapters exist
Financial	Adds value to the property as most people potentially will need an EV charging station	Partners	Collaboration with Housing Association Board
Other			

Main Implementation Challenge
Communication with board of apartment building. More complex systems

Lessons Learned
People prefer having own charging stations
People charge vehicles from afternoon. So there is potential for moving hours to shave peak loads
Make it easy to add charging stations

Financing Information

Initial Investment	< 50,000 Euros	ROI	
Scale of Investment	1 system with 5 chargers		

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	10%
EU funds		Financial institutions	
Regional funds		End User	90%
Others			

Revenue Streams/ Monetized Value
Housing Association could charge for the infrastructure or provide it as an additional facility

Project Details

Standard & Technical Details
Additional Basic Infrastructure, RFID system, electric system phase balancing, Management System (Zaptec System)

Necessary Projects

Supporting Projects
Solar Panels, Batteries and DC Charging from Home Batteries

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Create new jobs
Supporting environmental efficient transport	Improving Parking
Promoting sustainable behavior	
Promoting Electric Vehicles	

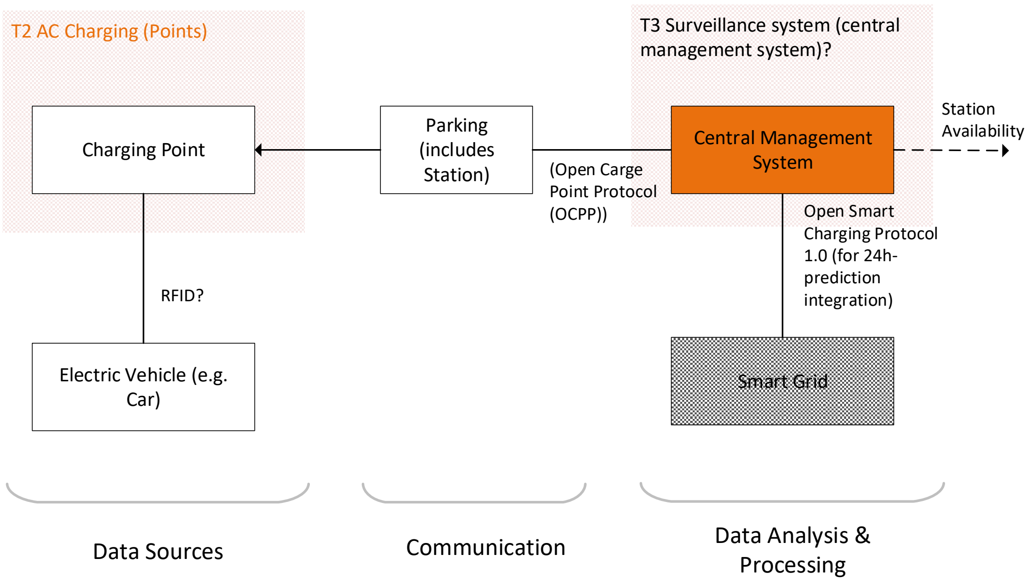
Increased value of the Apartment Buildings

Wider Benefits
BATE home association is interested in expanding it for all the housing associations.

Suggested Financing Options
Building Owner (Basic Infrastructure) along with tenants (Individual charging stations) or Building Owners changes it over monthly maintenance amount

Prospective Customers for future
Housing Associations in collaboration with tenants, business parks, office buildings

Contact for further Details
PerErling.Fjeld@lyse.no



The organization of the technical system behind UC-532c closely follows that of UC-532b. Instead of having a designated charging station, the chargers and the corresponding gateway entity (labeled ‘station’ in the figure) are integrated into the parking lot, which allows for convenient and automated overnight charging. The gateway lies again on the communication layer. Data processing is taken over by any kind of management system, akin to that one of UC-532b.

Relevant Standards: OCCP, Open Smart Charging Protocol 1.0, IEC 61851-24 (DC Charger), RFID

5.6.58 Blink: Innovative video for distance health care (UC-541a)

Blink: Innovative video for distance health care

General Information

City	Stavanger	Sector	ICT
Country	Norway	Triangulum	Yes

Short Description

It comprises of a video installation linked to the TV screen that enables two way communication between healthcare facilities and private homes to allow for efficient and personal home care.
Health relevant sensors and appliances (oxymeter), night (infrared) cameras and a bed sensor can be linked. It reduces the need for personnel to travel to the site and at the same time keeping direct interactions.

USP/Highlight

Full HD facilities are available. It is flexible and expandable. It has an easy User Interface.
(Different sensors and appliances can be added in accordance to the needs of the person. It has been tested for some appliances - new ones can be implemented with some efforts)

Project Scale	Individual site	Planning Time	2-5 years
Development Type	Technological Development	Implementation Time	< 2 years
Participation Model	Active participation	Active design workshops with the healthcare provider. Lyse designs the system and test with users and municipalities	

Stakeholder Analysis

Owner	several service providers	**Implementer**	several service providers/ technical management: one specialized company
Customer	Health Care service provider	**Service Provider**	t.b.d. (to be defined)

Implementation of UseCase

Supporting Factors

Legal		Geographical	
Infrastructural	Strong broadband connection available (symmetrical bandwidth on both user ends)	Social	Elderly people prefer to stay home as long as possible. Studies have proven that several illnesses speed up when people are moved away from their home. There has been a demographic change with local/regional hot-spots in more remote areas. (more elderly in remote areas)
Financial	High costs for personnel in the health care service sector makes the system financially viable	Partners	Partners with earlier experience in health care service provision helped in identifying needs(Norsk Telemedisin, Westcontrol)
Other			

Main Implementation Challenge

Refund system for the doctors only pays 25% compared to what he/she receives when a patient comes in. Hence, not enough financial incentive for doctors to use the distance video.(new law for e-health currently in development). Technology in testing phase and under development.

Lessons Learned
Technology development on hardware and software side is necessitated. Outsourcing hardware to specialized companies is much cheaper and reduces the time and efforts required.
Customer survey showed that elderly people were highly positive towards usage of the system. On the other hand the medical personnel underestimated the likeliness of the elderly to use the system.
Cost reduction for the healthcare sector (*in Norway: municipality) (i.e. user) is the main selling point of the solution; Ease of use is the most important factor for the patient

Financing Information

Initial Investment	< 50,000 Euros	ROI	< 5 years
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	
Others	100%	Health Care service provider	

Revenue Streams/ Monetized Value
Could be sold to end users, health care service providers or rented out in a service contract (to be decided)

Project Details

Standard & Technical Details
Open standards are being used to integrate island systems; Collaboration with Pexip to connect to other proprietary systems, different open standards still available

Necessary Projects

Supporting Projects
Different appliances for health monitoring can be built on this system.

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Encouraging digital entrepreneurships
Improving personnel efficiency	Enabling new business opportunities
Improving Life Quality	Reducing traffic congestion
Improving Health Care	Improving social integration
Improving Elderly Care	Increasing Safety
	Improving data availability

Easing the work for personnel with reduced travel time

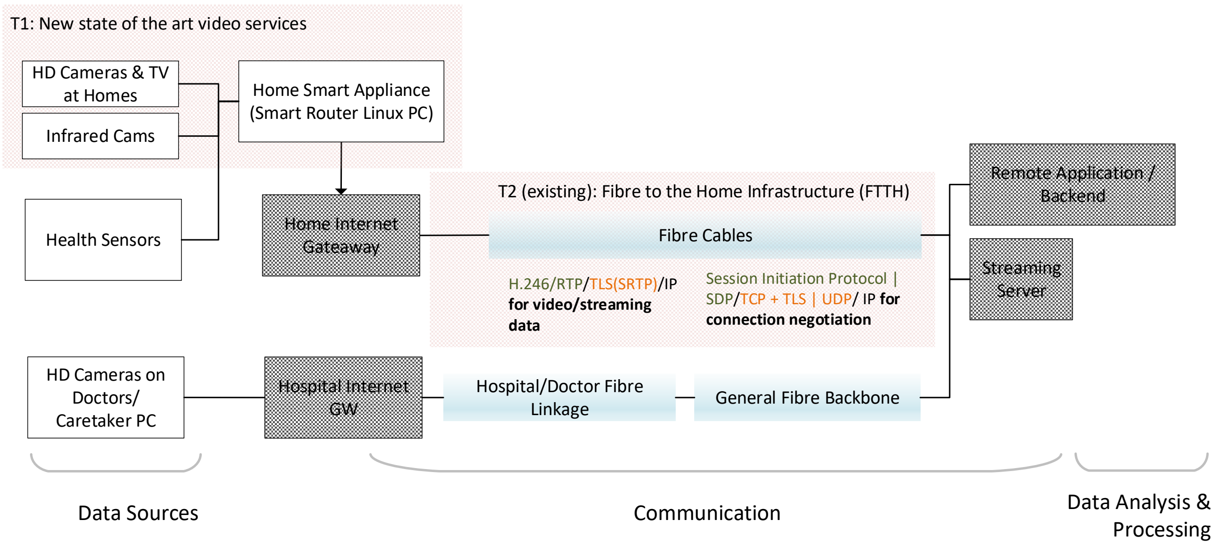
Enhancing the service provided as older experiences nurses, or experts could remotely help young nurses even when they cannot travel

Wider Benefits
Has been expanded to other Municipalities in Norway. Prague and Sabadell highly interested in replicating the Use Case Strategic Area for the company and its partner Strong Market identified for the service 10 sets moved to WP6 to aid replication in the FCs

Suggested Financing Options
Mainly the health care service providers. Could be patients or relatives based on how much they want it

Prospective Customers for future
Wide range of customer segments (health care service provider, relatives, patients)

Contact for further Details
PerErling.Fjeld@lyse.no



Cameras at both the homes of the patients as well as at the location of the doctor are necessary to allow for video conferences. Along with further sensors and infrared cameras that convey health related information about the patient to the doctor, these entities make up the data sources in this UC. The communication related infrastructure encompasses the local gateways, the newly added Fibre-to-the-homes infrastructure, the existing glass-fibre backbone as well as a streaming server. The backend is furthermore important for integration and display of the communicated sensor data and thus takes over both communication as well as processing tasks.

Relevant Standards: H.246, RTP, SIP, TLS, 95/46/EG, EC 45/2001

5.6.59 Blink: Innovative video for communication services (UC-541b)

Blink: Innovative video for communication services

General Information

City	Stavanger	Sector	ICT
Country	Norway	Triangulum	Yes

Short Description
Video installation linked to the TV screen that enables communication between private users/homes to allow for experience sharing between people. The system can link many different communication channels. Could link public services like library presentations.

USP/Highlight
Full HD facilities, different communication channels can be used, it has an easy User interface

Project Scale	Individual site	Planning Time	2-5 years
Development Type	Technological Development	Implementation Time	< 2 years
Participation Model	Active participation	Active design changes were made due to user inputs	

Stakeholder Analysis			
Owner	household	**Implementer**	t.b.d. (to be defined)
Customer	Small Businesses	**Service Provider**	t.b.d. (to be defined)

Implementation of UseCase

Supporting Factors			
Legal		Geographical	Long and twisted roadways prolonging travel times result in big demand for distance communication services
Infrastructural	Strong broadband connection needed (symmetrical bandwidth)	Social	Physical distance between family member is elongating as younger generation moves away for studies and work. Elderly feel lonely and are not used to smart devices. They are more familiar with operating and using the TV
Financial		Partners	
Other			

Main Implementation Challenge
Technology in testing phase and under development.

Lessons Learned
Technology development on hardware and software side is moving fast. Outsourcing hardware to specialized companies is much cheaper and reduces the time and efforts required.
Important to maintain high respect for the privacy of customers as you are in their homes

Financing Information

Initial Investment	< 50,000 Euros	**ROI**	
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	100%
Others		Private Owners	

Revenue Streams/ Monetized Value
Could be sold to end users, health care service providers or rented out in a service contract (to be decided); Different offers for different user groups to reduce overall costs: more expensive simple to use devices for elderly: more basic versions for young people

Project Details

Standard & Technical Details
Open standards are being used to integrate island systems; Collaboration with Pexip to connect to other proprietary systems, different open standards still available

Necessary Projects

Supporting Projects
The communication service can be used for a variety of different use cases which facilitate communication.

Benefits

Primary Benefits	Secondary Benefits
Reducing Operation Costs	Encouraging digital entrepreneurships
Improving personnel efficiency	Enabling new business opportunities
Improving social integration	Reducing traffic congestion
Improving Life Quality	Increasing Safety
	Improving data availability

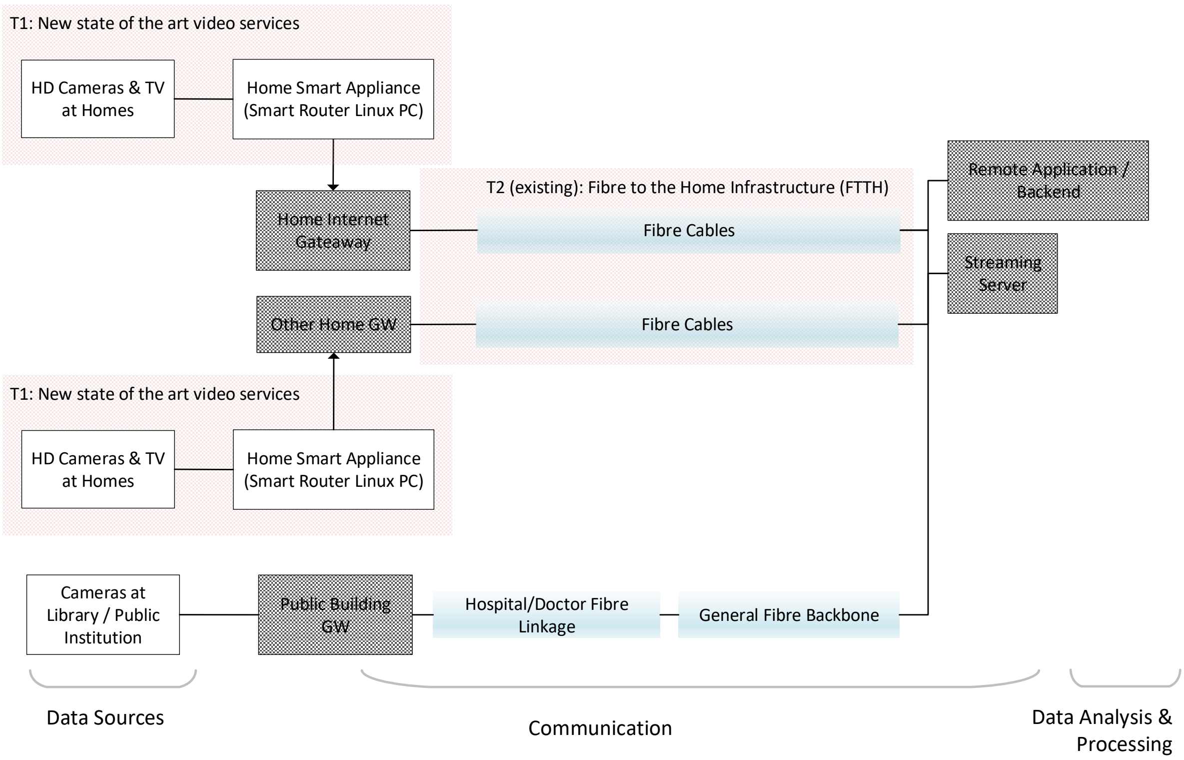
Closer connection to family members; Closer social integration

Wider Benefits
Video conferencing with HD services for companies and other users for home office. Possible application in Court for Interpreters to avoid traveling. Many wider use cases can be built (e.g. for communication with specially abled people)Can also be included in home entertainment devices.

Suggested Financing Options
Affordable system financed by end users

Prospective Customers for future
Small Businesses (reduce flying costs), Courts, Consultancy Services, Public Service Institutions

Contact for further Details
PerErling.Fjeld@lyse.no



Use Case 541b allows for sharing of information and experience between private users. Furthermore, cameras at i.e. public libraries capturing ongoing presentations could be linked as well, enlarging the group of data source entities. The communication infrastructure mirrors that of UC-541a. Remote applications can for example persist those presentations and deliver them on demand and furthermore act as a kind of market place that allows for indexing of public/private presentations and communication between potential participants. By virtue of this, the backend qualifies as an entity on the data analysis and processing layer in addition to its function for connection establishment.

Relevant Standards: H.246, RTP, SIP, TLS, 95/46/EG, EC 45/2001

5.6.60 Data Analytics Toolkit (UC-542a)

Data Analytics Toolkit

General Information

City	Stavanger	Sector	ICT
Country	Norway	Triangulum	Yes

Short Description
It is a set of tools and services for analyzing data on the cloud data platform. It increases accessibility of data and enhances its usability

USP/Highlight
The toolkit provides the possibility to process a wide variety of data. It also provides the opportunity to add new services and tools.

Project Scale	Beyond City Level	Planning Time	< 2 years
Development Type	Technological Development	Implementation Time	0.5 - 1 years
Participation Model	Not performed		Contact with data providers on what they want to measure throughout the development process

Stakeholder Analysis			
Owner	University of Stavanger	**Implementer**	University of Stavanger
Customer	data owners, data users (e.g. data driven businesses)	**Service Provider**	University of Stavanger

Implementation of UseCase

Supporting Factors			
Legal	Commercial use of data platform is limited due to legal boundaries of universities which helps prevent data lock-in.	Geographical	Good connectivity to other developed countries (Scandinavia and UK) as data partners.
Infrastructural	Access to NREN backbone network (available only for universities); Data Centre/Computing Platform (on which the cloud data hub is built)	Social	
Financial	As a public institution access to public funding is available, Vendors provide equipment for free as it is for University; No profit needs to be generated	Partners	Good connection to public authorities and data providers in the region
Other	Specialized research group working on that topic, aligned with university long term strategy		

Main Implementation Challenge
To receive relevant and properly documented data sets

Lessons Learned
Start with a background study/reference architecture/ best practices and guidelines
Have a pilot case that you can control fully to also show significant outcome.
Generate cross-disciplinary working groups, to understand the different requirements

Financing Information

Initial Investment	50,000 -250,000	**ROI**	
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds	100%	Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
Services to be used for generating knowledge/accessible for non/technical people (e.g. citizens and municipality) in addition to students and local businesses

Project Details

Standard & Technical Details

Necessary Projects
cloud data platform, computing platform or data centre

Supporting Projects

Benefits

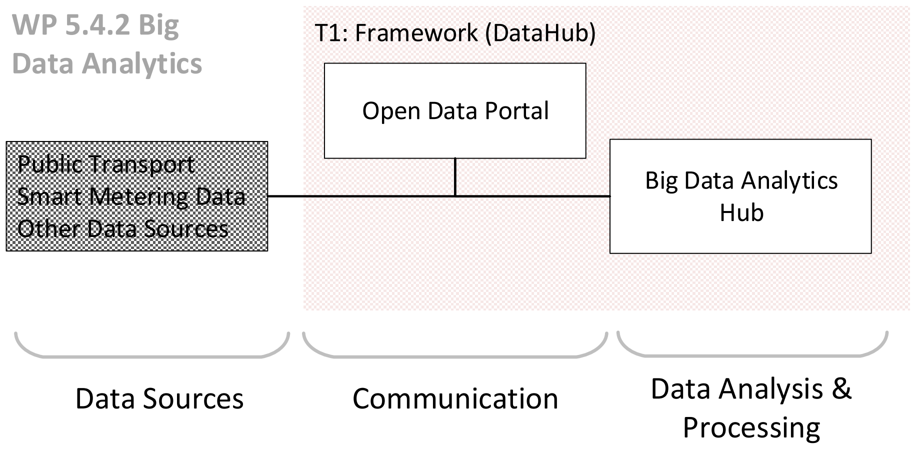
Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships	
Create new jobs	
Enabling new business opportunities	
Facilitating Citizen Engagement	
Improving data availability	
Increasing transparency	

Wider Benefits

Suggested Financing Options

Prospective Customers for future

Contact for further Details
katelien.van.den.berge@stavanger.kommune.no



The data analytics toolkit of subtask 4.2 in WP5 (Stavanger) allows for the transfer of data from various sources (that lie on the data source layer but are not actually a part of the module) onto a big data analytics hub. Data transfer and exchange with other data hubs can be mediated by an open data portal that keeps references to the data and thus streamlines communication. On the big data analytics hub itself, data may be persisted and is then integrated and processed by various processing engines. Therefore this data analytics hub can be assigned to the data analytics and processing layer. A more detailed version showing the different analytics engines is available in the previous deliverable.

Relevant Standards: ISO/IEC 13249, ISO/IEC 27040, ISO/IEC 27017, ISO/IEC 27018, CWA 16871-1, ITU-T Y.3600, ISO/IEC 10746, ISO/TR 9007:1987, ITU-T X.1601, HyperCat Initiative, OKF CKAN, ISO 37120, UNE 178301:2015,

5.6.61 Multimodal decision support service (UC-543a)

Multimodal decision support service

General Information

City	Stavanger	Sector	ICT
Country	Norway	Triangulum	Yes

Short Description

Web based tool providing inhabitants in city with information to plan their transportation through a mounted display unit. It enables them to choose a mode of transport based on the required time and carbon footprint generated through each mode. The tool could be used on different smart devices

USP/Highlight

Tool uses range of real time data and facilitates exploitation of available Open Data

Project Scale	Beyond City Level	Planning Time	<0.5 years
Development Type	Technological Development	Implementation Time	0.5 - 1 years
Participation Model	Not performed		

Stakeholder Analysis

Owner	Lyse	**Implementer**	Lyse
Customer	Citizens	**Service Provider**	Lyse

Implementation of UseCase

Supporting Factors

Legal	Exploits open data	Geographical	
Infrastructural		Social	
Financial		Partners	Collaboration and trust with data providers facilitates easier access to data. Local bus provider(Kolumbus) does real time mapping of their busses
Other	Hackathon organised by Stavanger City Council to enhance use of Open Data Platform		

Main Implementation Challenge

Getting data from national road authorities.

Lessons Learned
City Authority and Open Data Providers should provide data in real time format. This facilitates automatic updating of the data sets in real time and reduces the coding effort
Important to have standardised documented Open Data APIs

Financing Information

Initial Investment	50,000 -250,000	ROI	
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	100%
EU funds		Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value
The system fits well as a complimentary service in a bigger model. To make a strong business case alliances with other services(e.g. Taxi),existing smart home systems, could make a stronger business model. B2B product-companies might like to provide such a service to employees to reduce the travel hassle employees face while commuting to and from work

Project Details

Standard & Technical Details
Weather data, traffic information from Google , Open Data from City, air quality censor data

Necessary Projects

Supporting Projects
Good to build on: Smart Gateway (Existing smart home applications could help), Open Data Platform
Further Collaboration: Taxi Service, Other types of application which use data from different sources

Benefits

Primary Benefits	Secondary Benefits
Reducing use of fossils	Encouraging digital entrepreneurships
Improving Air Quality	Enabling new business opportunities
Reducing GHG Emissions	Improving Life Quality
Supporting environmental efficient transport	Increasing transparency
Reducing traffic congestion	
Promoting sustainable behavior	
Improving public transport	
Promoting Use of active modes	
Improving data availability	

Health Benefits,

Wider Benefits
Expanded to mobile devices

Suggested Financing Options
Financing from Local Authorities
Support by Structural funds
no direct subscription for the product but part of bigger service

Prospective Customers for future
Collaboration: Public transport providers (Local partners)
End Users: Citizens with transportation needs

Contact for further Details
PerErling.Fjeld@lyse.no

5.6.62 Cloud Data Platform for Stavanger (UC-544a)

Cloud Data Platform for Stavanger

General Information

City	Stavanger	Sector	ICT
Country	Norway	Triangulum	Yes

Short Description
It is an ICT Platform which facilitates collection, storage and processing of Smart City Data. It provides data access.

USP/Highlight
Built from scratch by researchers based on cutting edge knowledge. Open Source prevents vendor lock-in. Design of the Platform prevents data Lock-in

Project Scale	Beyond City Level	Planning Time	< 2 years
Development Type	Technological Development	Implementation Time	0.5 - 1 years
Participation Model	Not performed		

Stakeholder Analysis			
Owner	University of Stavanger	**Implementer**	University of Stavanger
Customer	data owners, data users (e.g. data driven businesses)	**Service Provider**	University of Stavanger

Implementation of UseCase

Supporting Factors			
Legal	Commercial use of data platform is limited due to legal boundaries of universities which helps prevent data lock-in.	Geographical	Cool climate supports server cooling; Good connectivity to other developed countries (Scandinavia and UK) as data partners
Infrastructural	Access to NREN backbone network (available only for universities); Data Centre/Computing Platform (on which the cloud data hub is built)	Social	
Financial	As a public institution access to public funding is available, Vendors provide equipment for free as it is for University; No profit needs to be generated	Partners	Good connection to public authorities and data providers in the region
Other	Specialized research group working on that topic, aligned with university long term strategy		

Main Implementation Challenge
RECEIVING THE DATA FROM PARTNERS, UNDERSTANDING PARTNER REQUIREMENTS AND EXPECTATIONS (terminology); University procurement procedures slow down implementation process; Need of Human resources (with highly specialized competencies)

Lessons Learned
Start with a background study/reference architecture/ best practices and guidelines
Ensure data availability for the hub: design different systems to generate many data sets which can be used as KPIs
Generate cross-disciplinary working groups, to understand the different requirements

Financing Information

Initial Investment	250,000 - 500,000	**ROI**	
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds	10%	Public Companies	
EU funds	10%	Financial institutions	
Regional funds		End User	
Others	80%	University	

Revenue Streams/ Monetized Value
Data to be used for generating knowledge in the university and facilitate usage for students and local businesses

Project Details

Standard & Technical Details

Necessary Projects
computing platform or data centre

Supporting Projects
data analytics toolkit

Benefits

Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships	Enabling new business opportunities
Create new jobs	
Improving data availability	
Increasing transparency	

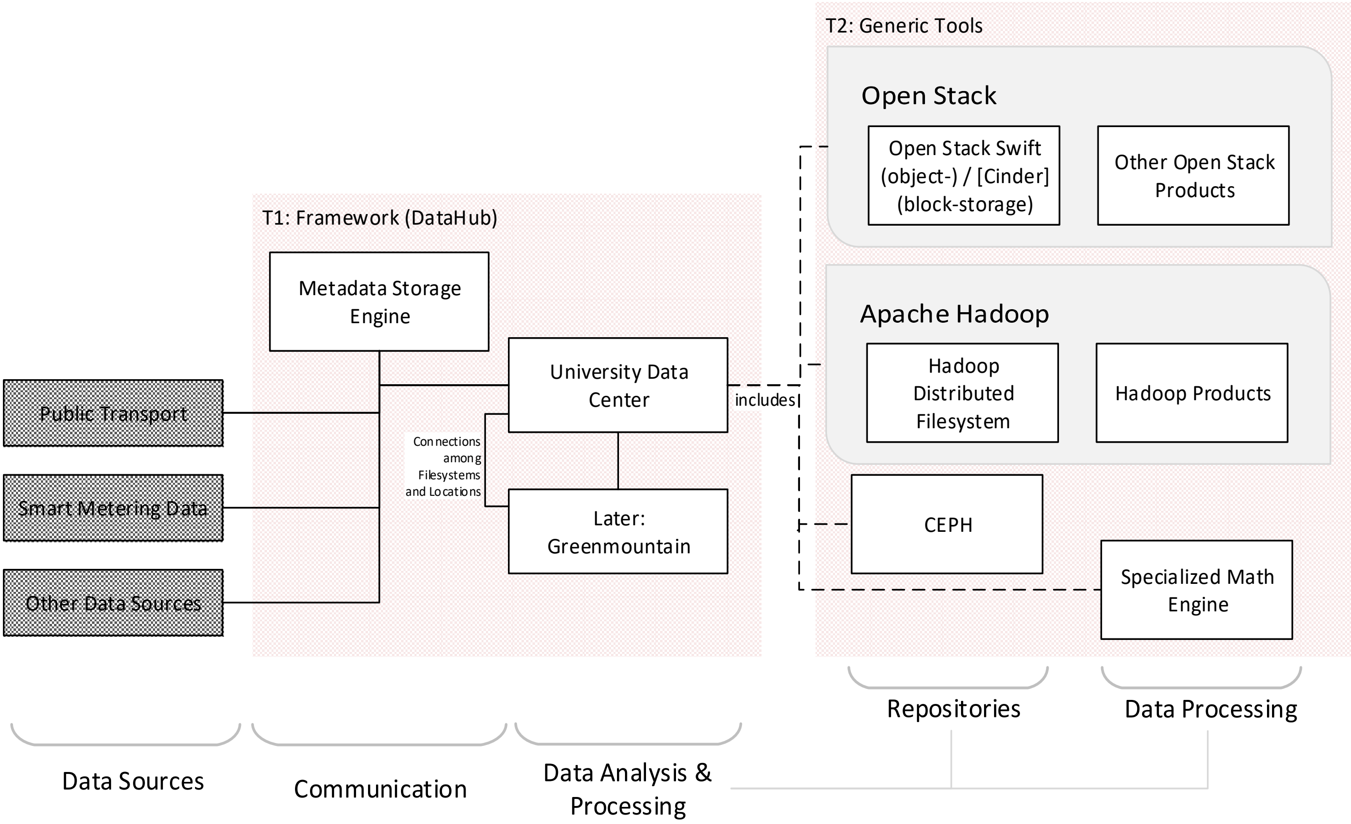
Cooling system from the servers can be used for heating purposes

Wider Benefits

Suggested Financing Options

Prospective Customers for future

Contact for further Details
katelien.van.den.berge@stavanger.kommune.no



The Cloud Data Platform integrates the Data Analytics Toolkit (UC-542a) and enables the generation of new knowledge based on different data sources and the aforementioned toolkit. Data transfer and exchange with other data hubs can be mediated by an open data portal that keeps references to the data and thus streamlines communication. On the big data analytics hub itself, data may be persisted and is then integrated and processed by various processing engines. Therefore, this cloud data platform can be assigned to the data analytics and processing layer. A more detailed version showing the different analytics engines is available in the previous deliverable.

Relevant Standards: ISO/IEC 13249, ISO/IEC 27040, ISO/IEC 27017, ISO/IEC 27018, CWA 16871-1, ITU-T Y.3600, ISO/IEC 10746, ISO/TR 9007:1987, ITU-T X.1601, HyperCat Initiative, OKF CKAN, ISO 37120, UNE 178301:2015,

5.6.63 Computing Platform (UC-544b)

Computing Platform

General Information

City	Stavanger	Sector	ICT
Country	Norway	Triangulum	Yes

Short Description
It is an ICT platform that delivers on demand access to a shared pool of computing, storage and networking resources.

USP/Highlight
open source and no vendor lock-in

Project Scale		Planning Time	
Development Type	Technological Development	Implementation Time	
Participation Model	Not performed		

Stakeholder Analysis			
Owner		Implementer	
Customer	data owners, data users (e.g. data driven businesses)	Service Provider	

Implementation of UseCase

Supporting Factors			
Legal		Geographical	
Infrastructural		Social	
Financial		Partners	
Other			

Main Implementation Challenge

Lessons Learned

Financing Information

Initial Investment		ROI	
Scale of Investment			

Financer (Contribution in Percentage)			
City		Private Sector	
National funds		Public Companies	
EU funds		Financial institutions	
Regional funds		End User	
Others			

Revenue Streams/ Monetized Value

Project Details

Standard & Technical Details

Necessary Projects

Supporting Projects

Benefits

Primary Benefits	Secondary Benefits
Encouraging digital entrepreneurships	Enabling new business opportunities
Create new jobs	
Improving data availability	
Increasing transparency	

Wider Benefits

Suggested Financing Options

Prospective Customers for future

Contact for further Details
katelien.van.den.berge@stavanger.kommune.no

5.7 Decision making tool

Chapter 5.4 displayed the relevant information in accordance to the Holistic Smart City Value Model including technical specifications and monitoring protocols. The Use Case template has the inherent property of making the information searchable through categorizations, classifications and quantitative data inputs. Within the LCs of Triangulum more than 50 Use Cases were identified and at least part of the relevant data collected. Baring in mind that Triangulum is only one out of several projects dealing with Smart City implementation projects and additional projects being realized with public national or private funding, one can easily imagine the number of relevant Use Cases in a database reaching several hundreds or even thousands. Guiding parties interested in replicating the Use Cases to the once most interesting to them and therefore supporting the decision process becomes of upmost importance. The following chapter will introduce the Decision making tool that was developed as part of Triangulum to perform exactly this task.

5.7.1 Tool Logic

Over the course of the on-sites, detailed information on 70 Use Cases implemented in the three Triangulum LCs were collected during the 2nd on-site visit (cf. Chapter 5.1.4) by the WP6 research team leaded by experts from Fraunhofer IAO and University of Stuttgart. The next step was to build the tool around this database to enable cities to find relevant Use Cases which they could replicate. To achieve this, four aspects of the tool were identified as critical:

1. **Input Form** - captures what users are looking for
2. **Linking Matrix** – identifies Use Cases that satisfy the users' needs
3. **Ranking system** – arranges the Use Cases in an order to show the most relevant first
4. **Output Form** – displays the relevant Use Cases in right order and provides detailed information on Use Cases which the user finds most fit

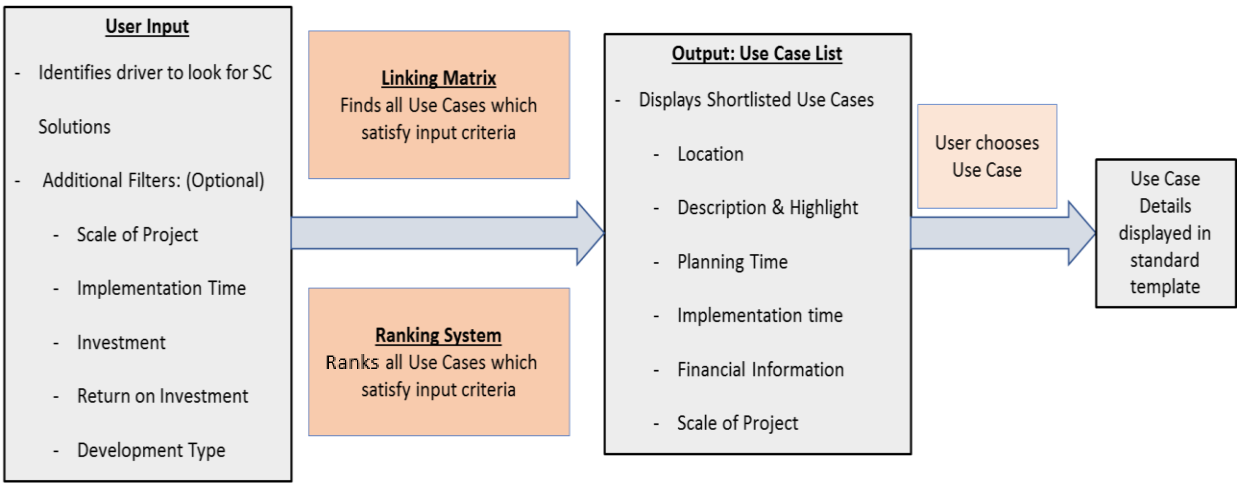


Figure 36: flow chart for Decision making tool

Before developing the tool a survey was undertaken with the LHCs and FCs of all the SCC1 projects which helped in identifying the needs of the cities. The various options in the tool have been based on several questions from the survey.

Additionally, over the course of the development of the tool constant feedback was received from the Triangulum business partners, LC- and FC representatives which helped in making the tool fit requirements of different stakeholders.

5.7.2 Input Form

At first, the tool was expected to be used mainly by municipal representatives and city decision makers. However, during workshops it was identified that industry partners would also be interested in informing themselves of the Use Cases. Hence, the tool is developed for two target segments.

a. City as User

Based on the results of the survey undertaken with the SCC1 team and the discussions with various Smart City managers, following were identified as the main drivers for cities to initiate Smart City Projects:

1. To tackle city challenges
2. To reach development goals
3. To improve liveability in city
4. To comply with EU/National regulations
5. To learn about Smart City Solutions developed in other cities

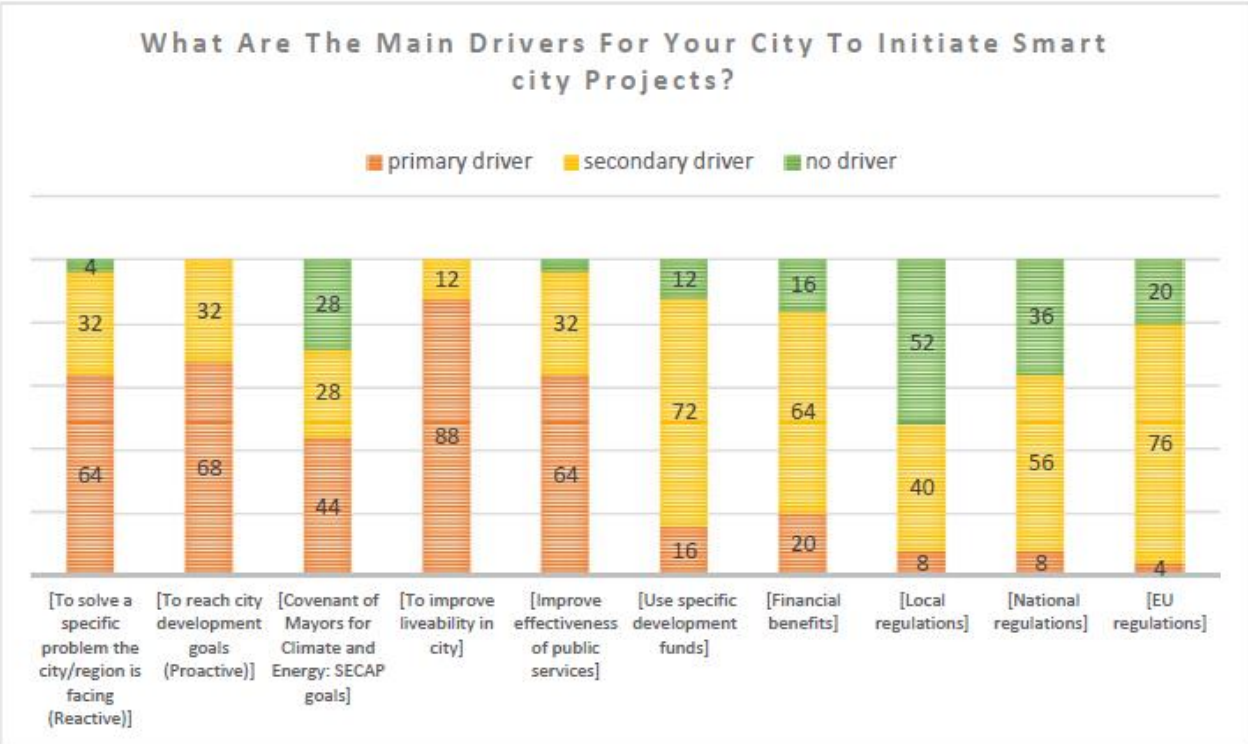


Figure 37: Survey Result: Main Drivers to Initiate Smart City Projects

Hence, the input form first asks the user why they are looking for Smart City Projects. Based on the first driver chosen, the user has wide range of options. Once the city representatives identify the driver, they are guided through two more levels to identify the target area they are looking at. This final input, called 'User Demand' is then used for filtering Use Cases in the next stage. Additional filters are also provided in case the city has specific constraints associated with the Smart City solution implementation (e.g. budget, deadlines, and existing infrastructure).

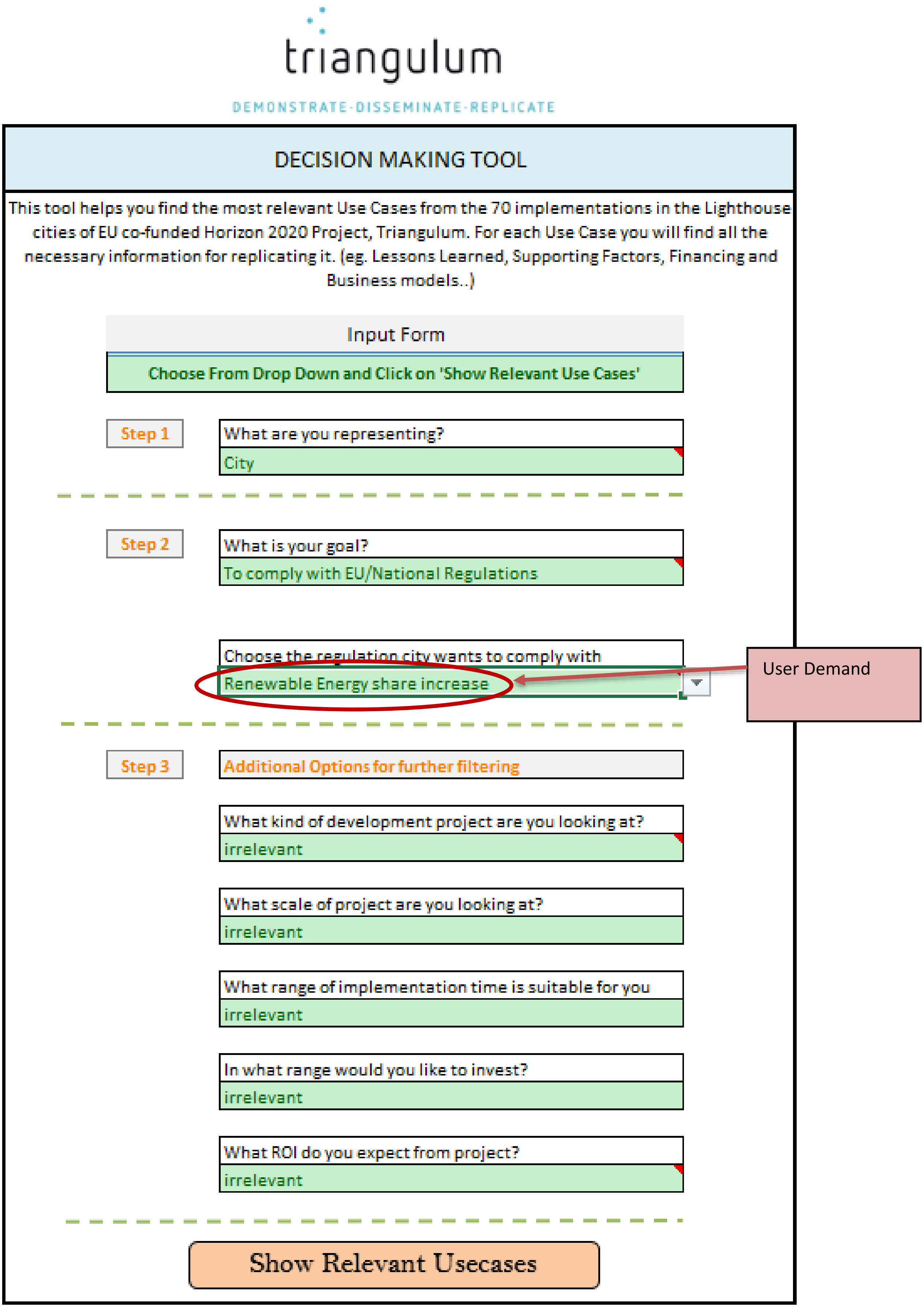


Figure 38: Input Form of Decision making tool for Cities

b. Industry as User

The input form is like the one for city except that as an industry representative, there aren't city specific drivers. Hence, only one stage of filtering based on the sectors they want to explore has been provided to the industry representatives.

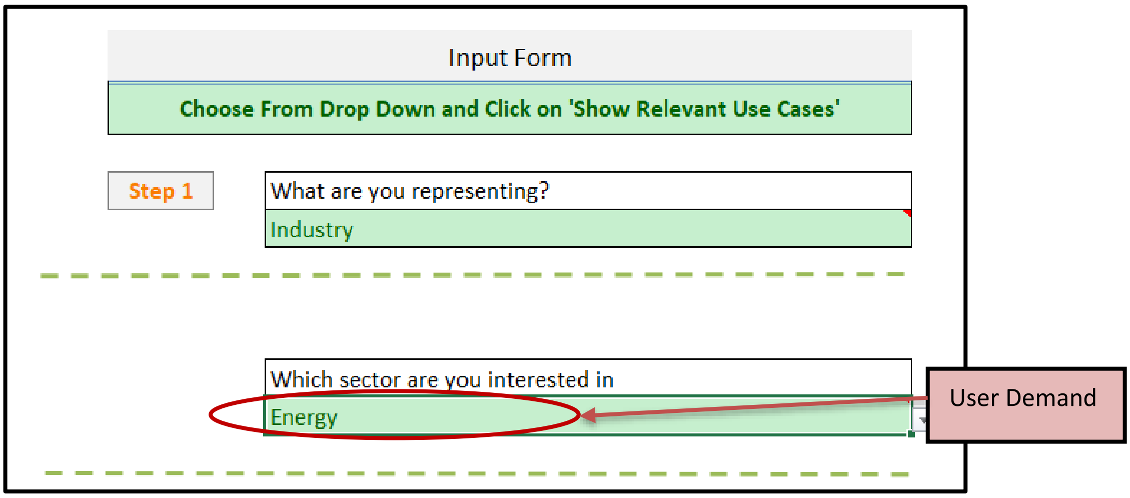


Figure 39: Input form of Decision making tool for Industries

5.7.3 Linking Matrix

The next step is to identify the Use Cases which are related to the ‘User Demand’ from the input sheet.

This is critical as the quality of the tool is based on the relevance of Use Cases displayed in the Output form for a specific input.

A matrix has been developed which links the benefits (property of the Use Cases) with the User Demand (input from the user). The linking is binary, i.e. a benefit is either related to a User Demand or not. Thus, for each Use Demand there is a list of benefits which are linked to it. The Linking Matrix links 99 User Demands with 40 benefits. Hence, it is a Matrix with 99 columns and 40 rows. All the benefits in a list have equal priority. Hence, the relevant Use Cases for a User Demand are the ones that have the linked benefits as primary or secondary effects. Figure 28 displays a section of the linking matrix. If the User Demand is ‘Peak Energy Demand’ (one of the Energy challenges), the shortlisted benefits are ‘Improving Energy Usage Efficiency’ and ‘Shaving Peak Energy Demand’

40 Benefits

99 User Demands

	Energy Challenges		
		1	4
List of All Benefits	Peak Energy Demand	Share of Renewable Energy	Energy Demand
Reducing use of fossils			
Reducing Operation Costs			
Improving personnel efficiency			
Encouraging digital entrepreneurships			
Create new jobs			
Enabling new business opportunities			
Improving Air Quality			
Reducing GHG Emissions			
Increasing share of renewables		X	
Decreasing energy consumption in buildings			
Supporting environmental efficient transport			
Reducing waste generation			
Reducing water pollution			
Improving Component Efficiency			X
Improving Energy Usage Efficiency	X		X
Improving Energy Supply Efficiency			X
Shaving peak Energy Demand	X		
Reducing energy Bill			X
Enhances Grid Stability			

Figure 40: Linking Matrix - Peak Energy Demand explanation

5.7.4 Filtering and Ranking System

The output of the Linking Matrix is a list of benefits which are linked to the User Demand. The next step is to find the relevant Use Cases and order them to show the most suitable first.

a. Filtering Use Cases

After having a list of benefits linked to the User Demand, the first stage is to identify Use Cases which have these as Primary or Secondary Benefits. Hence, initially all Use Cases which do not have any of the benefits from the list are deleted. However, since the database consists of around 70 Use Cases, there is a huge list of Use Cases which satisfy at the least one of the benefits. Hence, the next stage is to rank these Use Cases in the most relevant order.

b. Ranking of Use Cases

To rank the filtered Use Cases, each Use Case is then allotted the following scores:

1. **Benefit Scores**

   a. **Primary Benefit Score: (PS)**

   For having each benefit obtained from the Linking Matrix, a Use Case receives a plus point in this category if it sis a primary benefit. Hence, a Use Case which has both the benefits ('Improving Energy Usage Efficiency' and 'Shaving Peak Energy Demand') as Primary obtained for the User Demand of 'Peak Shaving' has a Primary benefit score of 2. A Use Case which does not have either of the benefits as primary, gets a primary benefit score of 0.

   b. **Secondary Benefit Score: (SS)**

   After the primary benefits are checked, the tool checks if the Use Case has any of the benefits as Secondary benefits. Each benefits adds one point to this score. Depending on the number of Secondary benefits the Use Case receives a Secondary Benefit Score.

		Eco-Environmental					
Code	Name	Improving Energy Usage Efficiency	Improving Energy Supply Efficiency	Shaving peak Energy Demand	Reducing energy Bill	Enhances Gri Stability	
521a	Smart Gateway for homes	Primary	No	Primary	Primary	Secondary	PS = 2 SS = 0
521b	Smart Gateway for nursing homes	Secondary	No	Secondary	Secondary	Secondary	PS = 0 SS = 2
~~521c~~	~~Smart Gateway for schools~~	~~No~~	~~No~~	~~No~~	~~No~~	~~No~~	

Figure 41: Filtering Use Cases and assigning Benefit Scores

2. **Filter Score (FS)**

In addition to the User Demand, the input form allows the user to set 5 filters to the search. These include type of development project, scale of project, implementation time, return on investment period, and initial investment cost. Hence, the next score called filter score is based on how many filters the Use Case satisfies. The maximum filter score possible is 5. Thus, depending on the set filters a Use Case can have a filter score anywhere between 0 and 5.

Once each filtered Use Case has a Primary Benefit Score, Secondary Benefit Score and Filter Score, the ranking order presented in Figure 42 is followed.

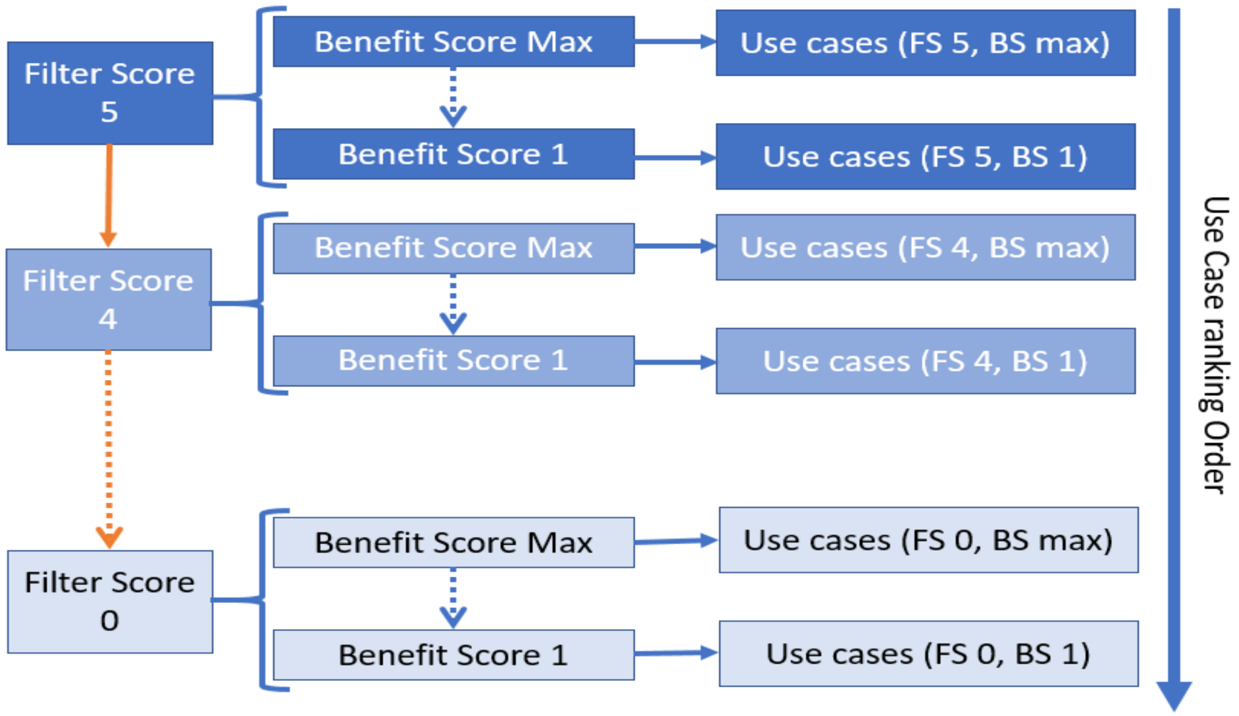


Figure 42: Ranking Order for Use Cases based on the scores

Hence, Use Cases which have all the benefits from the list and satisfy all filters are placed on the top of the list. The Primary benefit score is provided a higher importance than the Secondary Benefit Score. These are followed by the ones which still satisfy all filters but have some of all the benefits. This approach is followed mainly because all Use Cases which have a primary benefit score of one or more satisfy the User Demand. However, when it comes to filter score, Use Cases which do not satisfy a filter do not satisfy the User expectations as Users chose these filters actively. Hence, the Filter score is given priority over primary benefit score, followed by secondary benefit score for all Use Cases with either benefit score more than 1.

5.7.5 Output Form

Identifying a suitable way to display the output of the tool was one of the biggest challenges in the tool development process. As was described in the Use Case Template, for each of the 70 Use Cases from Triangulum detailed information was collected during the on-sites. However, displaying all this data for each shortlisted Use Case would confuse the user with a vast amount of information presented on an Excel interface.

Hence, it was decided to provide just enough information for all the shortlisted Use Cases so that the user can get a brief overview of the Use Case. This would enable the user to shortlist the most relevant Use Cases and find detailed information only about the shortlisted Use Cases. The list was decided based on the Input received from the Survey. As can be seen in figure 31, the most decisive factors in replicating a solution are the quantified benefits, business model details and financial information.

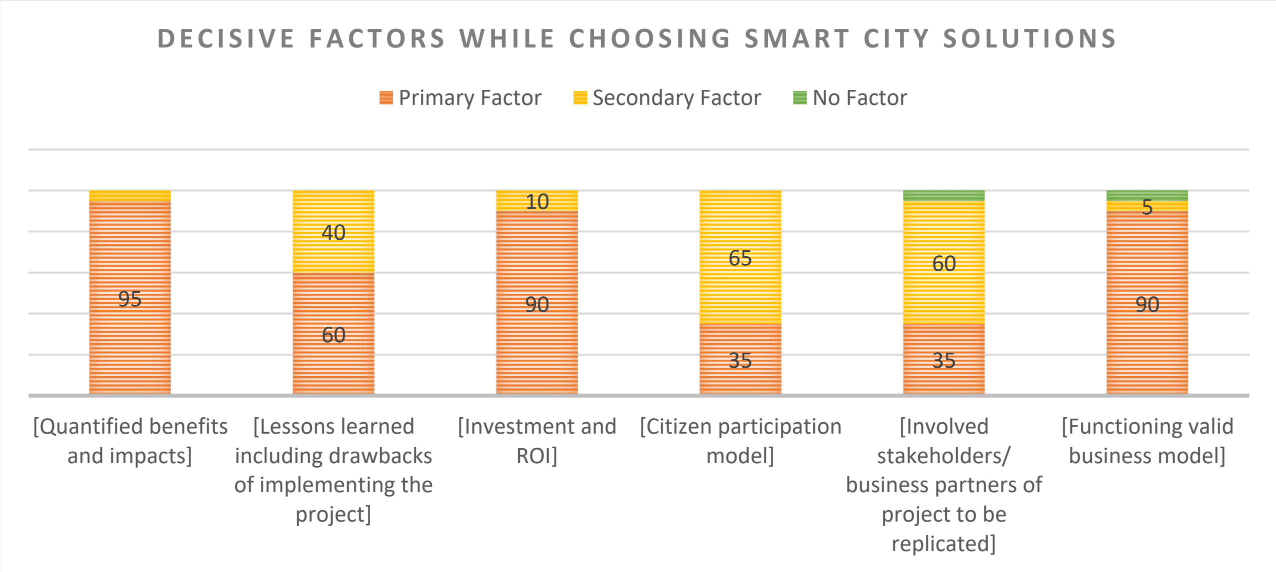


Figure 43: Decisive Factors in replicating smart city solutions

Hence, the output form provided the following details of the shortlisted Use Cases:

1. Name
2. City
3. Short Description
4. Scale of Implementation
5. Planning Time
6. Implementation Time
7. Development Type
8. Return on Investment
9. Scale of Investment
10. Score Filter
11. Details Button

Owing to space constraints all the tool output cannot be displayed in the report. However, the reader is encouraged to use to the tool and explore the different Smart City Solutions developed in Triangulum.

5.7.6 Validation of the tool

The tool was realized as a Microsoft Excel based vba-supported stand-alone application. After the development of first version of the tool, it was tested on numerous occasions with representatives from Triangulum FCs and LCs and the LCs' business partners during the On-Site visits and various workshops. These testing sessions provided valuable insights on how the tool could be improved. Most of these suggestions have been implemented in the final tool.

6 Customer centric approach

I addition to the technology transfer approach described in Chapter 5, the FCs in Triangulum were directly supported by several practical measures to allow implementation of Smart City solution in their municipalities. The customer centric approach gathers the needs of the FCs and provides them the relevant information in a structured and feasible format and way. The process of this approach is displayed in Figure 44.

Figure 44: overview of the customer centric approach

Chapter 6.1 displays the results of the analyses in the FCs including particular strengths, weaknesses and development goals to be the basis for the developments within the SCIS.

Chapter 6.2 describes the FCTM as the vehicle to transfer the knowledge from the LC partners to the FCs in order to support the development of the SCIS.

Chapter 6.3 shows the generic content of the FCs' SCIS which shall be the main outcome of the customer centric process. Each strategy is an individual deliverable by itself however follows the structure outlined in this chapter.

6.1 Analyses of the FCs

The in-depth analysis of the FCs Prague, Leipzig and Sabadell was carried out based on the Morgenstadt assessment framework for sustainable urban development.

6.1.1 Leipzig (D)

6.1.1.1 Introduction to the city

With almost 600.000 citizens, Leipzig already is the largest city of Saxony and with more than 10.000 people moving to the city per year, it has a very dynamic growth of its population. This has not always been the case, as many people moved away in the years after the German reunification. The strong and continuing growth is one of the mayor challenges to the municipality, since the aging infrastructure must be upgraded and adapted. Being the second poorest city in Germany with low purchasing power and a lack of budget in the city administration does not make this task easier.

Due to a high degree of old and protected buildings, increasing the energy efficiency of properties is lacking behind. The city therefore offers energy consulting to citizens and develops a future energy concept.

6.1.1.2 City analysis

During the on-site assessment, a group of researchers from Fraunhofer and TÜV Süd interviewed 25 local experts in the fields of energy, mobility, city planning, economics, governance and ICT in order to analyse challenges and demands for the future of Leipzig as a Smart City. Additionally, some of the interviews were conducted with experts working specifically on the development of the district *Leipzig West* (Plagwitz / Lindenau). The district will function as the city's laboratory for intelligent and integrated urban transformation. It will also serve as a blueprint for further smart district developments within the city. Leipzig West has undergone several significant stages of development which include the transformation induced by industrialization, a decline in population numbers along with political changes and de-industrialization, and, since the reunification of Germany, an ongoing urban renewal process giving the district a new vigor. Leipzig West is a mixed-used district featuring a high livability factor, engaged residents and continuous revitalization efforts which makes it a perfect demonstration area for future urban development. With the support of Triangulum, the City of Leipzig is developing the first Smart City Implementation Plan for *Leipzig West.*

The first insights into the required actions and potentials and evaluation of possibilities for Smart City Solutions on the city level could be revealed analysing the collected data.

In spite of having to deal with certain challenges, Leipzig has also demonstrated great potential. The city is turning from a shrinking into a booming one. At the same time Leipzig is the 2nd poorest regional capital city in Germany with aging infrastructure and lack of financial resources. Despite these challenges, the population is very actively involved into urban design and the sharing culture of the city is remarkable.

<u>Energy:</u>

A major challenge to the city is energy consumption, which in many cases is very hard to influence. Tenants suffer from high energy costs and missing comfort. There have been several approaches to make owners of apartment buildings renew the heating system, install heat insulation or to replace old windows. Since many of the buildings are owned by investors who do not live in the buildings or not even in the city, they only improve energy efficiency if it is economically reasonable, which often is not the case. In addition, many owners do not really care about their properties state and condition. Many buildings are under monument protection what makes measures impossible (like insulating the facades) or even more expensive and economically unattractive.

Therefore, the city sets a focus on energy production, which is on the one hand side dependant on the coal power plant Lippendorf that produces a large share of the cities energy. Due to the fossil-fuel phase out, there is uncertainty how long the plant can operate. Even if cost-effective heat-extraction reduces CO2-emissions, there is space for improvements in this category. On the other side, there are innovative projects like an energy association with its first PV System. The EEX Group, headquartered in Leipzig, offers a central marketplace for energy and commodity products in 30 countries.

Overall the result of the analysis was the lack of concrete objectives and goals and of an energy concept (under development).

<u>Buildings:</u>

As described previously, the energetic condition (and often the general condition) of many buildings in the city is outdated and owners have little interest to improve it. Due to tax reduction, many buildings have been partly renovated in the 1990ies but since then there is a lack of modernization. A positive aspect of life in Leipzig is the high living quality due to many green areas. The city also features mixed used areas (living, commerce, industry) but like in many other cities, those areas decrease due to conflicts between the different usages (e.g. noise from production).

Mobility

Leipzig has a high level of private transport convenience (e.g. parking spaces) and the share of private motorized transport therefore is high. Nonetheless there is a trend to cycle and citizens are very open for car and bike sharing.

ICT

Indicators show that the use of data and management of ICT development lacks an overarching digitalization plan. Some sectors like traffic management already make good use of real-time data while there are different IT systems in the municipality in different sectors. Shared access often is not possible which leads to inefficiency and is inconvenient for employees. Nonetheless Leipzig has worked on the creation of a spatial data infrastructure since 2012 in the EU initiative INSPIRE (Infrastructure for Spatial Information in the European Community).

As a result of the data analysis, six hypotheses were developed for the future Smart City development of Leipzig.

- **Hypothesis 1- Governance Structures:** To become sustainable, the city of Leipzig needs to link cross-sectoral themes and adjust its existing administrative structures to meet the requirements of flexible urban governance.
- **Hypothesis 2 – Innovations:** The know-how of the research institutes in Leipzig needs to be put to a greater use, to nudge **innovations** in companies and urban infrastructures.
- **Hypothesis 3 – Smart City Profile Leipzig**
- Leipzig can become a forerunner city in the development and implementation of **„Low Budget Smart City“**
- **Hypothesis 4 – Flexibility:** The Smart City approach creates additional **flexibility** and scope of action for the city planning and service development, as well as makes it easier to deal with the future uncertainties.
- **Hypothesis 5 – Digitization:** Digitization offers **greater potential** than the actors in Leipzig previously assumed. Enhancing this potential will provide additional development possibilities.
- **Hypothesis 6 – Test Field:** New solutions have to be tested in the Smart City. Leipzig West will benefit from becoming a **test field for new technologies** where companies are invited to test and demonstrate their innovative ideas.

Preliminary results of the on-site assessment were presented as an impetus for the discussion of the future of *Leipzig West* during the second *Zukunftslabor* meeting held on February 23rd, 2016. A large number of experts and citizens were invited to discuss and share their visions for the district on a variety of topics relevant for future urban development. During the meeting, such topics as sharing concepts, smart mobility, big data, decentralized rainwater management, affordable housing and micro logistics were addressed.

The *Zukunftslabor* together with the *Zukunftsforum* form the shareholding structure of the City of Leipzig's first Smart City Implementation Plan. The *Zukunftsforum* is held every 3-4 months and brings together the project advisory committee consisting of the Mayor, the City Council, representatives of companies and universities. The *Zukunftslabor meetings* are held parallel to the *Forums* on various topics (housing, energy, mobility, water, economy, governance, etc.). Each topic has a responsible operative team comprised of 10 experts from different sectors. To ensure widespread participation and to maximize the amount of new ideas, citizens are also invited to take part in certain Zukunftslabor meetings. The City of Leipzig with its Office for Urban Regeneration and Residential Development, in cooperation with the University of Leipzig is responsible for the overall management.

The results of the on-site assessment, together with the analysis results of the LCs and those of the study on the replicability of the implemented Smart City Solutions will become part of the Smart City Implementation plan which will be developed by the City of Leipzig in the framework of the Triangulum project.

The detailed results of the indicator analysis can be found in D6.5 Revised implementation plan Leipzig.

6.1.1.3 Focus areas of replication

Leipzig plans to establish a smart district around the "Baumwollspinnerei", a former production plant for cotton in the west of the city. The site consists of more than 20 historic brick buildings built between the late 19th and early 20th century being used by artists, agencies, hotels and other commercial purposes today. As the buildings are under heritage protection, modernization measures have to be chosen carefully to comply with regulation.

According to the SCIS (D6.5) and as a result of the City Lab, measures shall include energetic projects like a decentralized photovoltaic plant with energy storage (battery) and a CHP plant. The city looks very close to the projects implemented in Manchester (energy storage) and Eindhoven (innovative infrastructure at Strijp-S).

With small scale modernizations, the buildings are supposed to become a demo side (observing the regulation of heritage protection) featuring wireless sensors and a actuator network not relying on batteries, using wireless charging and energy harvesting. The wireless solution is deployed as a mesh network, allowing cost-efficient installation in existing buildings. The buildings will be able to forecast energy consumptions and users behaviour to act according to the need of the grid while still ensuring comfort. The city is very positive to learn a lot from Eindhoven where a building automatization solution has been developed already.

Other concepts on the list include smart economy, sustainable mobility, active neighbourhoods and smart municipality. Details can be found in the SCIS.

6.1.2 Prague (CZ)

6.1.2.1 Introduction to the city

Although Prague is a prosperous city in the centre of one of the strongest economic regions in Europe, the city has applied for the “Morgenstadt City Challenge” in 2014. Markets and societies are changing and there are strong challenges to assure a future-proof development of the city. Cities must link local innovation, value creation and sustainability in a stakeholder-centred approach.

Prague is the political, economic, financial and educational centre of the Czech Republic, seat of the national administration, national finance institutions and most headquarters of foreign enterprises present in the country and the nation’s biggest transportation hub. Prague’s economy is very dynamic with more than 25 % of the national GDP produced in the city. The GDP per capita is almost the double of the average national GDP per capita. Moreover, Prague demonstrates continuously improving living standards, relatively high social stability and a strong middle class. Unemployment is below average in the European Union.

Today Prague is standing at a crossroad how to proceed with development in the years to come: Prague has not developed a clear vision for the future and it has not quantified goals for development. However, the city is currently pushing for the re-development of a strategic plan and is in the middle of the process of developing the new Masterplan, but has not yet defined the main strategic pathways of transition. This combined with its economic strengths and its rich history and attractiveness (old town part of UNESCO World Heritage List since 1992) creates a large potential for a focused smart and sustainable urban development.

6.1.2.2 City analysis

Analysis in Prague started in March 2015 with a kick-off workshop, followed by three months of data assessment and two weeks of on-site assessment. In September, an innovation workshop was held and in November the final conference tool place.

During the assessment, more than 80 action fields and 100 indicators were analysed. 57 interviews with local stakeholders during the on-site assessment helped to identify current strengths, challenges and development opportunities of the city.

It was discovered that Prague has a decentralized administrative system, allocating many important decisions that are crucial to the Smart City development to the district level. This bares strong potentials for a bottom-up development process together with the civil society. On the other hand there are risks and barriers for a strong and integrated developments of the city, since Prague needs to deal with 58 districts and their representatives when pushing for strategic decisions that need to be carried out by the entire city. This combined with a recent political instability has hindered the process towards a Smart City.

The success of being one of the top locations for outsourcing and offshoring IT-related services and software design is based on the well-established tradition of excellent technical and mathematical education. Also, with its location in the heart of Central Europe, Prague is ideal for building trade links. The dynamic and successful development of many start-ups lead to a lack of innovation space within the city. The fact that university buildings are spatially spread all over the city significantly hinders cooperation between them and community building.

Prague also faces challenges related with the high number of tourist being concentrated within a small area between the castle and the shopping street. Although tourists contribute 50 % of the total income in the city, the city itself does not benefit much from it. A great amount of tax revenues goes straight to the national budget. Moreover, the infrastructure of the city centre is not sufficient for the current tourism flow.

The detailed results of the indicator analysis can be found in D6.4 Revised implementation plan Prague.

6.1.2.3 Focus areas of replication

Similar like other European cities, Prague is facing the trend of an aging population. Per estimations in the strategic plan of the city, by 2030 there will be an increase of 17% of people over 65-year-old and a 65 % increase of the population above 80 years old. More than 250.000 citizens will be over 65 by then. In correlation to the number of elderly, the number of people who are dependent on care will rise.

Costs for beds in home care is estimated five times lower than a bed in a nursing home. Moreover, most of the available studies have shown that the quality of life for people in home care is higher compared to life in nursing homes. Therefore, the Prague is looking for ways to support the provision of complex home care services that enable elderly to live self-sufficient for a longer period.

6.1.3 Sabadell (ESP)

6.1.3.1 Introduction to the city

With almost 210.000 inhabitants, Sabadell is the second largest city in Catalonia, Spain and is located 20 km north of Barcelona. Like Manchester and Leipzig, Sabadell has been a centre of the textile industry during the industrial revolution. It was called the “Catalan Manchester” during that time. Today some of the old plants have been refurbished and are being used for different purposes.

Economy today is mainly influenced by commerce and some industry. While the proximity to Barcelona has its benefits, it makes it harder for Sabadell to attract businesses. As a response to the economic crisis the city tries to diversify its economic activities.

6.1.3.2 City analysis

The on-site assessment in the FC of Sabadell took place from the 29th of February to the 9th of March. This assessment was led by researchers from the Institute of Human Factors and Technology Management (IAT) at the University of Stuttgart in coordination with the Institute for Industrial Engineering (IAO) and the Institute for Open Communication Systems (FOKUS) from the Fraunhofer Gesellschaft, together with TÜV SÜD. A two-week intensive on-site research phase made up the core of the systems analysis in Sabadell with 37 interview sessions with more than 60 interviewees. Participants were representatives from relevant institutions in Sabadell, the city council as well as private sector potential project partners. Based on the understanding gained from these interviews, the information provided by the city hall during the preparation phase previous to the on-site evaluation and the knowledge acquired from the on-site assessments in the LCs, the researchers developed more than 15 project ideas for the implementation of smart technologies that would contribute to the sustainable development of Sabadell. The LC of Eindhoven partially joined the assessment. In the final workshop that took place on the 9th of March, 14 project ideas were discussed in detail and further developed.

The detailed results of the indicator analysis can be found in D6.6 Revised implementation plan Sabadell.

6.1.3.3 Focus areas of replication

The collected information is being processed in the form of a project portfolio with 13 concepts. The projects on the list are on the one hand influenced by the critical and semi-critical indicators, discovered in the indicator analysis but also from exchange with the LCs.

Sabadell plans to energetically refurbish the buildings of an urban block that represents a good mix of buildings, including residential, commercial, industrial and public facilities. During the workshops possible areas have been identified and components, stakeholders and next steps have been defined (cf. implementation plan).

Other project ideas on the list include e.g. the installation of screens in public buildings to raise awareness for energy consumption, using technology to increase citizen participation or to create a local cooperative innovation hub for sports, health, design and technology-related start-ups and SME. The full list is included in Sabadell’s implementation plan.

6.2 FCTM

Within WP6, a training mission to the FCs was foreseen. The FCTM was a 10-month program (February – November 2017) to transfer the learnings from the LCs to the FCs. The FCs had to write an SCIS to plan and commit to implementing Smart City Projects in the future. The FCs communicated their needs to the LCs, who together with their industry partners named the persons to transfer the corresponding knowledge. The WP6 team then designed a program with 17 different sessions.

Originally, it was planned that an expert team (Fraunhofer, TÜV SÜD and one representative of each LC) would spend two weeks in each of the FCs. During a discussion in the 2nd GA in Sabadell it was however agreed to split the planned two-week sessions into various shorter sessions in order to provide additional added value and to reduce travel expenses. This new structure should optimally provide assistance to the FCs with their implementation and to foster city-to-city learning.

Following three steps were performed for the creation of a new structure for FCTM: First, the FCs communicated their training needs and a topic list was defined based on mutual discussions. Second, the vehicles for transferring knowledge were set-up. Third, an expert review was performed to ensure that there were no gaps in the flow of knowledge and all the FC needs were addressed. All these steps were conducted taking into account, not only the opinion of the FCs, but also the expertise of the LCs and the WP6-Team.

As a result, the WP6-Team created a new program for the FCTM, which represented the customer centric approach of replication and had the FCs' SCIS as its main outcome. It consisted of three different knowledge-transfer vehicles:

1) FC Training Days (chapter 2800)
2) Workshops (chapter 6.2.2)
3) Webinars (chapter 6.2.3)

Overall, the new structure of the FCTM allowed combining identical needs of several cities into more efficient sessions, to have accompanying site- and lab-visits for technology related schooling and to support the cities in developing their SCIS in several stages instead of one condensed on-site visit. The new structure also allowed improved involvement of the partners from the LCs as some sessions (FC Days) took place in each LC. In addition, by using this new structure, the webinars were opened to the other SCC1-projects and knowledge gained in Triangulum was therefore spread beyond the project.

The following table summarizes the activities performed during 2017.

Table 12: Overview of FC Days, Workshops & Webinars

	Topic	Date	Location
FC Days			
STA	Use Cases & lessons learned from Stavanger	08.-09.05.2017	Stavanger
EIN	Use Cases & lessons learned from Eindhoven	19-20-06-2017	Eindhoven
MAN	Use Cases & lessons learned from Manchester	03-04.07.2017	Manchester
Workshops			
WS1	Implementation Strategies	22 – 23.02.2017	Stuttgart (Fhg IAO)

WS2	Smart Grids, Energy Storage and Renewable Energies	06 – 07.04.2017	Stuttgart (Fhg IAO)
WS3	Intelligent and connected public space	20 - 21.06.2017	Eindhoven
WS4	Open Data and eGovernance	14 – 15.09.2017	Berlin (Fhg FOKUS)
WS5	FC Stakeholder-Workshop: Prague	31.08.-01.09.2017	Prague
WS6	FC Stakeholder-Workshop: Sabadell	13 – 14.11.2017	Sabadell
WS7	FC Stakeholder-Workshop: Leipzig	10.10.2017	Leipzig
Webinars			
WB1	Smart City Policies and Governance	17.03.2017	Online
WB2	ICT Reference Architecture	28.03.2017	Online
WB3	Smart Business Services and Innovation Management	18.05.2017	Online
WB4	Innovation Procurement	30.05.2017	Online
WB5	Citizen Engagement, Development of Living Labs	23.06.2017	Online
WB6	Financing the Smart City	06.09.2017	Online
WB7	Smart and Electric Mobility	06.10.2017	Online

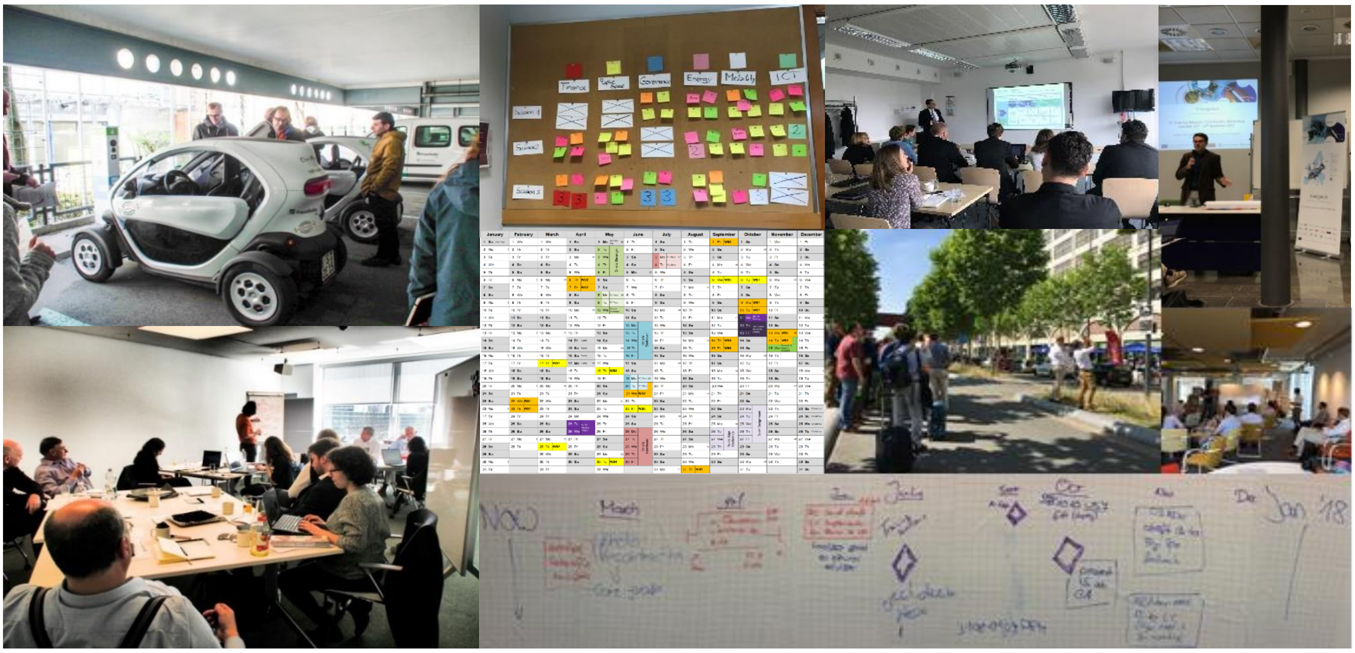


Figure 45: Impressions of the FC Training Mission

6.2.1 FC Days

The FC Days were part of the LC on-sites (3 sessions of 1.5 days each, one in each LC) and allowed in-depth discussions of the FCs and their partners with the LCs and their partners. The discussion topics were directly related to the specific modules and tasks implemented in the LCs. The sessions included presentations of the FC implementation ideas and the Use Cases in the LCs, as well as small (bilateral) meetings and workshops for discussing the FC project ideas. Additionally, the sessions also included lessons learned from the LCs and recommendations regarding the development process of their SC policy and their organisational challenges.

6.2.2 Workshops

The workshops addressed the schooling needs identified by the FCs for which partners from more than one LC were needed and for which a joint workshop was efficient and meaningful. Depending on the topic, relevant partners from the LCs were invited to participate to provide important insights to the FCs and their local partners. In total seven workshops (two days each) took place in 2017.

6.2.2.1 WS1 Implementation Strategies

The first workshop was held in Stuttgart on February, 22nd and 23rd 2017 and focused on the FC Implementation Strategies. Within this workshop, the content and structure of the Implementation Strategies was defined. Also, a timeline for 2017 including feedback loops was developed in order to optimally support the FC with the elaboration of their respective Implementation Strategies. Furthermore, the current status of the FC project ideas was discussed. This discussion included the linkage between the FC project ideas and the LCs Use Cases with their respective expert members of the Consortium. Also, the LCs representatives exchanged their lessons learned and recommendations regarding e.g. financing topics, development of a SC policy, etc.

6.2.2.2 WS2 Smart Grids, energy storage and renewable energies

The second workshop was held in Stuttgart on April, 6th and 7th 2017 and aimed to understand the theory and applications of smart energy management. In order to achieve this, several industry energy experts from the LCs (Siemens & Lyse) held presentations including Q&A sessions. Also, the FCs presented their project ideas related to the energy topic and the experts gave feedback on them. These ideas were further developed with the LCs and FCs together via business model canvas. Also, a site visit to the Fraunhofer Micro Smart Grid was conducted.

6.2.2.3 WS3 Intelligent and connected space

The third workshop was held on June, 20th and 21st 2017 and hosted by Volker Wessels in Eindhoven. This workshop provided insight into the topic of smart lighting and similar technologies and their usage in urban spaces. Once again, expert partners from this field held presentations with Q&A sessions (Lyse AS, City of Eindhoven, Volker Wessels and Strijp-S). Also, the FCs and their local partners exchanged knowledge with the experts from the LCs. The workshop also included a 120min site visit at night and live experience of a real-time surveillance and management system for the lively inner city area of Eindhoven distinguishing between several active modes of transport, public service and active safety management (The Cockpit in Stratumseind).

6.2.2.4 WS4 Open Data and eGovernance

This workshop took place on September, 15th 2017 in Berlin. Partners from the LC Eindhoven as well as from Fraunhofer FOKUS and Fraunhofer IAO spoke about different topics within the scope of Open Data and e-Governance. Topics that were covered include practical examples and the theory behind Open Data, scalable Smart City cloud platforms, open data platform for citizen engagement, mobility data and beyond, a learning solution for the public administration and an e-Governance case study.

6.2.2.5 WS5 Stakeholder-Workshop Prague

The stakeholder-workshop for Prague lasted two days, starting on July, 30th 2017. Here, several nationally renowned experts, public stakeholders from the national, regional and city level as well as industry partners from several health related backgrounds participated. The project ideas of the local SCIS were presented and discussed in detail with the over 30 participants. Several international experts including representatives from the City of Stavanger Fraunhofer FOCUS and Fraunhofer IAO gave presentations during the working sessions. Concrete next steps on further developing the ideas from the SCIS have been agreed on.

6.2.2.6 WS6 Stakeholder-Workshop Sabadell

This workshop was held on November, 13th and 14th in Sabadell. The aim of this workshop was to for the replication team to support the municipality of Sabadell in receiving the support of the local ecosystem and to help in further developing the Smart City Projects within Sabadell's SCIS. Therefore, on the first day an overview of the current status of the SCIS (D6.6) was provided to the local experts and stakeholders. Also, the knowledge and main results of the FC Training Mission were presented. These two blocks formed the basis for an in-depth discussion on the second day, where the participants further developed the project ideas in their respective area of expertise.

6.2.2.7 WS7 Stakeholder-Workshop Leipzig

This stakeholder-workshop took place on October 10th 2017 in Leipzig. Analogous to the workshops in Prague and Sabadell, the current status of the project ideas within the SCIS was presented and further developed in workshops and discussion rounds.

6.2.3 Webinars

In the webinars, partners from several cities came together for an exchange of information, experience and a discussion. In total, seven webinars with a duration of two hours each took place. The sessions were also open to partners outside of Triangulum. The structure of the webinars was as follows: in the first hour presentations were held. Contributions came from companies, cities, universities and research institutes. During that time questions were also possible. In the second hour further questions were answered and participants discussed on the topic. The webinars were recorded and shared via EMDESK with the participants. Moreover they were published on the official website of Triangulum www.triangulum-project.eu (only those parts for which the presenters gave their permissions).

The number of participants is depicted in Figure 46. Due to technical problems there was no participant list for Webinar 5 available. On average 21 persons attended the webinars. The participation of the LCs and FCs varied depending on the topic. The number of participants of the FCs was on average higher (9 persons) than the number of participants of the LCs (7.5 persons). This is in line with the initial idea of the webinars, which was the sharing of knowledge and experience from LCs to FCs. The Fraunhofer IAO and the University of Stuttgart IAT played a crucial role here since it organized and moderated all the webinars and also contributed with presentations to the webinars.

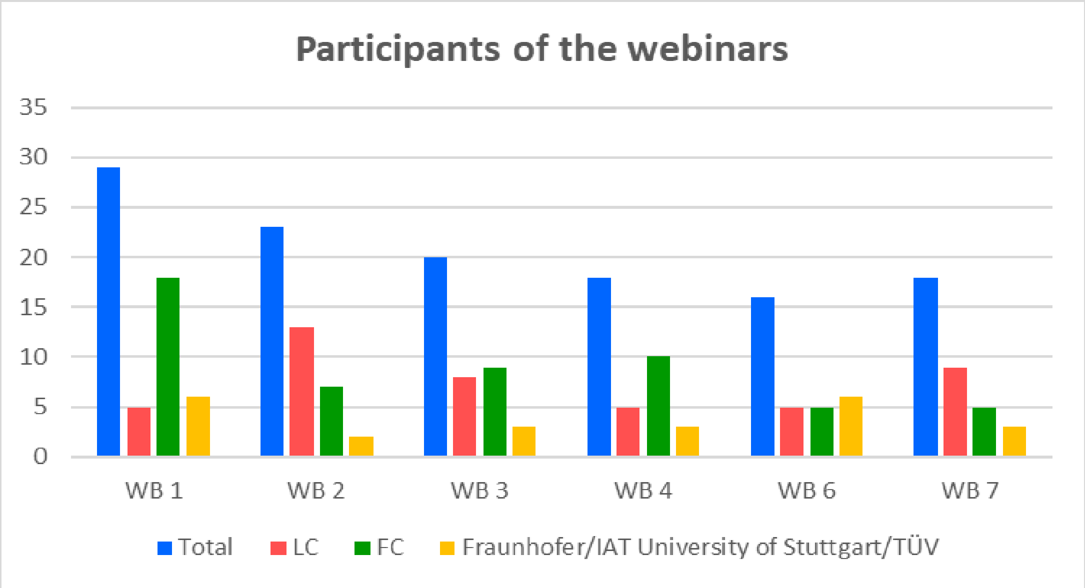


Figure 46: Participants of the webinars according to their belonging

Below a short description of each webinar will be given as well as the evaluation results of the webinars by the participants.

6.2.3.1 Webinar 1: Smart City Policies and Governance

In the first webinar Smart City policies and governance topics were discussed by using examples that had been already implemented. In particular the Morgenstadt approach, the Smart City policies of the city of Manchester as well as the Brainport Region in Eindhoven were presented. The main topics of the discussion were innovative procurement approaches as well as procurement rules. In this context useful links for information on procurement were shared. In this webinar the FCs had the most participants with 62%.

6.2.3.2 Webinar 2: ICT Reference Architecture

The topics covered in the second webinar were the ICT Reference Architecture in general, collecting data and linking platforms, a service layer and an open- data platform. In the discussion part the main focus laid on the security of data and what measures need to be taken in order to ensure security. This time the number of participants from the LCs was the highest with 57%.

6.2.3.3 Webinar 3: Smart Business Services and Innovation Management

Webinar 3 examined topics about start-ups, their special needs and their investment. Furthermore, the topic of how to enable data-driven innovation was presented as well as flexible city administration structures. The latter topic was of special interest for the city of Sabadell, therefore most of the discussion points were made by them.

The discussion covered trainings, survival of start-ups, financial aid by the government and living labs. The participation in this webinar was balanced since FCs amounted to 45% and the LCs to 40%.

6.2.3.4 Webinar 4: Innovation procurement

The fourth webinar was about innovation procurement and in particular how to carry out and carry on the procurement process. The discussion covered topics such as the comparison of innovation procurement between SME's and big corporations. Furthermore, funding opportunities of the EU for municipalities in order to finance innovative procurement were discussed. This time the number of participants of the FCs was the highest with 55%.

6.2.3.5 Webinar 5: Citizen Engagement & Living Labs

In this webinar an overview of the topic of citizen engagement was given as well as some practical examples, such as the e-bus projects. In the discussion the topic of living labs was highlighted.

6.2.3.6 Webinar 6: Financing the Smart City

Here, the topic of financing and procurement of a Smart City were discussed. During the discussion the business model of Strijp-S was analysed as well as funding strategies for start-ups.

6.2.3.7 Webinar 7: Smart and electric mobility

In this webinar the four megatrends for future mobility were presented (shared, autonomous, electric and connected mobility). A special focus laid on the battery buses in Stavanger and the charging infrastructures for future mobility concepts. One of the topics of the discussion were the E-cargo bikes in Manchester and solar energy for homes. The highest number of participants came from the FC, this time with 50%.

6.2.3.8 Evaluation of the webinars

The Fraunhofer IAO conducted a survey in order to let the participants of the webinars evaluate the webinars. Participants from all three participant groups were invited to fill in the evaluation survey, including partners from cities, industry and research institutes.

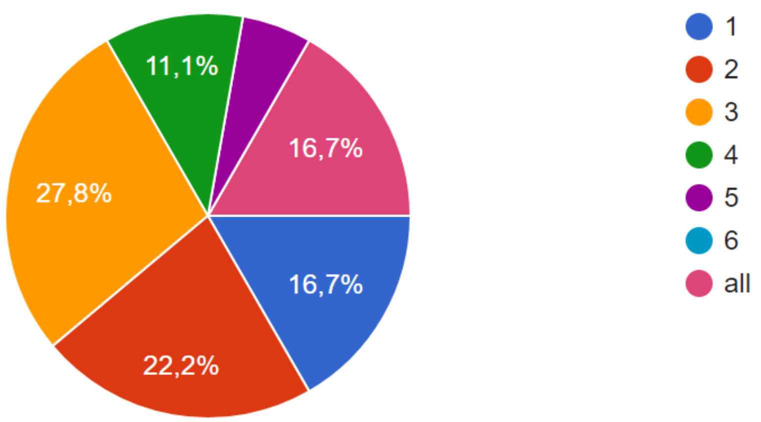


Figure 47: Results to the question "How many webinars did you attend?"[49]

The main results of the evaluation were that almost 70% of the participants were satisfied with the webinars and would recommend to watch the recorded videos available on the official Triangulum website. Also, in terms of knowledge gain the feedback was very positive, as 67% of the participants were convinced to receive the information they expected and 56% plan to apply the knowledge they learned in the webinars. Also, 50% of the participants attended four or more webinars (see Figure 47).

6.2.4 Learnings from the FCTM

All in all, the FC Training Mission was considered a very helpful program in terms of knowledge-transfer. Not only the FCs learned from the LCs, but also the other way round. There was an interesting exchange of knowledge and experience. Nevertheless, following learnings should be considered when conducting a training program like the FCTM.

Regarding the FCs, it is crucial for them to have a target and goal for each session. The outcome of each session depends on a solid preparation of the FCs and the participation of the right people. Not only the order and timing of the different topics should align with the FCs' needs, but also the different formats, like presentations, bilateral sessions, workshops, etc. should allow a direct exchange on the topics and questions delivered by the FCs. The blend of different knowledge-transfer vehicles helped to include a wide variety of different personnel into the process and therefore prevent the „Lone Wolf"-problem.

6.3 FC Implementation Strategies

The task of the FCs in the project was to write an SCIS (Task 6.7) to plan and commit to implementing Smart City Projects in the future. The WP6-Team provided support to the FCs by organizing different sessions and providing information directly linked to the FCs' SCIS.

These included the FC visits, where the cities' project teams together with the Triangulum WP6 research team and their corresponding local ecosystems (e.g. Universities, SMEs and start-ups) developed the initial sets of project ideas (cf. Chapter 6.1). Also, the first workshop of the FCTM (see chapter 6.2.2.1) addressed important topics, including the content, deadlines for feedback loops and templates for the FCs project ideas which should be fulfilled in the FCs Implementations Strategies. Furthermore, the FCs' project ideas were constantly and incrementally developed in each session of the FCTM. The WP6-Team also developed a milestone plan in order to successfully monitor the process of the FCs writing of their SCIS. This milestone plan is depicted in Figure 48.

[49] n=18

Figure 48: Milestone plan FC SCIS

The following sections describe the key principles of an SCIS and include guiding questions which should be addressed when writing an SCIS.

6.3.1 What is a SCIS?

A SCIS is a policy instrument that can be used to respond to policy challenges with innovative actions and technology-based projects. Each SCIS is unique, in terms of local context, theme and coverage. There is no set template.

- Drafting an SCIS is not an administrative exercise. It should be a concrete and useful tool to provide an answer to specific policy challenges and to structure implementation and investments.
- The SCIS is not an end point in itself: using the partnership and stakeholders to make it happen is important; therefore it is recommended to embed the drafting of an SCIS within a wider municipal strategy process.
- There is no 'one size fits all' approach to an SCIS. The content and format will vary depending on the policy challenges or processes being addressed, the territorial coverage and the local context in which it is proposed to be implemented.

One SCIS per FC are key deliverables within Triangulum. The Morgenstadt Framework, which has been applied in Prague, Leipzig and Sabadell provides some guidelines, examples and ideas on what could and should be included within an SCIS as part of the Triangulum project.

6.3.2 Using the Morgenstadt Framework

The Morgenstadt Framework emphasises that clear figures and a structured assessment of data helps gain in-depth insight into the local baseline for becoming a “Smart City”. At the same time the Morgenstadt Framework emphasizes a participative, systemic and stakeholder driven process of drafting an SCIS as collective action for a common goal.

- Ensuring an integrated approach: the SCIS should address the different dimensions of the Smart City, i.e. social, economic, physical and environmental dimensions, and consider the various territorial levels relevant to the solutions to be implemented.
- Using transnational networking with the Triangulum LCs, FCs and industry and research partners for transnational exchange on how to tackle the policy challenges, and how to achieve local benefits through investing into Smart City Technologies and strategies.
- The SCIS is the result of a participative process; it is developed with the stakeholders involved in the local group.

Table 13: Content overview of Smart City Implementation Strategies

Smart City	Implementation	Strategy
• Building on connected technologies and the IoT • Involving the three layers of a Smart City: Governance, socio-economic strategy, Technologies and infrastructures.	• Action oriented • Useful • Specific • In partnership with local stakeholders	• A structured document • Including timing, budget and investments • Task allocation – who does what when?

6.3.3 Co-producing the SCIS

The development and validation of each strategy should be a collective undertaking, designed to strengthen commitment and to increase the prospect of sustainable delivery. Using co-production is the best guarantee for an integrated approach and increases the chances of successful implementation. There are different degrees of participation from information to consultation to co-production.

For producing the Triangulum SCIS a specific action planning cycle has been defined as shown in Figure 49.

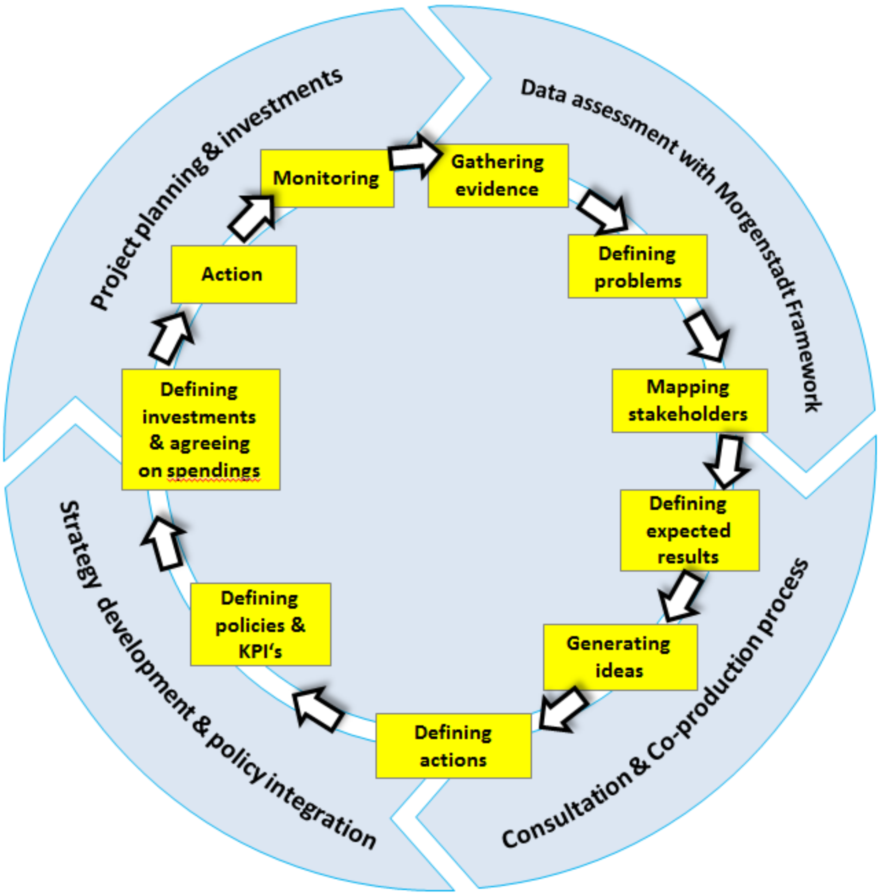


Figure 49: Action planning cycle

6.3.4 Main components of an Integrated Action Strategy

The main components of the SCIS are set out below. This is not an exhaustive list, but an indication of what should be included:

1. Executive summary in English outlining the key points
2. City context and definition of the initial problems / policy challenges
3. Brief overview over the Morgenstadt Methodology and the process
4. Results of data assessment and analysis
5. Actions and schedule
6. Funding scheme
7. Framework for delivery
8. Description of the process
9. Risk analysis

These chapters can include:

1. City context and definition of the initial problem/ policy challenge

Statistical and referenced evidence to demonstrate and define city context and challenges, for example:

- Population statistics and demography
- Location of the city
- Unemployment and employment statistics
- Industrial / employment composition
- Summary of relevant Operational Programmes (ERDF and ESF) covering the city

Current state of play with regard to Smart City development strategy and policies for example:

- Summary of institutional context – roles and responsibilities of different agencies
- Summary of existing strategies and policies relevant to this field (local, regional and national)
- Highlighting why the city decided to invest into Smart City strategies and projects
- Show existing development goals & strategies and how a „Smart City" will contribute to this

2. Brief overview over the Methodology and the process

This part described the general scientific process as described in Chapter 4 and refers to the involved stakeholders and to the specific process in the corresponding city. Interview partners, time frame and scope of assessment, difficulties you encountered etc. Reflection about assessment process and availability of data (indicators & action fields).

3. Results of data assessment and analysis

Top level analysis of indicators w.r.t benchmarks

- Pressure indicators
- State indicators
- Impact indicators

Top level analysis of the Action Fields based on the Morgenstadt Framework

- Governance level
- Socio-economic strategy level (urban innovation)
- Technologies & infrastructures

Analysis of the local impact factors and stakeholder interviews based on the Morgenstadt Framework

- Drivers *(underpin with indicators, action fields, documents and interviews)*
- Barriers *(underpin with indicators, action fields, documents and interviews)*
- Future opportunities *(underpin with indicators, action fields, documents and interviews)*
- Future challenges *(underpin with indicators, action fields, documents and interviews)*
- Ideas for action *(underpin with indicators, action fields, documents and interviews)*

Summary of the analysis, highlighting main findings and leading to the actions.

4. Actions and roadmap

Breakdown of planned activities / actions / projects which will be developed and delivered to help you meet the identified challenges and objectives and achieve results (you may choose to present this by putting different activities "under" the various objectives).

Structuring of activities according to their area of implementation (a) Smart City Governance, b) Socio-economic strategy, c) Technology & Infrastructure – you may chose a different structure!)

Gantt chart or diagram showing how actions interrelate and timetable for investments and projects

Priority list of actions based on the necessity for action, the ability for implementation and the availability of „best practices“ or existing solutions in the LCs that serve for replication purposes.

5. Detailed project plan & funding scheme

For each project with priority one (4 – 8 projects) fill out one project template. This template should include following information:

1) What current problem is the project trying to solve? Detailed explanation of proposed issue.
    - Related MS indicators: list the Morgenstadt indicators that are related to the issue in question
    - Related action fields: list the relevant action fields that are related to the issue in question
    - Related impact factors: list the relevant impact factors that are related to the issue in question
2) DNA of Project
    - Goal/main purpose of the project: What job is the project trying to get done?
    - Core Value of the project: What kind of value does the project create for the city and city stakeholders?
    - Consortium: Who should be partner in this project and why?
3) Minimum viable project
    - Must have: what is the minimal set of solutions to be implemented in order to deliver the core value (DNA) of the project?
    - Should have: what is the extended set if solutions that increases the value of the project to the next level?
    - Could have: What are optimal solutions and components that help us better deliver the project?
4) Process
    - Activities and stakeholder:
        - What activities are actually being proposed?
        - In what sequence and time?
        - Information on who will deliver actions – roles and responsibilities of stakeholders
        - Information on governance during and after Triangulum
    - Technologies: Which technologies are to be implemented in the project?
5) References and replication
    - Similar projects: Please add your references (incl. links and contact person) here. Ideally refer to the solutions from the Triangulum LCs.
    - Product and tools: Add your products and tools that are suitable for getting the project realized.
6) Financing and investment
    - Project costs: What are the expected costs of the proposed project? List budget categories and estimated costs.
    - Financing: How can the project be financed?
        - Summary of potential sources of funding (incl. but not limited to ERDF and ESF)
        - Where possible – include possibilities of innovative financing solutions (co-financing, crowdfunding, etc.)
7) Expected outcomes
    - Measuring success: What indicators are suitable to measure the success of the project?

- City vision: How does the project relate to the larger scale city vision for sustainable urban development?
- Beyond the city: Is there potential for transfer of benefits to other cities? (e.g. through disseminations and replication)

8) Planning and timeline: Please make a suitable Gantt chart and add any information relating to planning of the project
9) Contact details of responsible person for the project

7 Evaluation

The simple goal of the lighthouse projects including Triangulum is to replicate implementations publicly funded in LCs to the FCs. This chapter evaluates the Replication Framework by analysing its impacts on replicated implementation projects within Triangulum. The impact can directly be measured by analysing the FCs' SCIS i.e. the projects being named in them regarding their corresponding linkages to the Triangulum Use Cases. As the FCs have not started implementations, the stated and agreed planning is the only and best way to assess the impact the framework has on replication.

Figure 50 shows once again that the sessions and actions from the FCTM were designed to feed the knowledge from the LCs and the business partners directly into the FCs' SCIS.

Figure 50: Resources from FCTM for FCIS

Table 14 displays the links from the projects that are part of the FCISs for each of the intended implementations. From the 27 projects being part of the strategies at least 22 have a direct link to implementations in the LCs.

This means than more than **80%** of the planned measures originate or are supported by knowledge that has been provided via the Replication Framework.

Table 14: linkages of FC project ideas to LC Use Cases

FC	**FC project idea**	**Link to LC**	**Use Case LC**
Leipzig	Urban Data Platform	Eindhoven & Manchester	The well-equipped and operational open data platforms in Manchester and Eindhoven together with the logic of the ICT Reference Architecture help to focus the efforts during development.
	Baumwollspinnerei – Smart Grids and Energy Storage	all	Energy storage unit in Manchester; Smart Home and public building management via Smart Gateways in Stavanger; Smart Office Management in Eindhoven Strijp-S: Innovative infrastructure
	Baumwollspinnerei – Smart Building	all	Eindhoven: Strijp-S building automation Smart Grid Controller in Manchester Siemens,

			Smart Gateway and corresponding sensors from Stavanger (Lyse), Energetic analysis of public buildings (University buildings, student accommodations (Siemens) in Manchester, Eindhoven Office Management App (Volker Wessels)
	Smart Infrastructure Hub Leipzig		n.a.
	Smart City Tender	Eindhoven	Eindhoven: i-City Tender, Eindhoven innovation fund (TU/e)
	Corporate e-carsharing	Eindhoven & Stavanger	Eindhoven: Corporate e-carsharing Strijp-S/Mobility concept Strijp-S Charging in office-buildings/apartments (Lyse/Stavanger)
	Mobility concept	Manchester	Manchester: Corridor traffic management
	LivingLab Leipzig West	Eindhoven & Manchester	Eindhoven: Strijp-S triple/quadruple helix approach Manchester: LivingLab from the University of Manchester
	Digitisation strategy City of Leipzig		n.a.
	Smart City participation process and working structures	Eindhoven	Eindhoven: The City of Eindhoven made changes in their administrative structures to become the centre of the Brainport region and to enable innovation development in the city. Manchester and Stavanger: Strategic Smart City teams
Sabadell	Digital horizontal platform for real-time data integration	Stavanger & Eindhoven	Eindhoven: Data Hub Stavanger: Smart City data platform of platforms
	Videoconference applied to municipal services (home care & culture)	Stavanger & Manchester	Stavanger: Lyse (Blink) Manchester: Cityverve
	Digital platform for shared spaces/resources + Maker space in connection with the circular economy		No explicit link, it’s an idea originated at the first on-site assessment in Sabadell. In Eindhoven we were presented a similar project for resource sharing via Facebook (Ms. Lara Tamarinof from the nearby city of Helmond). In the first on-site assessment in Eindhoven in October 2015, we visited a “Repair café” which is similar with the project of Maker space we intend to develop.
	City beacons (Interactive screens in the public space in crowded areas)	Eindhoven & Manchester	Eindhoven: City beacon Manchester: Cityverve

	Renewal of municipal fleet of vehicles with sustainability criteria	No explicit link, but indirectly Manchester and Eindhoven	Manchester: Corporate electric car-sharing for university Leasing electric vans for state management Eindhoven: Station-bound district car sharing
	Application of energy efficiency measures to existing residential buildings	Mainly Eindhoven	Renovation of semi-attached homes of housing association using WoonConnect tool Wind energy for common areas of apartment building
	Innovative public lighting adapted to the natural periurban environment, festivities/commemorations, decorative purposes, running circuits	Eindhoven	Public sound sensor safety project in Strijp-S Sound sensor for vehicle operation safety Public sound sensor safety project in Stratumseind Smart lighting in Strijp-S Unidirectional functional lighting in Eckart Smart interactive floor light for walking and running in Eckart
	Public governance of energy at local/county scale	Stavanger, but it is not included as a Triangulum Use Case Nottingham, part of SCC1 “Sharing cities” project (quoted by Manchester as a good British example)	Lyse’s model of governance, as public utility providing energy services to the Rogaland county
	Start-up companies acceleration programme + Adapted “I-city” tender [50]	Eindhoven	Although not included in the booklet as a Use Case, during the FC Days, meetings took place on “Innovative financial instruments”, “How to attract start-ups and investors in the city”, “Set up an energy and Smart City accelerator for start-ups”, and “Capital-risk funds/contests for innovative projects of start-ups”.
Prague	System for support of integrated care	all LCs	smart and innovative Use Cases
	Service portal for senior citizens	Eindhoven & Manchester	Collectively inspired by ICT infrastructure deployed in Manchester and Eindhoven (urban and open data platforms) + by the platform initiatives by Fraunhofer (BABLE and Smart Society Academy)
	Extended emergency care	Stavanger & Manchester	welfare technologies from Helsehuset (Helsehuset) + innovative video for distance

[50] name of action may change according to final content

		health care and for communication services (Lyse); smart health and social care (CityVerve)
Smart home for senior citizens	all	Smart Gateway for homes and for nursing homes (Lyse); Smart Energy offices, smart control of individual rooms and individual floors in existing buildings (Volker Wessels), sensors in public buildings for energy improvements (Siemens)
Electric mobility for social services and seniors	all	electrical vehicle public fast-charging infrastructre + electrical vehicle private home charging infrastructure; e-vehicles and e-buses; use of e-vehicles for social services (Lyse+ Stavanger) + public charinging infrastructure Strijp-S) Volker Wessels) distribution, e-bike fright distribution, last mile deliveries (Manchester)
Mobility of senior citizens	all LCs	smart and innovative projects on smart mobility Use Cases
Update of Prague´s 3D model	Eindhoven + cities not connected to Triangulum	knowledge exchange about the 3D models of the cities and spatial data in connection to the project during the FC Days in Eindhoven (City of Eindhoven)

8 Conclusions and next steps

The deliverable “Smart City Framework” plays an important role in order to ensure the replication of existing solutions from LCs to the FCs. As previously described, two of the main goals of work package 6 in Triangulum are to design a Replication Framework as well as a Decision making tool for Smart City Project development and implementation.

In section three of this particular deliverable we presented the necessity of such a Smart City Framework and the Morgenstadt methodology, on which the Smart City Framework was based upon. The following section outlined the designed methodology, which was split into two different approaches that were presented and evaluated in section five and section six respectively. Chapter five elaborated in detail the application and evaluation of our designed approach whereas section six focused on the customer centric approach.

During the exchange between LCs, FCs and research, the team of work package 6 came up with three very important realizations that will be elaborated in the following paragraphs.

PROCESS LEARNING IS CRUCIAL: With regards to the replication of Smart City solution from LCs to FCs, the process and organisational competencies being transferred are more important than the actual knowledge about technologies. The FCTM has shown that sparking ideas for replication and implementation in FCs arise most intensively indirect, moderated and targeted interactions between partners. Using the right mixture of different vehicles i.e. workshops, webinars and site visits is crucial to targeted knowledge transfer. It is important to include implementation and knowledge gained within the LCs but outside the project for partners to receive a full picture of the strategy and deployment within cities. A strong focus has to be put on the involvement of the right personnel within the replicating cities to ensure information being distributed in the organisation and/or city. The Triangulum partners have managed to do so.

IMPLEMENTATIONS EVOLVE TO PRODUCE MUCH MORE INSIGHTS THAN EXPECTED BY THE WP6 TEAM: the impact and variety of lessons learned is much higher than expected. During the early implementation phase, it was planned to implement about 20 different technological solutions within Triangulum. During the project many technologies have been adopted and repackaged in order to build the basis for additional applications. The actual implementations show insights into more than 50 different Use Cases, each one with a new comprehension of processes, lessons learned and of practical learning on applicability and scale-up. Using the right stakeholder engagement methods simplifies the process and ensures high levels of participation with all partners involved. Some implementations have particularly exceeded the expectations. Overarching tools and methods such as the ICT Reference Architecture were used to map the Use Cases with regards to protocols for data transfer and standardized layers. This process supported significantly understanding and systematic collection of information.

THE PROJECT TRIGGERS ADDITIONAL ACTIONS TO SUPPORT SMART CITY DEVELOPMENTS: the project Triangulum has triggered actions of many partners that enhance the scope of the project-tasks. Those are however helping to significantly boost the generation of a Smart City market in Europe. The company Lyse for example has found new application areas for its Smart Gateway technology, the Smart City tender in Eindhoven has delivered 8 innovations that could not only transform the corresponding lighthouse district Strijp-S but could have an impact far beyond. The University in Manchester has bought additional electric vehicles to enlarge the fleet provided by Triangulum. Several cities and companies have successfully bid for additional national and international projects of which the Manchester based “CityVerve” and the EU-funded “UNaLab” (incl. Stavanger, Prague and Eindhoven) are only the most prominent ones. In addition, parts of the ICT Reference Architecture that was previously presented and was developed within work package 6 contributed to standardization efforts such as the “*Memorandum of Understanding: Towards Open Urban Platforms for Smart Cities and Communities*“, as well as the German standard “*DIN SPEC 91357: Reference Architecture Model Open Urban Platform (OUP)*”.

With respect to next steps, the team of work package 6 had a lot of fruitful discussions with the whole consortium and realised that there is still need for further support and knowledge transfer between the partners. The consortium came up with an initial list of further activities that should be tackled in the following months. Some examples are the knowledge transfer of ICT Reference Architecture and its benefits to the local stakeholders in the city of Leipzig or knowledge transfer between the research institutes. The team of work package 6 will gladly support whenever their help is needed.

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