

SYNCHRONICITY



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Executive Summary

As one of the EU IoT Large Scale Pilot projects, the SynchroniCity project represents the first attempt to deliver a Single Digital City Market for Europe by piloting its foundations at scale in reference zones across 8 European cities, and other cities globally. It addresses how to incentivise and build trust for companies and other stakeholders to actively participate in finding common co-created IoT solutions for cities that meet citizen needs and to create an environment of evidence-based solutions that can easily be replicated in other regions. Further, SynchroniCity aims to synchronise existing IoT-enabled smart city ecosystems in Europe by removing barriers of fragmentation and misalignment that currently sets them apart. It will pilot the necessary building blocks and drivers for change to foster an environment that will contribute towards technical, legal and socio-economic harmonization of the European smart city market.

This deliverable evaluates the impact of the SynchroniCity project and introduces methodology to be used in future IoT deployments.

In the first section, the impact evaluation looks at firstly, what kind of ecosystem was built during the SynchroniCity project. It describes the activities to increase the awareness of SynchroniCity and illustrates the nature of the created ecosystem. It shows that the number of Open Call applications exceeded the expectations and included a number of new cities and SMEs interested in joining SynchroniCity through the Open Call. During the project, the SynchroniCity ecosystem broadened as partners with different roles joined, for example there was a major increase in the number of ICT/IoT partners. Secondly, it reports what validated services were implemented during the project and what was their use. In addition, it looks at the replication potential as well as the perceived value of the services. Third, the IoT infrastructure development is evaluated by looking at the creation and consumption of the open data sets as well as the perceptions of the quality of the open data and the improved interoperability.

In the second section, the Performance in Use (PIU) Framework describes a methodology that can be used to evaluate the impact of IoT deployments. At this level, the focus is on the measurable change the technology deployment has had on the user and citizens at large. This report provides an overarching framework for carrying out impact assessment on IoT deployments of large-scale innovation programmes such as SynchroniCity. Key principles and concepts underlying robust impact assessment described in this report can be used for future impact assessments.

Abbreviations

AI	Artificial Intelligence
D	Deliverable
DESI	The Digital Economy and Society Index
DoA	SynchroniCity Description of Action
EC	European Commission
FCC	Future Cities Catapult
IoT	Internet of Things
KPI	Key Performance Indicator
LCA	Life-Cycle Assessment
M	Month
MIM	Minimal Interoperability Mechanisms
PIA	Privacy Impact Assessment
PIU	Performance In Use
RZ	Reference Zone
SME	Small and medium-sized Enterprise
U4SCC	United for Smart Sustainable Cities
WP	Work Package
WT	Work Task

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1 Introduction

The objective of Work Package 6 (WP6) – Impact and Sustainability is to build upon the technological and socio-economic breakthroughs established in the reference zones and smart city standards created through the project and to demonstrate how, together, they will form a successful European ecosystem for smart city solutions.

The four different work tasks of WP6 contribute to impact and sustainability from their own perspectives (Task 6.1 on exploitation and sustainability, Task 6.2 on standardization, Task 6.3 on communication). Task 6.4 focuses on impact evaluation.

This report has three sections:

SECTION I focuses on impact evaluation of the SynchroniCity project with the selected indicators and explains the methodology of selecting the relevant indicators.

SECTION II introduces Performance in Use (PIU), a framework for investigating economic, social and environmental aspects of urban innovation projects, and discusses its potential to be used in future IoT deployments. Both of the main sections are summarised in the end of each section (section 6 for impact evaluation and sections 11 and 12 for PIU).

SECTION III presents the overall conclusions in section 13.

1.1 Smart City Indicator Systems

Several indicator systems exist to measure and evaluate the impact of implemented smart city projects. Different systems focus on different aspects, therefore, evaluators need to select the focus based on the needs and goals. Table 1 below illustrates the different types of indicators used for different stages of smart city development.

Table 1. Indicator typology in regards to key stages in smart sustainable city transformation (Huovila et al., 2019)

Type of indicator	What is measured?	Type of assessment	When to use?
Input	Resources needed for interventions	Planning	Planning of needed resources to achieve some goal
Process	Implementation of activities	Quality assessment on means of implementation	Evaluation of implementation
Output	Effectiveness of implementation	Short-term monitoring	Reporting on immediate progress of implementation
Outcome	To which extent did the activities reach their objectives?	Mid-term evaluation	Reporting on intermediate results (e.g. adoption rate of urban solutions)
Impact	What was achieved by the interventions?	Long-term evaluation	Reporting on real impacts or overall performance

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The first section of this report and the indicators of the SynchroniCity KPI framework represent mainly output indicators, representing short-term monitoring and reporting immediate progress of implementation (cf. Huovila et al., 2019). Despite the aim of projects like SynchroniCity to create real impact, these impacts are rarely to be evaluated during the project life span but can only be observed in long-term evaluation activities. The second section of this report reaches out to the economic, social and environmental impacts by introducing the PIU framework.

1.2 The Context of SynchroniCity

SynchroniCity is an IoT large scale pilot which aims to deliver a single digital market starting in Europe and then expanding to other regions throughout the world. Its main premise is for IoT-enabled services and domains to be more easily procured across cities via an innovative, standards-based approach. The key themes of replicability, scalability and interoperability tie the project together.

After the Minimal Interoperability Mechanisms (MIMs) were developed in the first stage of the SynchroniCity project, the core cities and project partners of the project developed Atomic Services which used this new standards-based approach framework.

The internal pilots were created collaboratively by the technical partners and the core cities (also known as reference zones) commencing in the earlier stages of SynchroniCity, and make use of the Atomic Services. The Atomic Services implemented a single functionality, representing building blocks for the more comprehensive smart city services. Atomic Services are agnostic to the application and these initial applications were used among three application themes: human-centred traffic management, multi-modal transportation, and community policy suite. These were created and built by the SynchroniCity consortium partners. The initial applications are later in this report referred to as Internal pilots. Currently the Atomic Services are openly offered to external parties (that is, SynchroniCity pilots and other projects), and the community using the framework is continuing to grow.

Following this internal validation of the MIMs, an open call for market-ready solutions was undertaken and 16 SME-lead consortium groups were awarded funding to deploy their solutions across the SynchroniCity core cities – Antwerp, Carouge, Eindhoven, Helsinki, Manchester, Milan, Porto, and Santander. Subsequently, new cities joined through the open call pilot groups using the SynchroniCity framework. These consortium groups are in this report referred to as Open Call pilots. In the Open Call pilots, 16 market-ready solutions received funding to deploy their solutions in different cities (both core and new cities). They were made up of a combination of single applicants and multi-applicants, mostly SMEs and some larger businesses. For more information on the pilots please refer to the *D5.6 Report on the Selected SME projects - delivery and lessons learnt*.

2 SECTION I: SynchroniCity Impact Evaluation

The impact evaluation work is based on the KPI framework (D6.3 KPI Framework) that was built on previous knowledge on smart city indicators. D6.3 KPI Framework reflects the CITYKeys framework (Bosch & Jongeneel, 2016) and the U4SCC -indicators (United 4 Smart Sustainable Cities. Collection Methodology for Performance Indicators for Smart Sustainable Cities) as key references for SynchroniCity indicators.

1.1 DESI Local

The Digital Economy and Society Index (DESI) looks at Europe's digital performance on 5 dimensions: Connectivity, Human Capital, Use of Internet, Integration of Digital Technology and, Digital Public Services (<https://digital-agenda-data.eu/datasets/desi/visualizations>).

Recent development linked to DESI is the DESI local, which with the same 5 dimensions, reaches the local level with the effort of developing and implementing the DESI local indicators to measure and monitor the benefits for the public, local authorities, businesses and other stakeholders at local level.

DESI local includes three groups of indicators: Local Services Action Cluster, Local Economy Action Cluster and, Local Democracy Initiative. While the SynchroniCity KPI framework was built on the previous smart city frameworks and indicators (D6.3 KPI Framework), the ongoing initiative DESI local will reach out to evaluate similar issues. The examples of DESI local indicators in the table below (Table 2) are linked with SynchroniCity indicators.

Table 2. DESI indicators and links with SynchroniCity indicators

DESI Cluster of indicators	Example of indicator with a link to SynchroniCity indicators
Local Services Action Cluster	Availability of sensors in the city
Local Economy Action Cluster	Number of ICT companies joined as cluster member in any cluster organized in the city
Local Democracy Initiative	Availability of open datasets

1.2 Cross-LSP KPI Work /Create-IoT

In the Create-IoT project, impact measurement domains were aggregated into four main domains, which are shown in table below (Table 3).

Table 3. Create-IoT Horizontal KPIs (D.2.03 "Common methodologies and KPIs for design, testing and validation, CREATE IoT, June 2018)

Horizontal KPI domains:
1. IoT Technology and standards validation, up-scaling, replicability and sustainability;
2: Business opportunities, economic, environmental and societal impacts
3. Ecosystem openness, development and value chain actors' involvement
4: General acceptability, user validation, perceived value and benefits

The SynchroniCity indicators fall in these domains. In this report, especially one of the domains, ecosystem openness development and value chain actors' involvement proved valuable in SynchroniCity impact evaluation. This indicator, looking at the different stakeholders' involvement and the area they represent, was used to evaluate how much the ecosystem development was promoted through the involvement of different kinds of stakeholders.

1.3 SynchroniCity Focus

People, Planet and Prosperity as generally accepted bottom lines in the development of indicators systems (Huovila, Bosch & Airaksinen, 2019). In the SynchroniCity project, the bottom lines of smart city projects (People, Planet and Prosperity) form the basis and are included in the application themes of the Atomic Services: Human Centric Traffic Management, Multimodal Transportation and, Community Policy Suite (D3.6 Customized IoT service prototypes for lead ref. zones – advanced). Further, the bottom lines can be seen in the foci of the Open Call pilots, as the below figure shows.

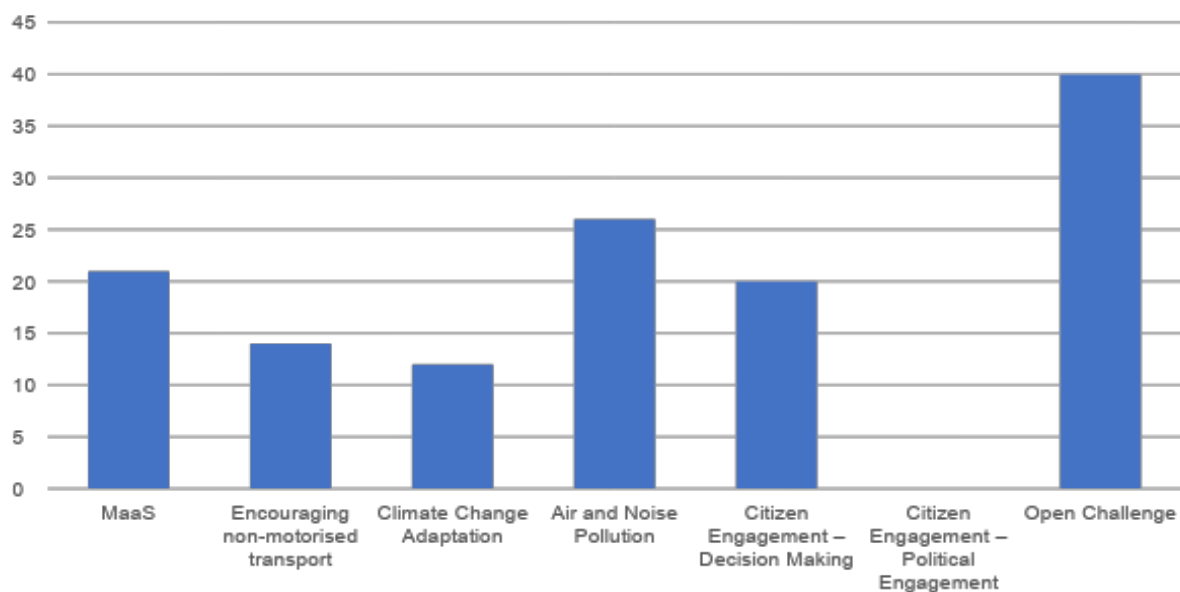


Figure 1. The different challenges of the SynchroniCity Open Call (SynchroniCity general slide set)

Further, the challenges represented in the final selected and implemented Open Call pilots (Figure 2, below) show that all the aspects were covered.

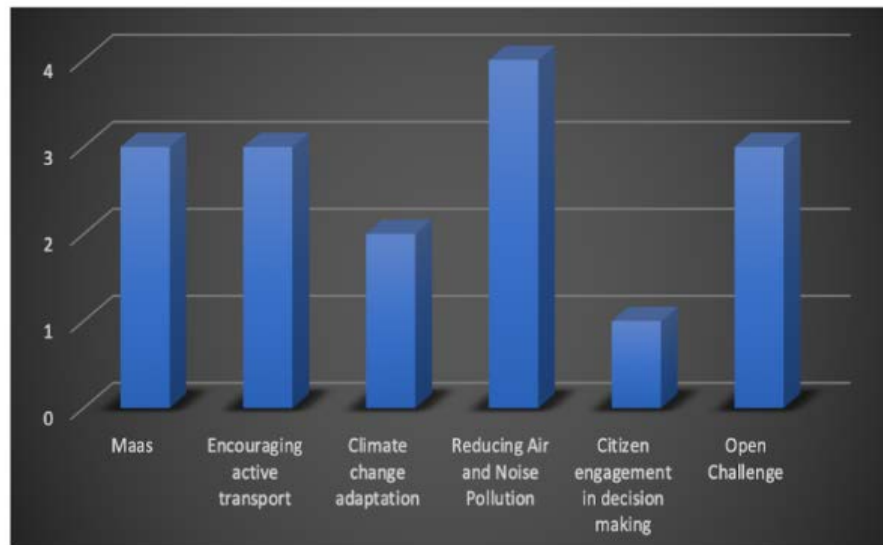


Figure 2. The challenges in the final selected Open Call pilots (SynchroniCity general slide set)

1.4 SynchroniCity Indicators

As described in SynchroniCity Description of Action, the project set the following objectives (DoA, part B):

“To establish the technical foundations of a digital single market for IoT-enabled smart cities in Europe and beyond, where IoT device manufacturers, system integrators and solution providers can innovate and compete in an open environment.”

“To provide a set of advanced marketplace enablers that increase the confidence of businesses and individuals in sharing and consuming IoT based data and other data sources, in order to enable the emergence of a richer marketplace and integration tools that lower barriers for participation.”

“To establish reference zone environments for the large-scale experimentation with co-created, scalable and replicable IoT-enabled citizen-centric services around the created marketplace in eight European cities that are at the forefront of European smart city development, connected to global reference zones.”

“To pilot IoT-enabled services that directly address citizen needs and enable breakthroughs in several high-impact areas, starting with human-centric traffic management, multimodal mobility, community-based policy making, in order to establish proof-points of the proposed marketplace mechanisms for others to follow.”

“To establish and grow a thriving open innovation ecosystem around the proposed digital single smart city marketplace that empowers SMEs and entrepreneurs to deliver successful business cases at European scale and beyond.”

“To provide set of methodologies, processes and guidelines that empower IoT technology and smart city service providers to better design solutions to address citizen needs around the marketplace.”

“To establish a framework that enables a holistic quantification of the real value of IoT-enabled smart city interventions that considers economic, environmental and social benefits, while providing a tool that allows tracking and monitoring of the effectiveness during pilot periods and beyond.”

“To provide insights into new business model opportunities enabled by the marketplace through the generation of secondary revenue streams from IoT infrastructure investments and enabled multi-sided platform ecosystem constellations.”

“To empower cities to digitally transform their policy-making and urban planning processes by introducing more agility through IoT-based data-driven evidence and adoption of common information models.”

The objectives can be compacted in three overarching aims:

1. Ecosystem building
2. Services and the value created
3. IoT Infrastructure development

16 indicators were selected to evaluate the impact of the SynchroniCity project. The indicators are listed in the table below (Table 4). In the following chapters (3-5), these indicators are reported under the identified three overarching aims: Ecosystem building; Services and the value created; and IoT infrastructure development.

Table 4. SynchroniCity KPIs

KPI	Description	Aim
Awareness impact	Target groups that have been reached and/or are activated by the project	Ecosystem building
Co-creation (Participatory governance)	Share of population participating in the service definition	
SME involved	Number of SMEs involved in all the process in all the pilots	
Partners' engagement	Number of local ecosystem partners involved in the project during its lifecycle, in all the pilots	
Local Job creation	Jobs created by the project	
New follower city members/interested	Number of new follower cities or interested decision makers	
Service implementation	Number of services implemented during the project lifecycle.	Services and the value created
Citizen-Centred	Number of users of the services	
Replication potential	Number of replicated services during the project lifecycle.	

Perceived value from the citizens	Perceived value for the end users and citizens involved	
Perceived value from the local government and decision makers involved	Perceived value for the local government and decision makers involved	
Data privacy	The level of data protection by the city	
IoT connected devices	Number of IoT connected devices implemented during the project lifecycle in all the pilots	IoT infrastructure development
Open data sets	Number open data sets in use	
Quality of open data	The extent to which the quality of the open data produced by the project was increased	
Improved interoperability	The extent to which the project has increased interoperability between infrastructures,	

1.5 Methodology

The following describes the methodology used in the impact evaluation. It comprises work package deliverables and other data collected during the project. Both quantitative and qualitative data were used.

Work packages and their deliverables and other material contributing to impact evaluation:

WP1. As part of Work Package 1, a monitoring framework was conducted throughout the project to monitor the RZ activities. The monitoring framework collected RZ's perspectives of the project activities, including the KPIs (D1.7 Monitoring framework template 2; D1.8 Monitoring framework template 3)

WP2. D2.7 Catalogue of IoT devices ready for Smart City platforms integration

WP3. Work Package 3 focused on the Atomic Services. The deliverables D3.3 Suite of atomic implementations - advanced; D3.6 Customized IoT service prototypes for lead ref. zones - advanced; D3.8 Report on reference zones IoT service deployment, provided information for the impact evaluation.

WP4. Work Package 4 deals with the validation in terms of architecture, services, user acceptance, market and replication. The deliverables of WP4 contributed to impact evaluation and especially, the deliverables D4.3 Technical Validation (Phase 2); D4.4 Assessment on the user, stakeholder, replication and market validation; D4.5 Technical Validation of the SME projects.

WP5. The activities of Work Package 5 focused on the open call of the project. Its materials and deliverables (D5.3 Open call dissemination report; slide set of the project) were used in impact evaluation. As part of WP5, the pilot reporting collected the Open Call pilot perspectives twice during the pilot phase (M3 and M6), including the KPIs (for the templates, see D5.6 Report on the selected SME projects delivery and lessons learnt).

WP6. One of the tasks in work package 6 was communications, the deliverables of which (D6.10 1st Report on Communication, Dissemination and Marketing activities; D6.11 2nd report on communication, dissemination and marketing activities; D6.12 3rd report on communication, dissemination and marketing activities) were used in impact evaluation. In T6.4, the initial framework (D6.3 KPI Framework) served as the initial plan for impact evaluation. A survey for RZ leads was conducted in M18 to get their perspectives on the perceived value. This was later merged into the monitoring framework (see WP1 description). At the London bootcamp, the new Open Call pilot companies' perceptions of the firms' business models were collected with a questionnaire (M0). The new cities' perspectives of the project were collected with a questionnaire after the pilot phase was finished (M34). T6.4 also collected information about the partners' roles in the project.

3 Ecosystem Building

This chapter evaluates the activities around the SynchroniCity ecosystem. It describes what has been done to increase the awareness of SynchroniCity and illustrates the nature of the created ecosystem. This means, who were the partners involved and how their inclusion was supported. That is, the chapter reports the following indicators: Awareness impact; Participatory governance; SME involved; Partners' engagement; Local job creation and New follower city members/interested.

3.1 Awareness Impact

This indicator aims to capture the awareness impact made by the project. That is, it describes what target groups and to what extent, have been reached. For the project period before the SynchroniCity Open Call, the aim of the activities to increase awareness of SynchroniCity was clear: To build such a set-up (communication strategy, tools & channels) that would reach a satisfactory amount and quality of Open Call applications (D6.10 1st Report on Communication, Dissemination and Marketing activities; D6.11 2nd report on communication, dissemination and marketing activities). Target groups of communications activities were small and medium-sized enterprises, large companies and cities. The percentages of the reached target groups couldn't be measured. However, based on the results of the Open Call, it can be evaluated as successful. The result of 133 applications with 227 SMEs and 45 new cities exceeded the expectation of reaching 100 in the number of applications (D5.3 Open call dissemination report).

In the latter project period, after the Open Call, the communication strategy shifted along the project focus. Instead of reaching specific target groups, the awareness-increasing activities were focused on empowering SynchroniCity partners to build ownership of SynchroniCity and ensure sustainability after the project. First, communication support services were offered to help the Open Call pilots' own dissemination as a business and in the relevant local context of the pilots. D5.6 presents the full list of support services provided to all 16 Open Call pilots before, during, and after their pilot period. Second, based on the pilot outcomes, the overall communication strategy shifted back to its policy maker audience and set itself the goals of creating content to last beyond the project life. This also meant a return of emphasis on the project as a whole through its own content creation and social media. Albeit with an emphasis on high-quality engaging content - instead of content to ensure a daily, constant presence - that aligns with long-term exploitation objectives (e.g. focus on high-profile events, promotion of project results on G20 Global Smart City Alliance, preparation work for "Join, Boost, Sustain" Declaration). The final comms deliverable (D6.12 3rd report on communication, dissemination and marketing activities) shows how this strategy was realized and why this strategy was successful. From the impact evaluation perspective, this meant that the original indicator (percentage of people reached) was no longer valid. Instead, the impact can be evaluated based on the realisation of the strategy.

3.2 Co-creation

The original indicator ‘participatory governance’ refers to the engagement of the users in the service definition. In general, the core idea of participatory governance is to increase the citizens’ participation in the decision-making of a city or community. In the context of the SynchroniCity project, this refers to the aim of creating IoT-enabled services for and with the citizens. As the majority of the users in the pilots were organizational users, we use the term co-creation instead of participatory governance.

Co-creation looks at the collaborative development of different actors. In the SynchroniCity project, co-creation was conducted at different phases of the project (for further description, see D4.4 Assessment on the user, stakeholder, replication and market validation). This means, that the co-creation methodology was used both in internal and Open Call pilots. The internal pilots refer to the pilots with RZs and the Open Call pilots to those in which the new partners were involved.

To evaluate the impact of co-creation activities, we look at to what extent were the co-creation tasks accomplished in the different pilots. It is to be noted that the original expectation with this indicator referred to the percentage of citizens participating, and after the scoping of the pilots this was no longer a valid to be measured. Therefore, a description of the co-creation tasks is provided for an understanding of the impact through co-creation. When looking at the co-creation tasks in the different pilots we see that in the Internal pilots, five of the eight RZs accomplished a reachable percentage of accomplished tasks or exceeded the minimum level, which is shown in figure below (Figure 3).

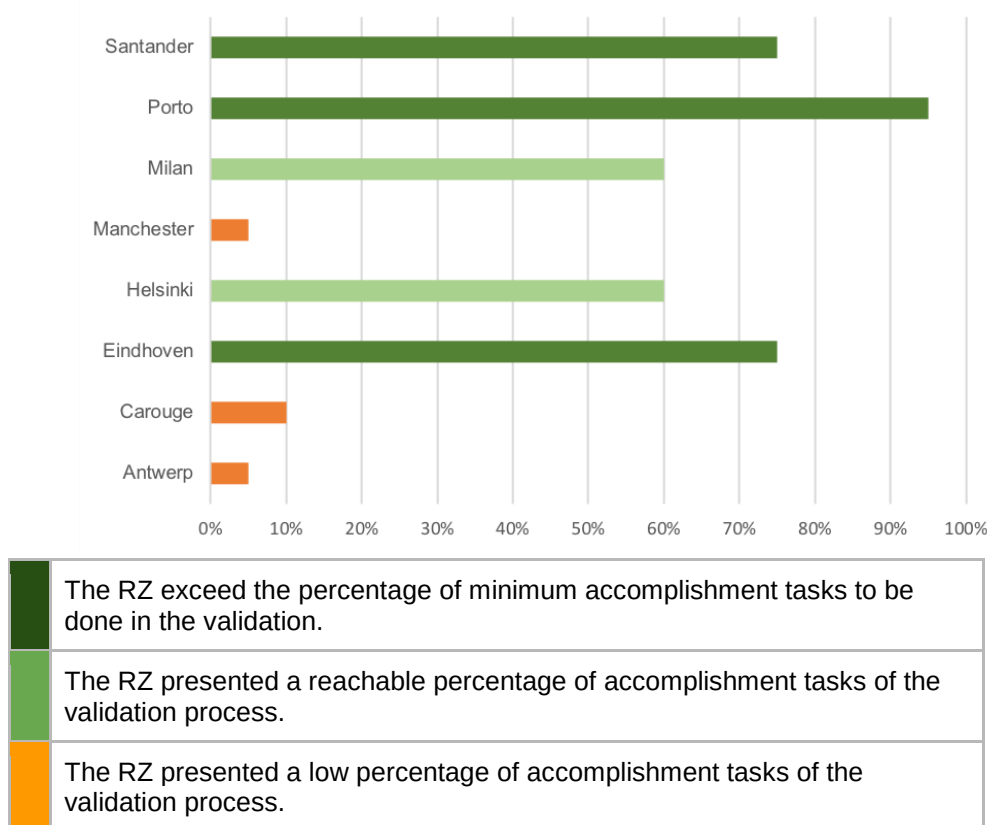


Figure 3. Percentage of Toolkit tasks' accomplishment for Internal pilots (D4.4 Assessment on the user, stakeholder, replication and market validation)

Regarding the Open Call pilots, six of the 16 pilots exceeded the minimum level of accomplishment, as the figure below shows (Figure 4). Three pilots showed a low percentage of accomplishment and seven report 0% of accomplishment.

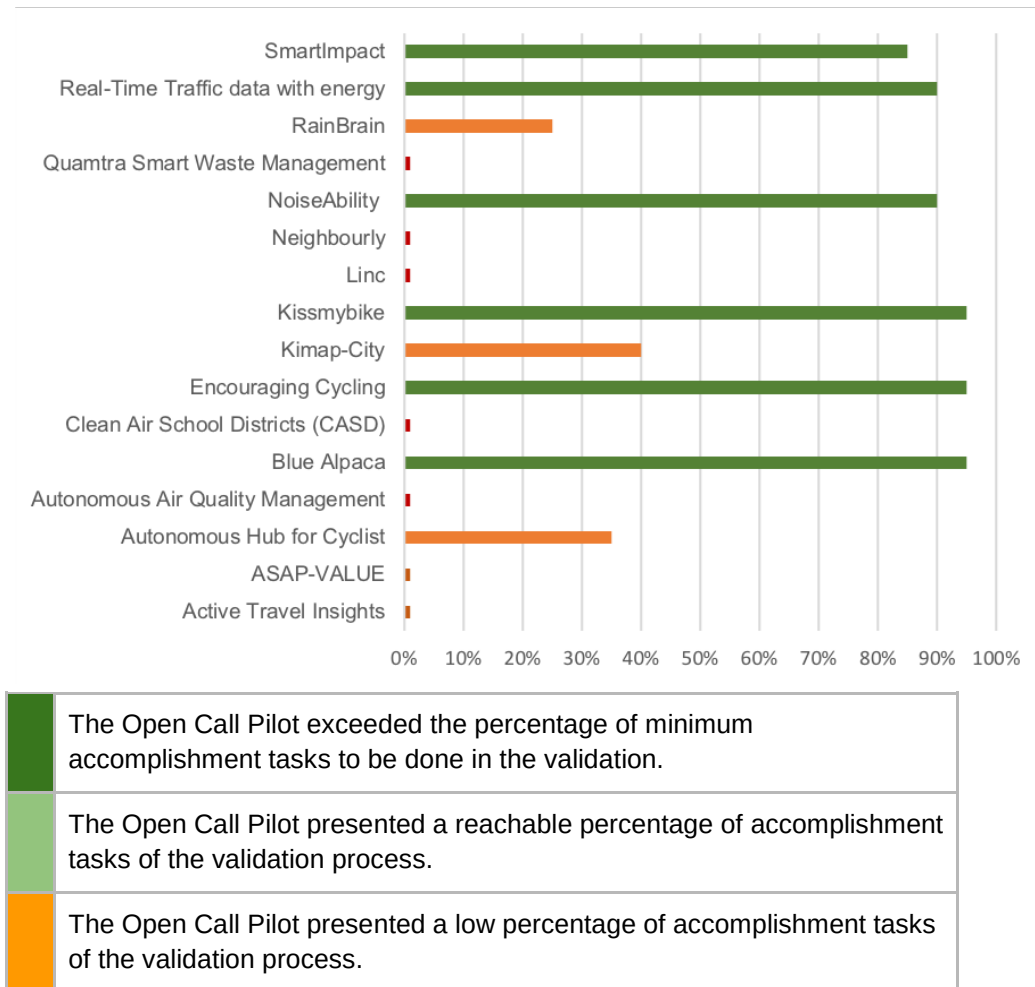


Figure 4. Percentage of Toolkit tasks' accomplishment for Internal pilots (D4.4 Assessment on the user, stakeholder, replication and market validation)

Table 5 (below) summarizes to what extent the co-creation tasks were accomplished in the pilots. As the numbers show, the percentage is higher in Internal pilots, where 62,5% of the tasks were accomplished.

Table 5. The percentages of reachable level of co-creation tasks in pilots (D4.4)

Pilot type	Percentage of reachable level of co-creation tasks
Internal pilots	62,5 %
Open Call pilots	37,5 %

An additional perspective on co-creation is to look at how did the pilot solutions change during the co-creation. The data come from D4.4 Assessment on the user, stakeholder, replication and market validation and includes respondents (N=11) from both pilot types. The first figure (Figure 5) illustrates the number of features or functionalities that were added to the pilot solution to fit end-user needs. It shows that the majority of respondent pilots added features based on co-creation activities. With an average of 1,55 added features, the highest amount was five and the lowest was zero.

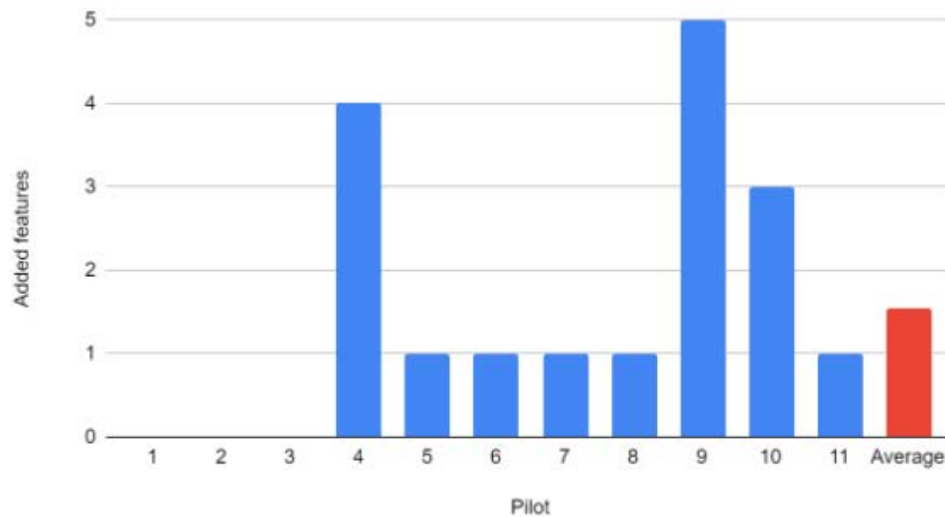


Figure 5. The number of added features to fit end-user needs (D4.4 Assessment on the user, stakeholder, replication and market validation)

The second figure (Figure 6) visualizes the number of features or functionalities that were changed or improved during the pilot project in order to fit end-user needs. As with the previous figure, we can see that for the majority of the pilots, co-creation led to changing or improving functionalities in the pilot solution. With an average of 1,91 changed or improved features, the highest amount was nine and the lowest was zero.

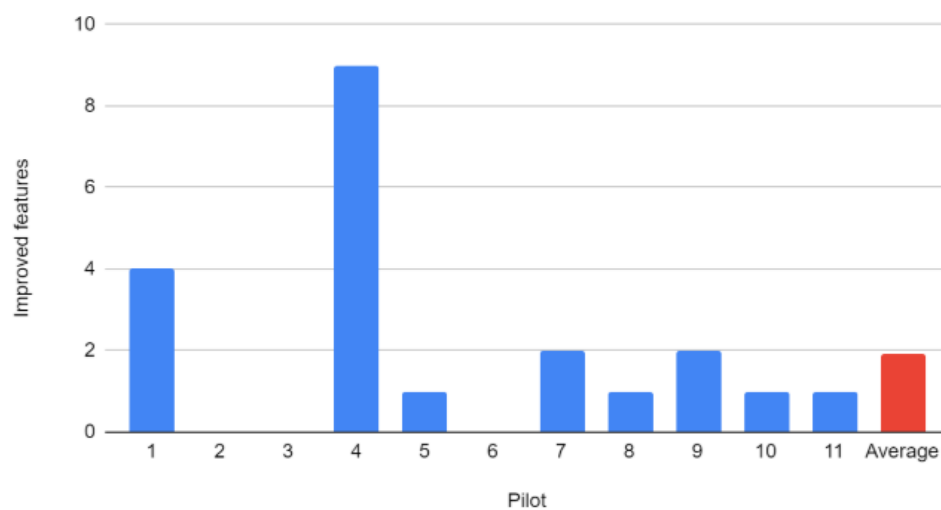


Figure 6. The number of changed or improved features to fit end-user needs (D4.4 Assessment on the user, stakeholder, replication and market validation).

Accordingly, the third figure (Figure 7) gives a perspective on the number of eliminated features or functionalities to fit end-user needs. The figure shows that only four of the pilots who responded eliminated features or functionalities from their pilot solution based on co-creation. With an average of 1,18 eliminated features and significant variance, the highest number was ten and the lowest was zero. The majority (64 %) of the pilot solutions did not consider eliminating pilot features necessary.

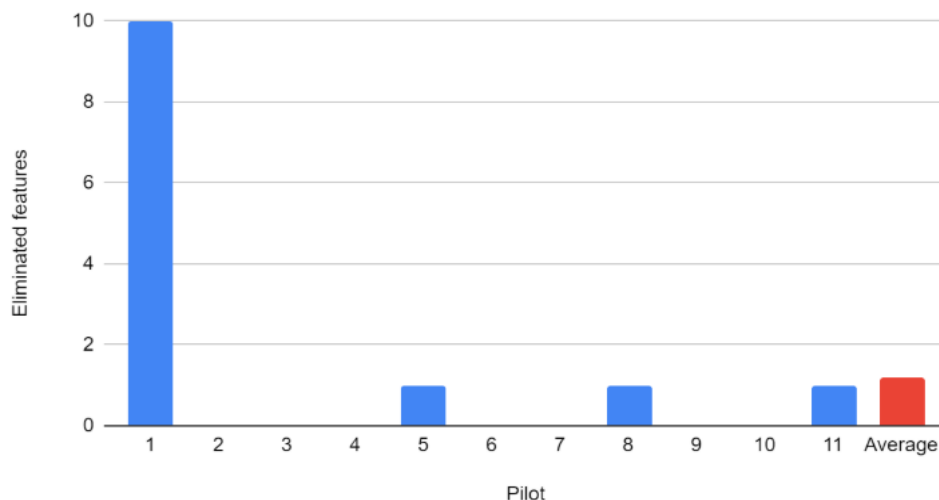


Figure 7. The number of eliminated features to fit end-user needs (D4.4)

3.3 SME Involved

This indicator refers to the number of SMEs¹ involved in all the processes in all the pilots. The Open Call applications involved 227 SMEs, who would have wanted to join SynchroniCity. As such, this already exceeds the expectations (100). In the selected and implemented Open Call pilots, the number of SMEs involved was 28 (M6 reporting). Additional ten SMEs (subcontractors or local partners of the cities) can be identified in the Internal pilots (D3.8 Report on reference zones IoT service deployment), resulting in 38 actively involved SMEs in the different pilots.

3.4 Partners' Engagement in the SynchroniCity Ecosystem

This indicator seeks to evaluate the ecosystem created during the project. Therefore, an indicator looking at the number of ecosystem actors involved was defined. However, additional understanding is provided by examining the nature of the ecosystem created. The illustration below (Figure 8) shows the variety of partners included in the ecosystem, ranging from software providers to education institutions.

¹ Following the EU recommendation 2003/361, small and medium-sized enterprises (SMEs) are defined as firms as 1. Staff headcount <250 and 2. Turnover ≤ € 50 m or Balance sheet total ≤ € 43 m (<http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition>).

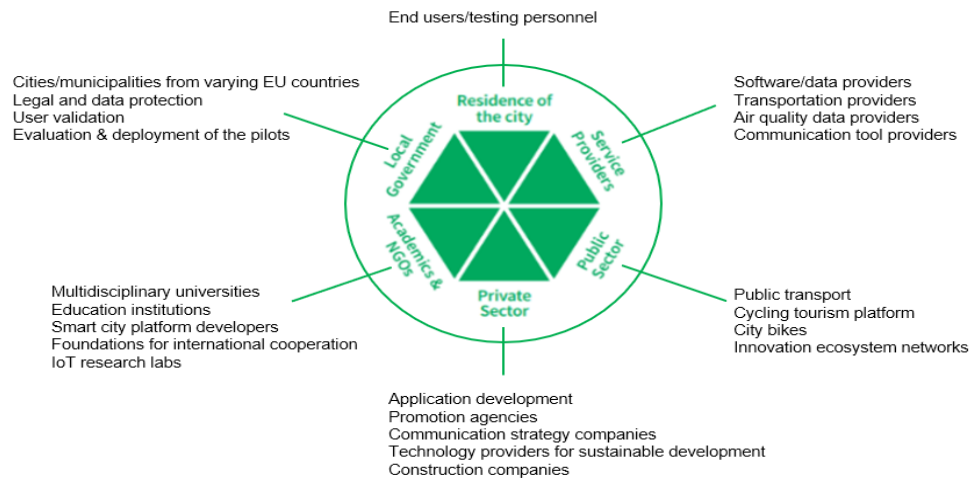


Figure 8. Diversity of SynchroniCity ecosystem partners (T6.4 data collection)

A further classification of the roles the ecosystem partners played is provided by the cross-LSP-KPI framework by the Create-IoT project. It differentiates the following stakeholders: R&D; ICT/IoT provider; Technology provider; End user; Other. Under the ICT/IoT provider category, there are 3 subcategories (Infrastructure provider, Connectivity provider, Software/App provider). The Other-category includes Strategy and Engagement (Figure 9.)

R&D	ICT/IoT provider				Technology provider	End users	Other		
	Infrastructure provider	Connectivity provider	Software/app provider	IT service provider	device provider		Other	Strategy	Engagement

Figure 9. The partner categorization (following the Create-IoT categories; T6.4 data collection)

Instead of acting in only one role, it was rather typical for partners to act in more than one role (Figure 10). For example, a partner may have identified themselves acting as both infrastructure providers as connectivity providers. Almost half of the partners acted in one role during the project while the rest identified two or more roles.

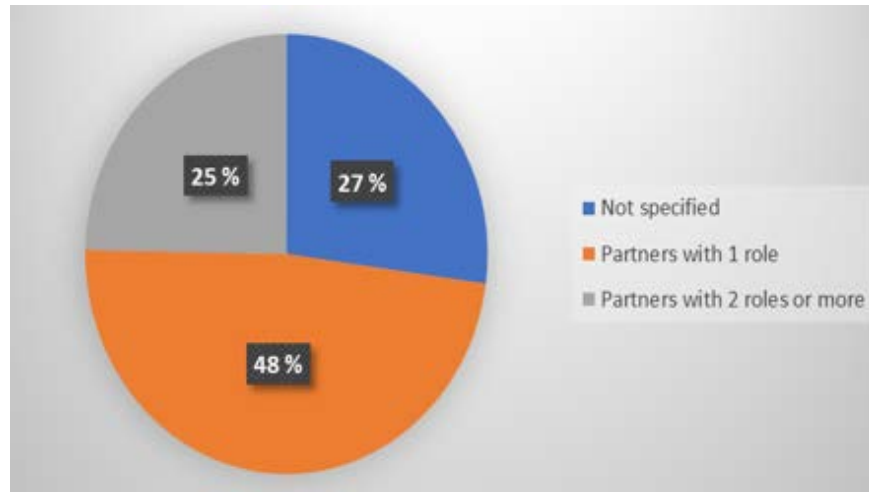


Figure 10. Illustration on the number of different roles in the ecosystem partners' contribution (T6.4 data collection)

The distribution of the roles between the categories (Figure 11) shows that 37 % of the partners represented the role of ICT/IoT providers. The smallest representation was by Technology/Device providers whereas the representation of the rest of the categories was quite the same size.

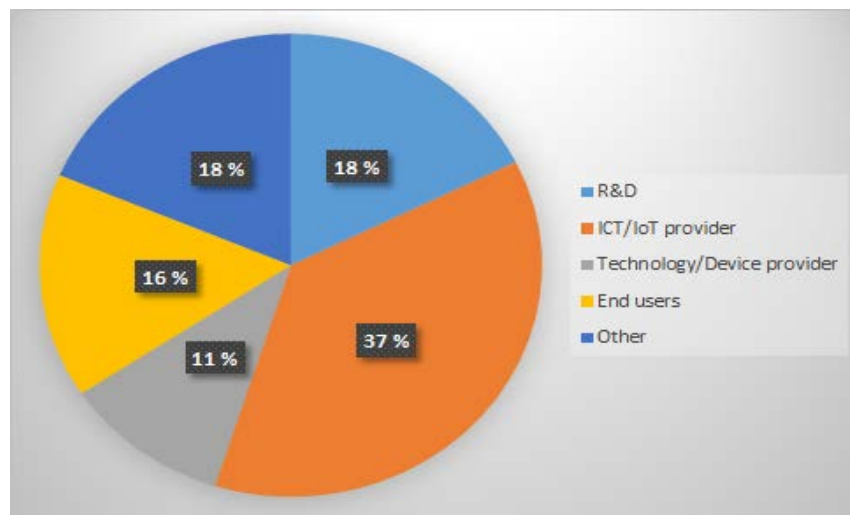


Figure 11. The different roles in the SynchroniCity ecosystem (T6.4 data collection)

A further look at the ICT/Infrastructure provider category (Figure 12) shows that the most typical role was the software/app provider with 45%. IT service providers (with 26%) and infrastructure providers (with 24%) were the second largest roles involved whereas the connectivity providers (5%) were the least represented role within the category of ICT/IoT provider.

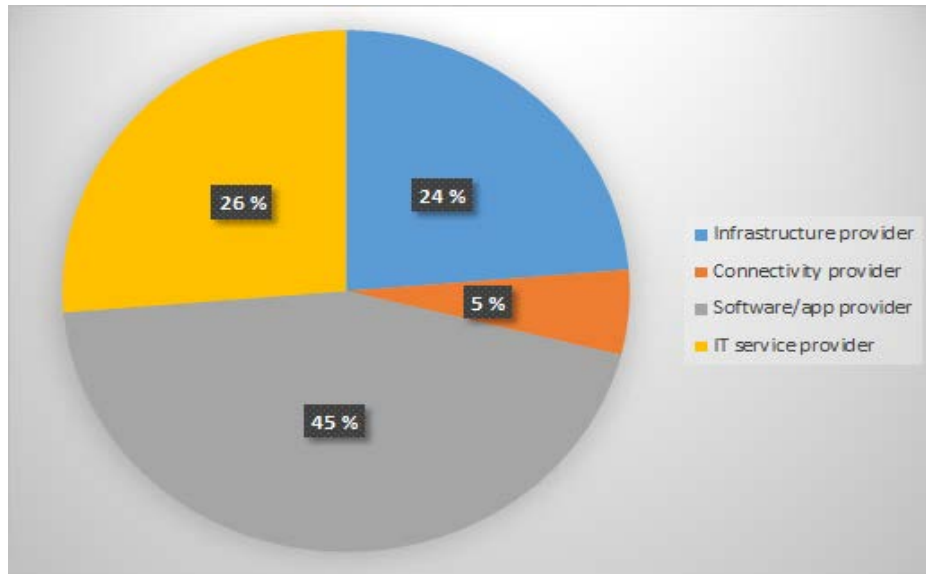


Figure 12. Distribution of the "ICT/IoT provider" subcategory (T6.4 data collection)

Finally, we can aim at counting the number of ecosystem partners. In the beginning, there were a total of 34 partners involved in the SynchroniCity project. The ecosystem was later expanded to 91 organisations. The number of partners thus had a relative increase of 168 %. The figure below (Figure 13) shows that especially the number of ICT/IoT providers increased significantly. The proportional increases in the different categories are presented in the table below (Table 6).

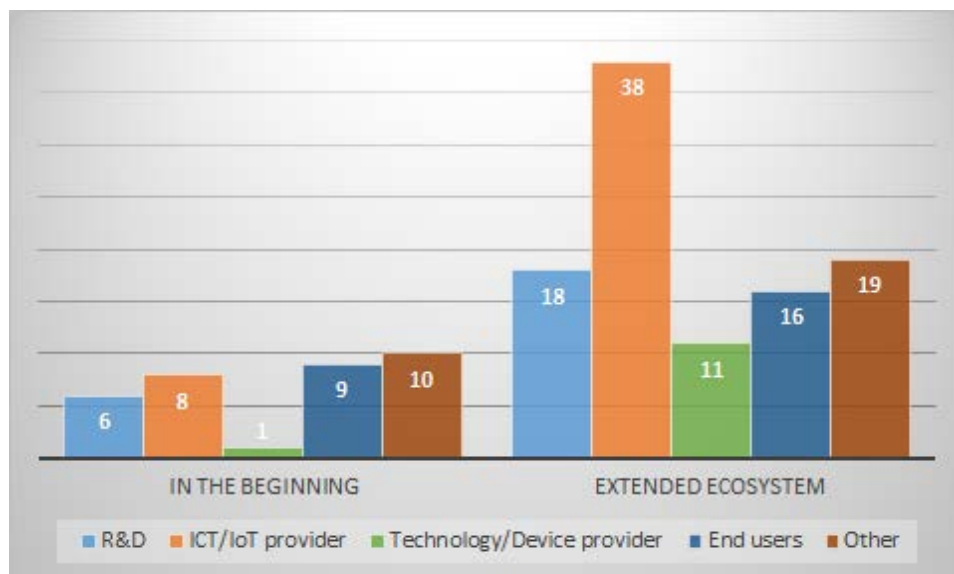


Figure 13. The number of organizations in the beginning of the projects compared to the later extended ecosystem (T6.4 data collection)

Table 6. The ecosystem extension during the projects illustrated (T6.4 data collection)

Category	R&D	ICT/IoT provider	Technology/ Device provider	End users	Other
In the beginning	6	8	1	9	10
Extended ecosystem	18	38	11	16	19
Increase-%	200 %	375 %	1000 %	78 %	90 %

However, we can reach a bigger number of ecosystem partners when including those who were not in contractual relationship with SynchroniCity, but acted for example as subcontractors for the pilot companies. A representative example of this is the number of ecosystem partners involved in the Open Call pilots. The pilots reported that there were a total of 123 ecosystem partners involved in the 16 pilots. The following description from the pilot final reporting characterises the dynamics of the ecosystem and its evolution:

“Furthermore, we have realized the need to involve local partners (electricians, ESCOs) to execute the installation works in order to prevent scalability bottlenecks. To this end, we are now working with a number of local partners to develop distribution and training procedures.”

3.5 Local Job Creation

This KPI refers to the number of jobs created by the project. The evaluation of the number of jobs created is based on the information from the monitoring frameworks (M18, M24) and the Open Call pilot reporting (M3, M6). Altogether, 37 jobs were reported to be created. The RZs reported 22 jobs created and the Open Call pilots 15.

3.6 New Follower Cities

This KPI refers to the number of new follower cities or interested decision makers. Two perspectives provide the main points for evaluating the number of new follower cities. First, the interest shown by those who applied for the Open Call funding can be evaluated as a strong sign of interest. During the Open Call phase, 45 new cities were interested in joining SynchroniCity (D5.3 Open Call dissemination report). Second, the active involvement of those who were part of the winning applications and the implemented Open Call pilots can be looked at. The number of new cities actively involved in the Open Call pilots was 13. The expectations were set at eight new cities, which was exceeded.

It is to be noted that here we focus now on the active participation in project pilots (Figure 14 below illustrates the potential variation in the levels of interest). In addition to this, countless interactions with new cities have taken place during the project, raising the awareness and interest in SynchroniCity. For example, in each round of the Monitoring Framework, the Reference Zone Leads were asked about their interactions with other cities and whether they would name some cities as interested in SynchroniCity. These inquiries revealed dozens of interactions with new cities interested in SynchroniCity. One of the most visible signs of interest among cities is the declaration “Joining Forces to Boost Digital Transformation in Europe's Cities and Communities”, which will be signed in January 2020 in Porto.

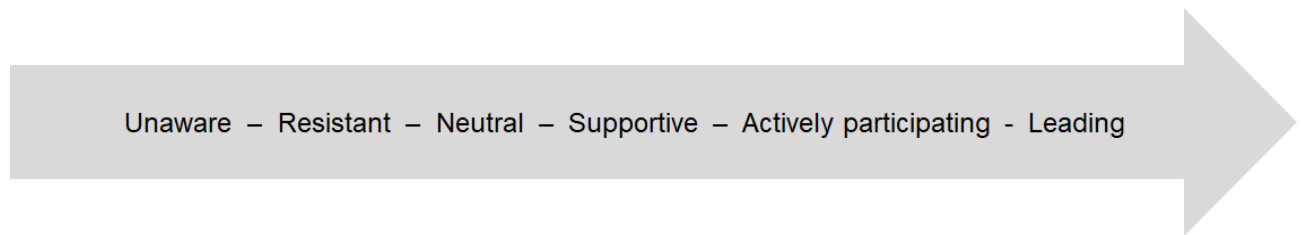


Figure 14. The levels of interest

4 Services and the Value Created

This chapter reports what validated services were implemented during the project and what was their use. In addition, the replication potential as well as the perceived value of the services are looked at. Thus, the following indicators are included: Number of services implemented during the project lifecycle; Number of users of the services; Number of replicated services during the project lifecycle; Perceived value for the end users and citizens involved and; Perceived value for the local government and decision makers involved.

4.1 Services Implemented During the Project

This report covers the validated services created during the SynchroniCity project, Atomic Services and the Open Call pilot services. It is to be noted that other services were provided during the project, too. For example, the IoT Product and IoT Data Marketplace (see for example D2.7 Catalogue of IoT devices ready for Smart City platforms integration) are examples of the services not included in this report.

During the project, eight validated Atomic Services were created (see also Cirillo et al., 2019). The validated Atomic Services are described in the table below (Table 7). It is to be noted that the development of the Atomic Services continued also after the initial phase and therefore, the number of the validated, developed and deployed services differs. A recent article on this development reports 15 Atomic Services that were deployed in 25 RZ applications (Cirillo et al., submitted). The adoption of the Atomic Services in the internal pilots will be covered in chapter 4.3. (for more information of the deployed use cases in D3.8 Report on reference zones IoT service deployment and operations).

Table 7. Validated Atomic Services (D4 3 Technical validation (phase 2))

AtomicService Name	Description
Routing	Open Trip Planner (OTP) [16] based, provides the end-user with multimodal routes, considering data about bus and taxi stops, city bikes and bicycling routes, plus disruption information.
Parking Prob. Estimator	Using Artificial Intelligence techniques, it predicts the probability of finding a free parking spot within a particular area of a RZ in 15, 30, 45 and 60 minutes.
Traffic Flow Estimator	By exploiting traffic flow sensors, it trains a model that predicts the intensity of traffic in the next hour, giving a slotted array of outputs (i.e. 15, 30, 45 and 60 minutes).

SmartCity Dashboard	User-friendly interface that visualises the devices (location and relevant information) that compose the SynchroniCity deployment in a Reference Zone.
Metrics Visualizer	Custom deployment of Grafana [17] software working on top of SynchroniCity framework, exploiting all the dashboard creation capabilities of this software.
GTFS Fetcher	Component that fetches GTFS files (static timetables and related info) from NGSI GtfsTransitFeedFile SynchroniCity context entities and loads them into the SynchroniCity Routing AS.
NGSI Urban Mob. 2 GTFS	Converts Urban Mobility NGSI entities to GTFS feed format, performing the inverse mapping done when defining the NGSI counterpart.
GTFS-RT Loader from NGSI	Consumes information from SynchroniCity ArrivalEstimation and GtfsTransitFeedFile data models to generate compliant GTFS-RT feeds.

The Open Call pilots implemented 16 services with 50 IoT deployments. Included below (Table 8) is a list of each pilot group, the challenge area they responded to, the organizations involved and their submitted description of their solution and service.

Table 8. Open Call pilot services (D5.6 Report on the Selected SME projects - delivery and lessons learnt.)

Pilot title Challenge Organisations involved	Description of pilot solution
Active Travel Insights Encouraging non-motorised (active) transport Vivacity Labs Ltd iSensing Limited Tracsis Traffic Data Ltd	Piloted in cities: Antwerp, Helsinki and Manchester. Active Travel Insights is a first-of-a-kind project, amalgamating data feeds from our sensors and comparative open data provided by the cities, to provide insights into how the routes of interest in each city are being used by modes of non-motorised transport. Active Travel Insights provides a detailed understanding of cyclist, pedestrian and vehicle movements across each city through the amalgamation of open, real-time and cutting-edge data. The solution combines data feeds from three types of sensors (Vivacity sensors, iSensing sensors, and air quality sensors) with comparative open-air quality data provided by the partner cities where available.
ASAP-VALUE: A Standards-based AProach to enhancing VALUE from city data lake Open Challenge Sensinov	Piloted in cities: Bordeaux, Carouge and Seongnam ASAP-Value is a data lake converging city data from different sources and exposing it to application developers through a standardised API to encourage application proliferation for Smart Cities. Sensinov offers a city data lake, consisting of hot pluggable connectors paving the way for a single standards-based API to encourage entrepreneurs to take part in a citizen-centric journey by leveraging high quality data and building applications. The data is enriched with contextual information and exposed according to NGSI-LD standards APIs developed by ETSI ISG CIM. A smart mobility application is deployed to demonstrate the benefits access to IoT data through an open data API. ASAP-Value has made a significant part of its development available as an open source,

	namely djane.io with the ambition to encourage other contributors as well as replication across cities.
Autonomous Hub for Cyclist Enabling Mobility as a Service (MaaS) <i>Intelligent Parking S.L.</i> <i>La factoría Bike-In S.L.</i> <i>TuryBike Emotion S.L.</i> <i>CITY La Nucía Municipality</i> <i>Eurovelo</i> <i>CITY of Donegal (Ireland)</i>	Piloted in cities: Bezana, Donegal, La Nucia, Palencia, Santander and Tarrasa Autonomous Hub for Cyclist is an App-based solution, with the objective to develop a network of safe parking for residents, which facilitates mobility by private bicycle storage through the city. Its features are: • Autonomous generation and consumption of energy using photovoltaic panels, aero-generator and support of batteries • Safe intelligent parking – connected, safe and with video-surveillance • 10 bike capacity • Easy installation • Environmental sensors • Sharing cargo e-bike • Self-maintenance for bikes • PVerde App The solution has validated the SynchroniCity vision and the technical framework as we have used data from the SynchroniCity platform, facilitation and ensuring the replicability and scalability of the solution in different Synchronicity-based cities. Other agreements are being made with other European Cities. The pilot started in TRL6 and has reached TRL9 with a full system testbed and operational in real environments.
Autonomous Real-Time Field Service Solution for Public Real Estate Air Quality Management Reducing Air and Noise Pollution <i>Multi-Agent Technology Ltd</i> <i>Metosin Ltd</i> <i>City of Tampere</i>	Piloted in cities: Helsinki, Santander and Tampere Autonomous Air Quality Management (AAQM) is a full-cycle solution to enhance air quality in public premises and buildings. AAQM helps improve the quality of life of citizens while bringing cost-saving solutions for cities. AAQM provides a full-cycle solution autonomously integrating all necessary phases: • Collecting building air quality data via sensors • Applying relevant open data for analytics in the planning process • Providing automatic alerts and maintenance tasks, including scheduling and resource selection for required maintenance operations • Executing follow-up and reporting requirements. To enable this whole cycle, we combine Internet of Things, analytics and autonomous artificial intelligence in our solution. Alongside a high-tech approach, our solution features a user-friendly game style experience making the solution extremely easy to use. Benefits for citizens: • Clear and easy to understand facts on the quality of their air • Responsive and improved air quality management. Benefits for cities: • Improved efficiency and service level in public space maintenance services • Holistic view, situational awareness in real-time • Less personnel on sick leave via improved air quality • Cost savings through: autonomous planning, optimal resource selection, improved action and reaction to issues around property management, and maximising the lifecycle of properties and therefore ensuring the highest return in use of real estate investment.
BlueAlpaca	Piloted in cities: Antwerp, Helsinki, Milan and Santander

Open Challenge <i>U-Hopper srl</i>	BlueAlpaca is a pilot project that aims to assess the technical replicability and scalability of a conversational information service (chatbot), developed by the Italian tech company U-Hopper, that enables rich interactions between the public administration and its citizens and makes information and smart city services easily accessible. The proposed solution offers smart cities a truly human-centred service with a lower total cost of ownership, unlocking innovation potential and lowering the entry barrier for cities to experiment with chatbot services. Similarly, citizens can benefit from timely information access, 24/7 multi-channel availability, no need to install any app, and faster, engaging interaction. The implementation involves the development and launch of different chatbots across four European cities, covering different use cases. BlueAlpaca in Helsinki and Antwerp provides suggestions and warnings related to air quality; in Santander, it supports access to the city bike sharing service; in Milan, BlueAlpaca facilitates access to public services online.
Clean Air School Districts (CASD) Reducing Air and Noise Pollution <i>Leapcraft ApS</i>	Piloted in cities: Antwerp, Carouge and Helsinki Clean Air School Districts utilises the deep sensing technology offered by Leapcraft's flagship environment sensors AmbiNode and CphSense in the context of a school and its classrooms to understand and solve the problem of poor indoor climate in classrooms. For the project, an activity kit for schoolteachers, including teaching material and smartphone app to incorporate environmental data in real-time into their classroom activities has been developed. A view of the dashboard is available as a public screen with live data on local air quality and noise to be installed in the school. This is designed to raise awareness and also display scores (leaderboard) from classroom activities and games designed to minimise air quality and noise issues. A cloud software tool for the city enables multiple stakeholders to share a common view of the data, run impact assessment models and benchmark the data against various classrooms and neighbourhoods.
Encouraging Cycling through use of Crowdsourced Data-Driven Insights (See.Sense Smart Cycling) Encouraging non-motorised (active) transport <i>See.Sense (Limeforge Ltd)</i> <i>BT</i> <i>Dublin City</i>	Piloted in cities: Antwerp, Dublin and Manchester See.Sense and BT delivered an innovative smart cycling project providing cities with new, crowdsourced mobility insights into travel patterns and the use of city infrastructure with the overarching aim of encouraging growth in active travel. The project engaged 800 citizens in the collection of cycling data (including near real-time location of journeys, speed, dwell time, road surface quality, collisions and qualitative survey data) gathered through the See.Sense bike lights and companion app. This data has been analysed and visualised in the BT DataHub, alongside other data sets that the cities hold. The pilot will also seek to contribute to the development of a new International Standard for cycling data, to be developed and applied in conjunction with Cycling Industries Europe (CIE).
Kimap-City Enabling Mobility as a Service (MaaS) <i>Kinoa s.r.l.</i> <i>ReteSviluppo s.c.</i>	Piloted in cities: Milan, Porto and Santander Kimap-City aims to remove the information barriers around accessibility of public transports by providing citizens with detailed accessibility maps, so they can better plan their movements. Kimap-City will provide citizens with a Map Visualization service, containing information on the accessibility level of streets, sidewalks and bus/tram/metro stops related to specific areas of the city. Our solution will help all the citizens affected by motor disabilities or by limited mobility capacity (e.g. old people), to find out which parts of the city are accessible for them and which public transports best fit their conditions. Kimap-City will be the first European accessibility portal of its kind, available in 5 languages and capable to scale-up and include more cities across the continent.

Kissmybike Enabling Mobility as a Service (MaaS) KMB Lab srl Actum4 Innovation SL	Piloted in cities: Antwerp, Milan and Santander Kissmybike is an IoT tracking device designed specifically for bicycles. Kissmybike enables the KMB Lab's Micromobility optimization platform – a solution for cities and micromobility operators, that improves city transportation system based on tracking data collected from bicycles. The tracking data analysis shows the patterns of bicycle usage by real cyclists in the city and allows optimization of micromobility fleet management and improvement of city infrastructure to meet the real needs of cyclists, e.g. determination of best places for cycling paths and parking racks. By closing the gap between current conditions of urban infrastructure and cyclists' real needs, we can encourage more and more people to use bicycles (and other non-motorised transport) instead of cars. KMB Lab's Micromobility optimization platform has been successfully deployed in our pilot cities.
Linc Open Challenge Linc Systems ApS	Piloted in cities: Carouge, Milan and Porto Linc has developed an IoT device that performs a detailed, real-time analysis of electricity consumption in any type of building – down to individual appliances and building systems. It helps identify inefficient operations, malfunctioning equipment, the selection of optimal tariff plans, and the integration of renewable generation. Linc's building energy management solution is available as an ultra-low-cost service with no upfront costs. It is compatible with all residential, commercial, and industrial buildings, new or old, and can be installed by an electrician in less than 40 minutes. Linc saves on energy costs and reduces carbon emissions by as much as 30%. Our SynchroniCity pilot has been deployed in our pilot cities and provides city planners and facility managers with an urban-scale overview of their municipal buildings. Based on data and learnings from these pilots, we are scaling up this solution into a specialised platform for smart-cities building management (www.linc.city).
Neighbourly™: A Smart City Platform Citizen Engagement: Increasing citizen engagement in decision making Wastehero Everimpact	Piloted in cities: Herning, Manchester, Porto and Santander. Neighbourly is a smart city platform that shows the impact of waste production and recycling on a city's environment, at the level of each neighbourhood. Our solution proposes an intelligent use of the available waste and CO₂ data that citizens produce to better shape the planning of their neighbourhood with local authorities. The goal of Neighbourly is to provide cities with a practical solution to encourage citizens to recycle more waste, leading to an improvement in a city's carbon footprint and environment. What's unique about our pilot is that we're using data that's already readily available (weight ticket/truck routes and satellite CO₂). Neighbourly solves citizen engagement for cities, by allowing them to concentrate their efforts on areas with the most need.
NoiseAbility Environment & Wellbeing: Noise pollution UrbanTide Limited The Lunar Works Ltd City of Bilbao - Bilbao TIK City of Edinburgh Council	Piloted in cities: Bilbao, Edinburgh and Eindhoven. Our vision for NoiseAbility is to demonstrate that cities can holistically incorporate noise measurement into their management of urban spaces for improving liveability. This project pilots the capacity for cities to understand noise in the context of the citizen's perceived level of noise acceptability, using IoT at the heart of citizen-centric engagement with noise; and with intelligent data at the core of city-based multi-layered responses. By linking noise monitoring to other city and citizen-centric data via USMART – a data integration platform – and to the acceptability of noise to specific citizen 'personas', we can unleash a powerful predictive tool for noise planning, linked to other strategic city objectives.

Quamtra Smart Waste Management Open Challenge Wellness Telecom, SL Ayuntamiento de Calatayud	Piloted in cities: Calatayud, Carouge and Porto Through the project Quamtra, Smart Waste Management, Wellness Telecom and the Municipality of Calatayud aim to foster innovation in the area of public and private interest in waste management by demonstrating the IoT technologies with potential to optimize current EU waste management operational methodologies and to establish a way forward for the standard adoption of a more sustainable model. Currently, the waste collection of solid urban waste is considered a non-optimized public service in the cities, based on predefined routes causing unnecessary energy and economic costs (e.g. empty containers collected, non-optimized routes), as well as an over or underutilization of the equipment. The Synchronicity Project brings to the consortium an excellent opportunity to test a solution which is capable of reducing the problems related to waste management, offering an optimized waste collection service. For this, we pilot a system that allows reducing the frequency of collection based on the level of filling of containers and bins. An optimized waste collection service results in lower investment and lower impact derived from the effects of externalities from collection operations (pollutant emissions, odours, noise, energy consumption)
RainBrain Climate Change Adaptation Sumaqua bvba Greenbeat Agilis AS	Piloted in cities: Antwerp and Eindhoven Green roofs are an important climate adaptation tool for cities. They manage rainwater, reduce floods, increase biodiversity and can even clean the air. However, extreme weather gives green roofs a hard time: extreme temperatures and long periods of drought have a devastating impact on the vegetation, limiting the positive impact of green roofs. RainBrain tackles this problem by optimizing the water availability in and around green roofs. The system monitors the vegetation health, watering needs and available water. RainBrain combines sensors, actuators and IoT with predictive models and open data. When plants need water, RainBrain automatically waters the green roof and if a heavy rainfall event is predicted that could lead to floods, RainBrain empties water buffers proactively to create more storage capacity. RainBrain is rolled out in our pilot cities together with an app to monitor green roof health and watering needs.
Real-time traffic data with energy savings on street lights Enabling Mobility as a Service (MaaS) SixSq Schröder S.A.	Piloted in cities: Antwerp and Porto This pilot leverages real-time traffic data to provide added-value services in the fields of adaptive lighting, environmental monitoring, traffic optimization, and public safety. Schröder and SixSq have developed the Volumlight solution, which optimizes street lighting based on traffic volume. With this system, lighting levels are continuously updated to reflect real-time traffic patterns, providing savings during periods of low circulation and ensuring safety at all times. Volumlight has a dynamic edge computing nature which allows for a continuous management of its data processing software. Therefore, this solution can be adapted, remotely and in real-time, to be compliant with other types of traffic data sources and data exchange platforms (like SynchroniCity). This pilot has been deployed in our pilot cities, and successfully integrated with SynchroniCity's framework, allowing for an easy exploitation of the collected traffic data in other uses cases, such as: mobility, traffic categorization, traffic analysis and traffic data visualization
SmartImpact Reducing Air and Noise Pollution	Piloted in cities: Carouge, Novi Sad and Santander SmartImpact provides IoT enabled service for the management of impact of urban development projects and public city activities by providing impartial evidence, real-time feedback and engagement between involved stakeholders such as city authorities, construction firms, entertainment venue operators and affected citizens. The impact

DNET Labs PUC Informatika ORBIWISE SA ALU MARKOM COM	measurement as a service provides unique opportunity for the municipality to assess the influence of different entities on the related pollution in the city. The service goal is to solve air quality and noise-related issues in the deployed cities.
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4.2 Users of the Services

This indicator focuses on the users of the services developed in SynchroniCity. The original focus was on the number of users of the services, however, while looking at this, the question of who the users are, became at least as relevant for the understanding of the impact created. The Atomic Services were developed with the RZs so no further analysis of the number of the users is included (for further information of the use cases in RZs, see D3.8 Report on reference zones IoT service deployment and operations).

As to the users of the Open Call pilot services, the pilots reported that the number of users in all the 16 pilots was 57500 (M6 reporting). There were some challenges in measuring the number of users due to the nature of different groups and thus varying reporting units; cars per day, citizens, organisations. Nevertheless, the end result was 57 500 users in total (but obviously a significantly higher amount of people were connected with the solutions; more in the following section).

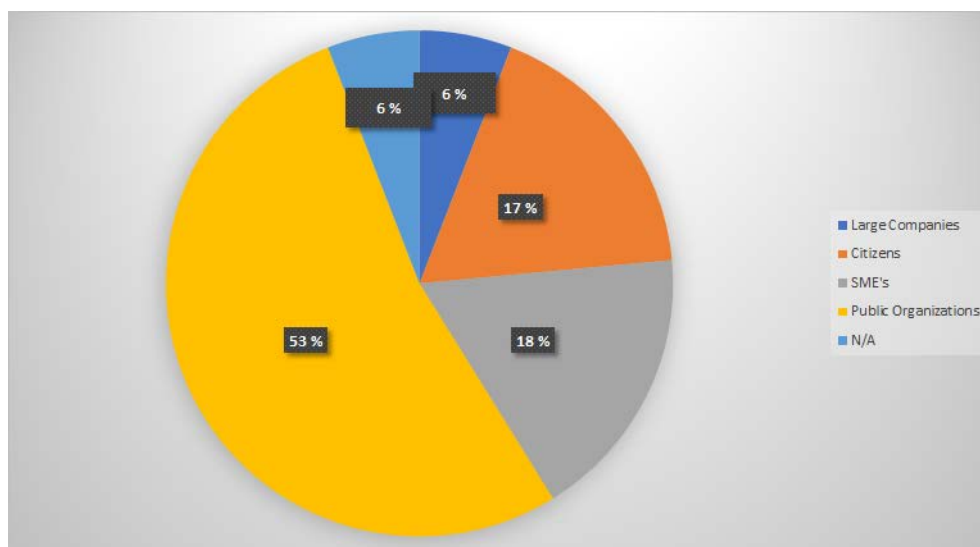


Figure 15. Open Call pilots categorised with their main focus (>50%) user categories (SynchroniCity M6 final pilot reports)

The figure above (Figure 15) indicates that with over half of the Open Call pilots, the dominant user group (>50 %) was public organisations. As the pilots were asked to report the user group distribution, the results were as follows: Nine pilots focusing mainly on public organizations, three focusing on SMEs and citizens, and one focusing on large companies. It is important to note that this categorisation does not contain information on the number of people using the solution as it varies across organisations.

4.3 Replication Potential

With replication potential, the initial aim is to look at the number of replicated serviced during the project. As one of the underlying ideas of SynchroniCity has been to create scalable services, it is exactly this

we are looking at. In addition to looking at to what extent the services were replicated in other cities, we also aim to understand the overall SynchroniCity value for the replication potential. Therefore, we look at how the Open Call pilot companies perceive the value of the SynchroniCity framework for their competitive advantage as well as how the business model clarity of the Open Call pilot companies evolved during the pilot period.

The SynchroniCity deliverables (D3.6 Customized IoT service prototypes for lead ref.zones – advanced; D3.8 Report on reference zones IoT service deployment) describe how the Atomic Services were adopted in the applications by RZs. AS mentioned in 4.1, the latest developments of the Atomic Services show an increase in the number of the Atomic Services and their deployment. A recent paper by Cirillo et al (submitted) shows that the Atomic Services were applied in 25 RZ applications (Table 9).

Table 9. Atomic Services applications (Cirillo et al., submitted)

Atomic Service	Application	RZs application?	Theme
Smart City Dashboard	Environment monitoring (Cartagena)		Community Policy Suite
	Bus stops crowd monitoring (Santander)		Enabling Mobility as a Service (MaaS)
	Air quality management (Onda)		Community Policy Suite
	Air quality monitoring (Cabildo de la Palma)		Community Policy Suite
Metrics visualizer (Grafana)	Data-driven bicycle mobility (Eindhoven)	x	Human-centric traffic management
	Clean Air Journey planner (Helsinki)	x	Multi-modal transportation
	Agile Governance (Manchester)	x	Community Policy Suite
	Environment monitoring (Cartagena)		Community Policy Suite
	Bus stops crowd monitoring (Santander)		Enabling Mobility as a Service (MaaS)
	Air quality management (Onda)		Community Policy Suite
	Air quality monitoring (Cabildo de la Palma)		Community Policy Suite
GPS to TFO transformer	Bicycle patterns (Antwerp)	x	Human-centric traffic management
Bike Data Visualiser	Bicycle patterns (Antwerp)	x	Human-centric traffic management
Traffic Estimator	Multimodal assistant (Porto)	x	Multi-modal transportation
	Park & Move! (Santander)	x	Multi-modal transportation
Parking Estimator	Park & Move! (Santander)	x	Multi-modal transportation
	Smart parking & Bus info (Carouge)	x	Multi-modal transportation
Noise Estimator	Noise monitoring near bars (Carouge)	x	Community Policy Suite
Routing Service (OTP)	Decision support system for cycle path planning (Milan)	x	Human-centric traffic management
	Multimodal assistant (Porto)	x	Multi-modal transportation
	Park & Move! (Santander)	x	Multi-modal transportation
	Clean Air Journey planner (Helsinki)	x	Multi-modal transportation
	Multimodal navigator for disabled people (Milan)	x	Multi-modal transportation
	Smart parking service (Carouge)	x	Multi-modal transportation
NGSI Urban Mobility to GTFS adapter	Park & Go (Santander)	x	Multi-modal transportation

	Multimodal navigator for disabled people (Milan)	x	Multi-modal transportation
GTFS-RT Loader	Clean Air Journey planner (Helsinki)	x	Multi-modal transportation
	Multimodal assistant (Porto)	x	Multi-modal transportation
	Park & Move! (Santander)	x	Multi-modal transportation
GTFS Fetcher	Clean Air Journey planner (Helsinki)	x	Multi-modal transportation
	Multimodal assistant (Porto)	x	Multi-modal transportation
	Multimodal navigator for disabled people (Milan)	x	Multi-modal transportation
	Park & Move! (Santander)	x	Multi-modal transportation
Grafana NGSI Map Plugin	Electric bike usage monitoring (Aarhus)		Encouraging non-motorised (active) transport
NGSIv2 to NGSI-LD Service	Elderly care service monitoring (Aarhus)		Community Policy Suite
NGSI Validation Service for NodeRED	Building energy management (Vejele, Odense)		Community Policy Suite
Legacy to NGSI Conversion Atomic Service	Building energy management (Vejele, Odense)		Community Policy Suite

All validated Atomic Services (for description of the validated Atomic Services, see Table 7) were replicated at least in two cities, which was the aim. Figure 16 shows that the expectation was exceeded as 63% of the Atomic Services were replicated in more than two cities (13% in 3 cities, 25% in 4 cities and 25% in five or more cities).

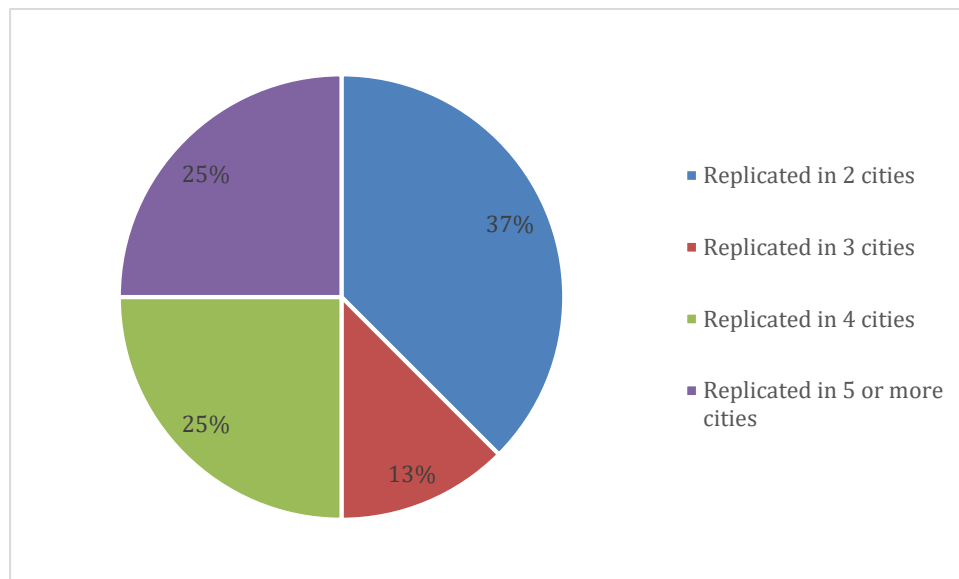


Figure 16. Replication of the validated Atomic Services

All the 16 Open Call pilot services were also replicated in at least two cities. The following figure (Figure 17) illustrates the geographic replication across all pilot projects. It also differentiates the new cities (red) from the reference zones (blue).

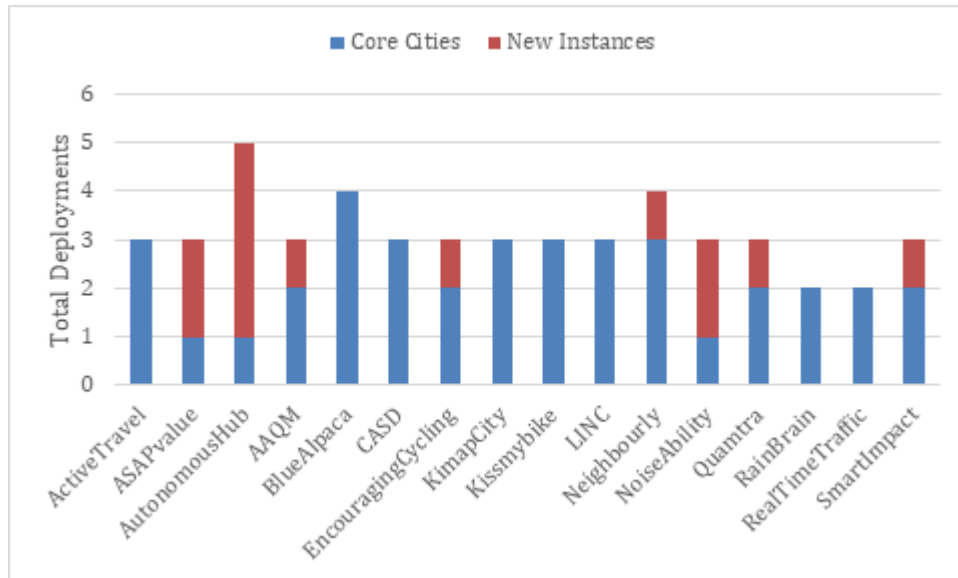


Figure 17. Number of cities where Open Call pilot services were deployed (D4.5 technical validation of the SME projects)

As Figures 17 and 18 show, the expectation to replicate a service in at least two cities, was exceeded. 69 % of the Open Call pilot services were replicated in three cities, 13 % in four cities and 6% in five cities.

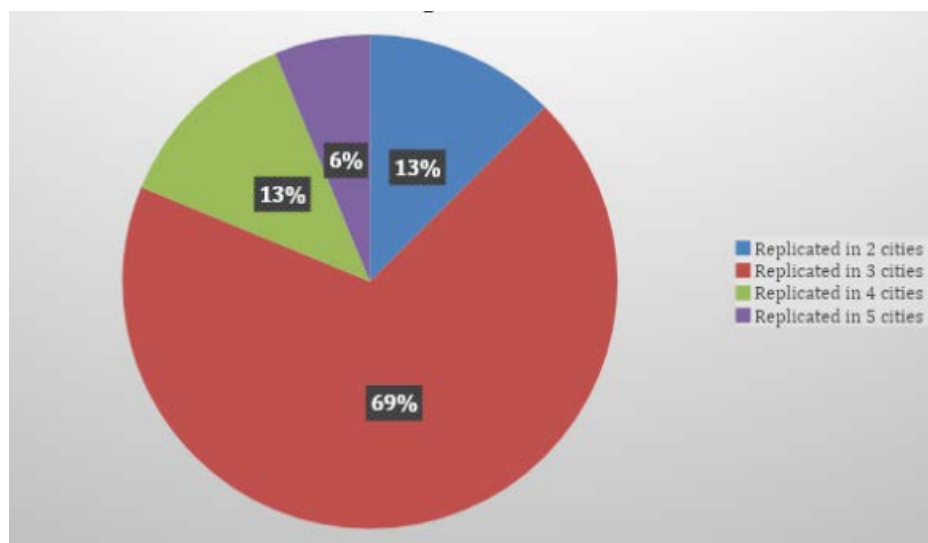


Figure 18. Number of cities in which the Open Call pilot service was replicated (SynchroniCity M6 pilot final reports)

As mentioned in the introduction to this section, an additional aspect in evaluating the replication potential is the RZs' and pilots' evaluation of SynchroniCity ecosystem in bringing advantages in competition. The figure below (Figure 19) shows that the SynchroniCity ecosystem was seen valuable in bringing advantages.

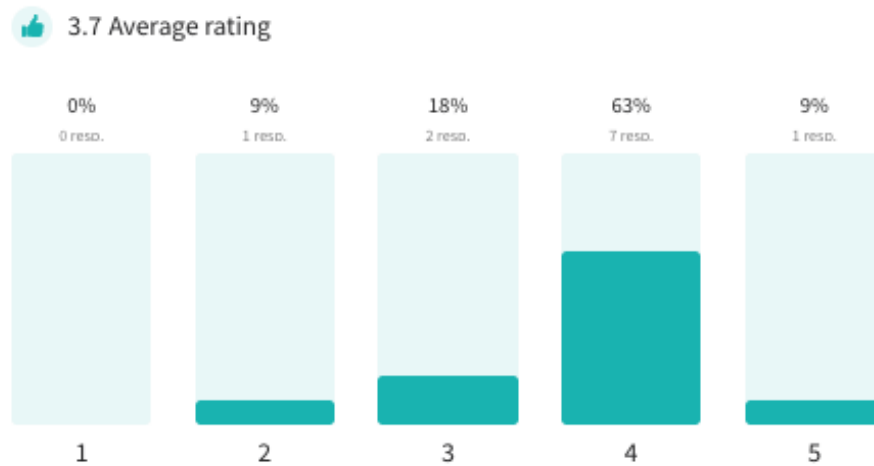


Figure 19. RZs' and Open Call pilots' evaluation of whether the SynchroniCity ecosystem provides them advantages when compared to competing solutions (D4.4: Assessment on the user, stakeholder, replication and market validation)

What are the advantages that the respondents see valuable? As the figure below (Figure 20) shows, these advantages include access to data, potential business scalability, potential technological scalability and technological implementation.

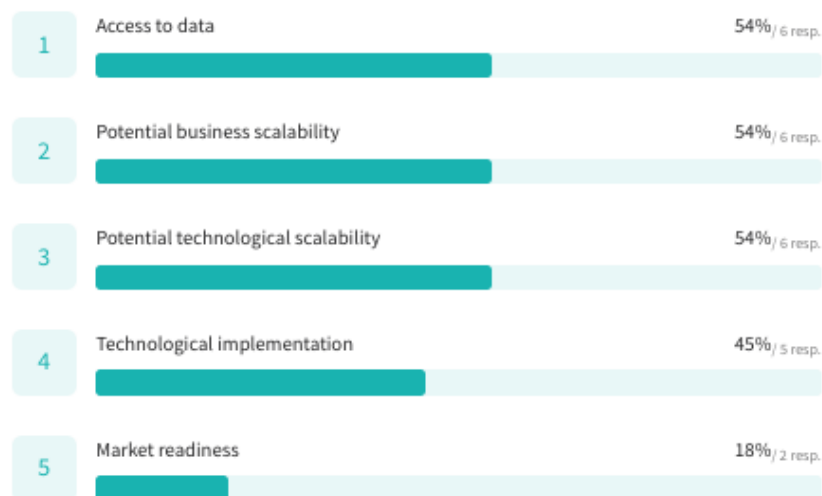


Figure 20. RZs' and Open Call pilots' identified advantages of SynchroniCity ecosystem for the implementation and the future of the solution (D4.4: Assessment on the user, stakeholder, replication and market validation)

Finally, we look at how the business model clarity of the Open Call pilot companies evolved during the pilot period. This contributes to the understanding of replication potential by illuminating the potential changes in the companies' perceptions of value creation. The business model clarity was operationalized through questions related to the companies' value offering, value architecture and revenue. Through the following figures, we provide an analysis on how the business model clarity evolved during the project by comparing the pilots' initial kick-off answers to the evaluations in the final pilot reports. The answers are on a scale of 1-5.



Figure 21. Kick-off evaluation (left) and final report evaluation (right) comparison. "In our pilot, each company knows exactly how to generate value for the user." (SynchroniCity M0 survey; M6 pilot final reports)

The first question was related to the Open Call pilot companies' perspectives on the clarity of the knowledge of how to generate value for the user. Figure 21 shows an increase in this respect as initially, 81 % of the pilots gave a rating of 4 or higher. In the final report, 94 % gave a rating of 4 or higher.



Figure 22. Kick-off evaluation (left) and final report evaluation (right) comparison. "In our pilot, each company has a clear view on its market position." (SynchroniCity M0 survey; M6 pilot final reports)

The second question asked the company representatives' perceptions of how clear view they have on their market position. Figure 22 shows that initially, 56 % of the pilots gave a rating of 4 or higher. In the final report, 88 % gave a rating of 4 or higher.



Figure 23. Kick-off evaluation (left) and final report evaluation (right) comparison. "In our pilot, each company knows exactly the competences and resources needed for value creation." (Synchronicity M0 survey; M6 pilot final reports)

The third question dealt with the value architecture, asking whether the companies perceive they know the competences and resources needed for value creation. Figure 23 shows that initially, 75 % of the pilots gave a rating of 4 or higher. In the final report, 94 % gave a rating of 4 or higher.



Figure 24. Kick-off evaluation (left) and final report evaluation (right) comparison. “In our pilot, each company has partners with clear roles for value creation.” (SynchroniCity M0 survey; M6 pilot final reports)

The fourth question asked whether the companies had partners with clear roles for value creation. Figure 24 shows that initially, 81 % of the pilots gave a rating of 4 or higher. In the final report, 75 % gave a rating of 4 or higher.

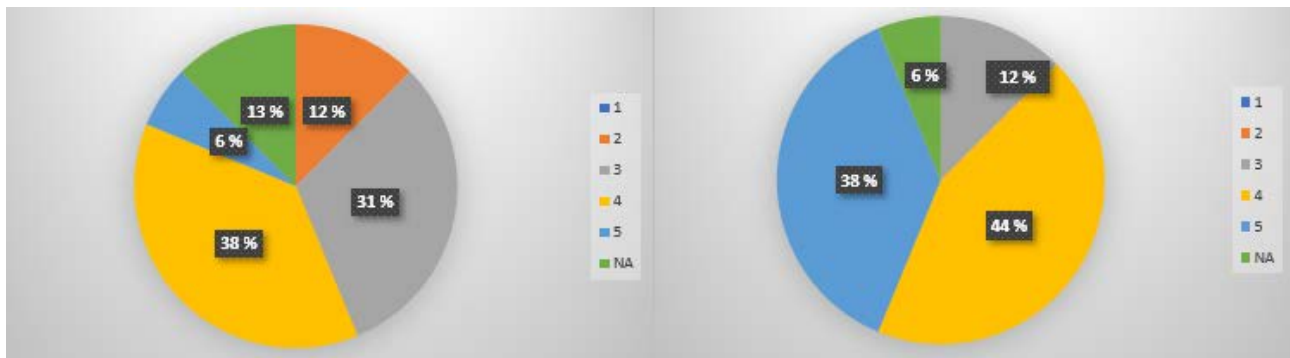


Figure 25. Kick-off evaluation (left) and final report evaluation (right) comparison. “In our pilot, each company knows exactly how to make money.” (SynchroniCity M0 survey; M6 pilot final reports)

The final question was related to the revenue aspect. Figure 25 shows that initially, 44 % of the Open Call pilots gave a rating of 4 or higher. In the final report, 82 % gave a rating of 4 or higher. To sum up, in four out of five questions, the number of “4 or higher” answers increased during the pilot project.

4.4 Perceived Value for the End Users

First, we will look at the perceived value of the SynchroniCity technical framework for the pilots as users. The figure below (Figure 26) shows the RZs' and Open Call pilots' evaluations of how the SynchroniCity platform helped them to improve or develop the pilot solution in the frontend end-user interface. The average rating was 3 (with a scale of 1 to 5), with 54% of respondents evaluating moderate help from SynchroniCity platform.

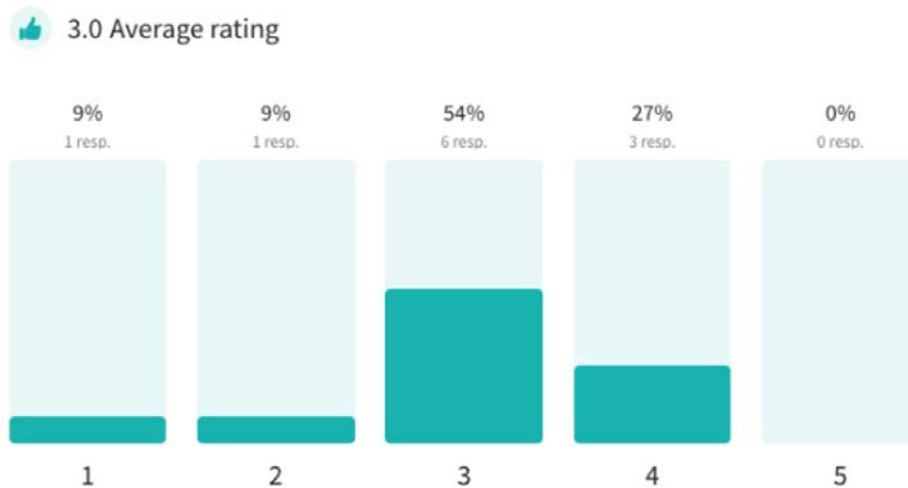


Figure 26. RZ's and pilots' evaluations of SynchroniCity platform help in improving or developing the pilot solution in the frontend end-user-interface (D4.4: Assessment on the user, stakeholder, replication and market validation)

Figure 27 below specifies their experiences and shows that it was perceived most valuable for integrating with other services /products and accessing real time information.

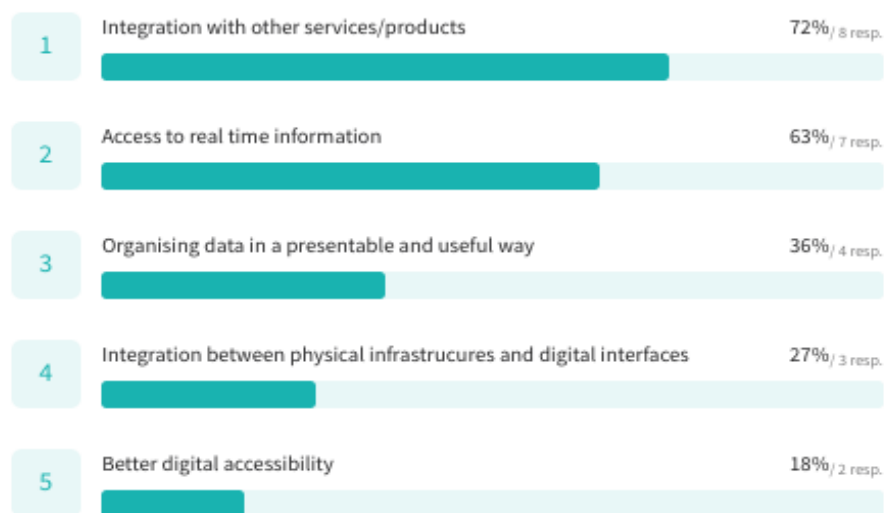


Figure 27. RZs' and pilots' experiences of the SynchroniCity platform (D4.4: Assessment on the user, stakeholder, replication and market validation)

At the end of the pilot period, the Open Call pilots were asked about their perceptions of the SynchroniCity technical framework. Figure 28 shows that the Open Call pilots perceived that the SynchroniCity technical framework either slightly (50%) or significantly (50%) improved their service offer.

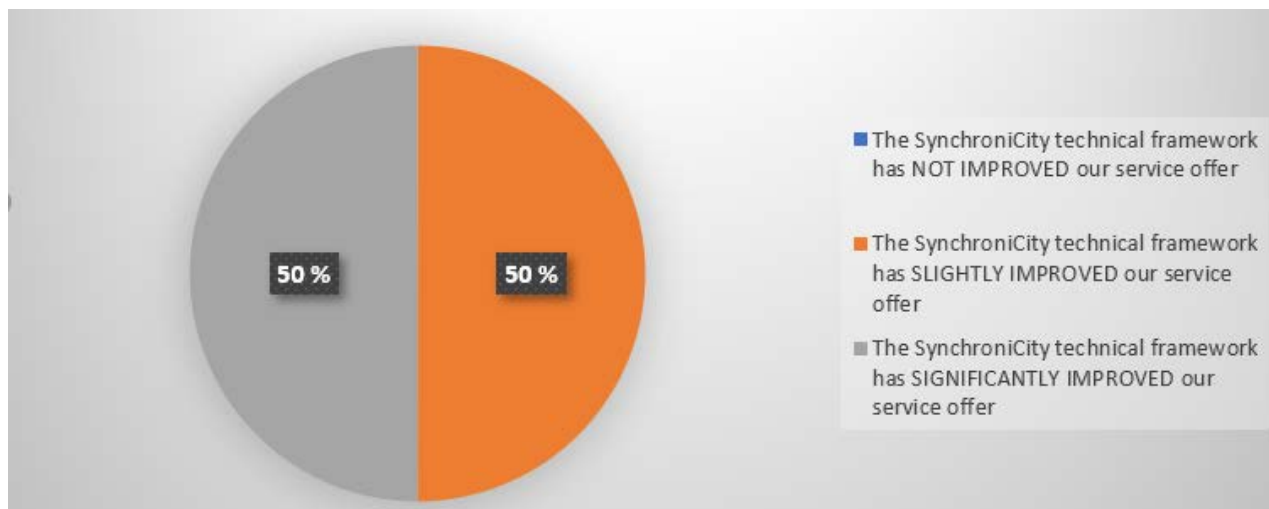


Figure 28. The Open Call pilots' answer distribution on the quality of the solution. (SynchroniCity M6 pilot final reports)

They were also asked to reflect on the timeframe of their solution development. For the majority of the pilots, the SynchroniCity technical framework meant that their solution developed in the expected timeframe (Figure 29).

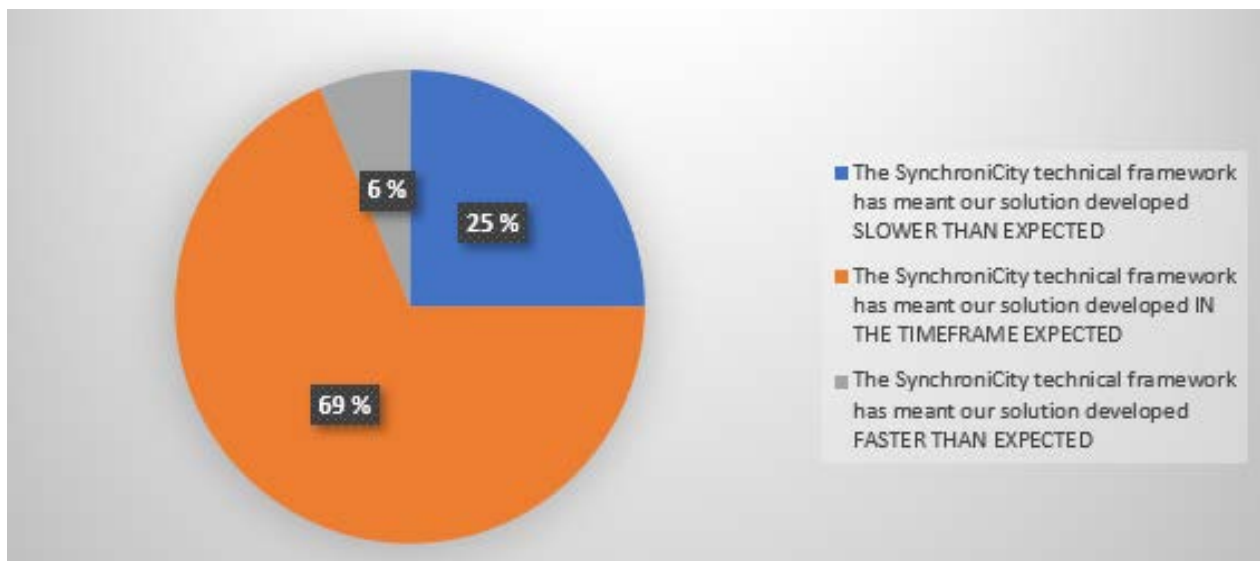


Figure 29. The Open Call pilots' answer distribution on the time taken to develop and deploy the solution. (SynchroniCity M6 pilot final reports)

Second, we look at the perceived value by the end users of the Open Call pilot services. The perceived value for the end users was extremely high. The self-reported data was received from all the Open Call pilots except one (M6 pilot final reports). On a scale of 1-5, 88 % of the Open Call pilot projects were considered to have a satisfaction rate of *4 or higher* (Figure 30). There was one sole rating of 3 and none below 3. With the average value of 4,17 / 5, it can be concluded that the expectation (70 % satisfied) was exceeded.

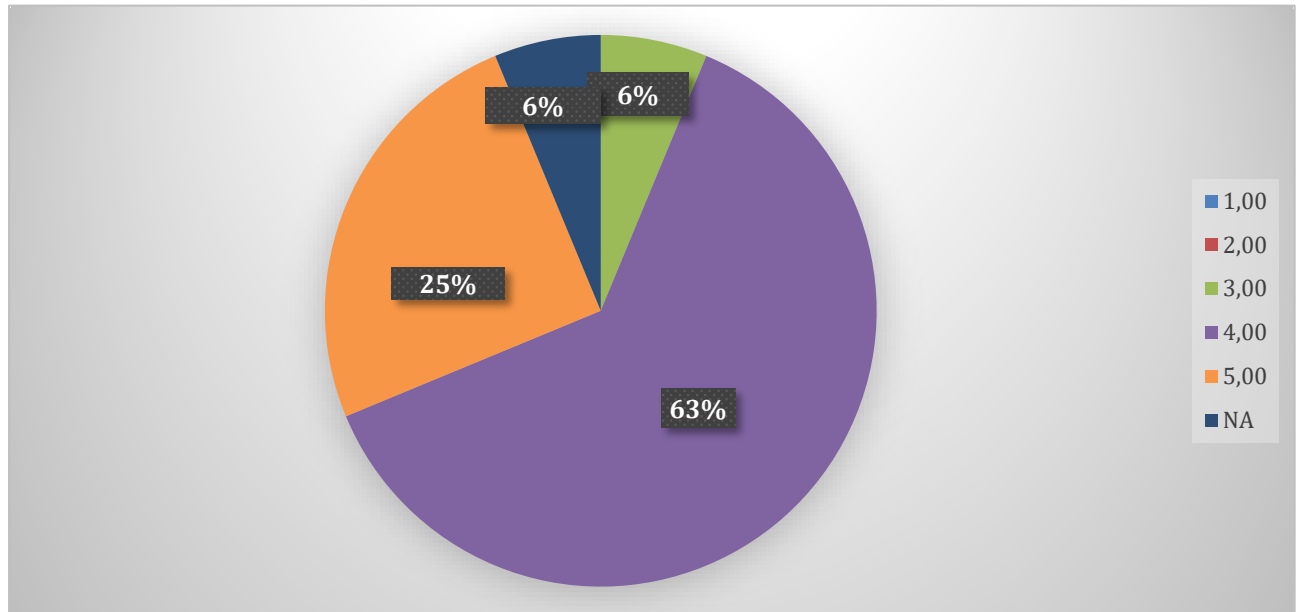


Figure 30. Illustration of the Open Call pilots' satisfaction rates (scale of 1-5). (SynchroniCity M6 pilot final reports)

4.5 Perceived Value of SynchroniCity for the Local Government and Decision Makers

This indicator refers to the perceived value for the local government and decision makers involved. The data gathered for this indicator concerns Reference Zone leads' evaluation of the perceived value for the local government and decision-makers (D1.7 Monitoring framework template 2; D1.8 Monitoring framework template 3). It is to be noted that at the time of writing, the data from the last round of the monitoring framework was not yet available, so the evaluations by RZ leads at the end of the project are not presented.

By reaching the stage when the Open Call was to be launched, the RZs evaluations of the perceived value were rather positive, as the following quotations show:

"The main idea of the SynchroniCity project, the performance and the results obtained so far make us very positive value. However, it is necessary to look at future development to make a more accurate judgment."

"It has been important to push pressure on data, data models, standards and on interoperability."

"It is good to have the basic infrastructure and, in this way, to be prepared to receive more and more real time data on the platform in the future."

"Great help and great impulse for the future."

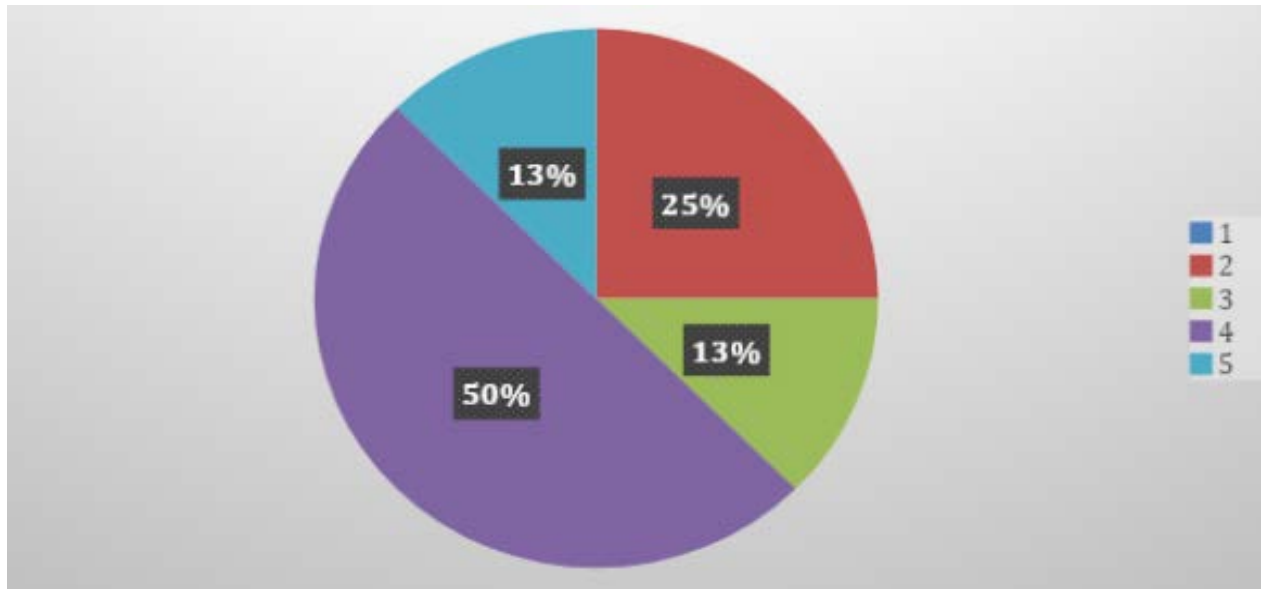


Figure 31. Perceived value of the project evaluated by RZ cities (scale of 1-5). (SynchroniCity M6 final pilot reports)

At this point, the RZs were also asked to evaluate the value of SynchroniCity with a scale of 1 to 5. 63 % of the cities considered the perceived value of the project to be 4 / 5 or higher (Figure 31). None gave an evaluation below 2 / 5.

In addition to the RZs perceptions, the representatives of the new cities involved in the Open Call pilots were asked about their feedback and evaluation of the project. The four responses received from the new cities (Figure 32 below) show mainly positive evaluations.

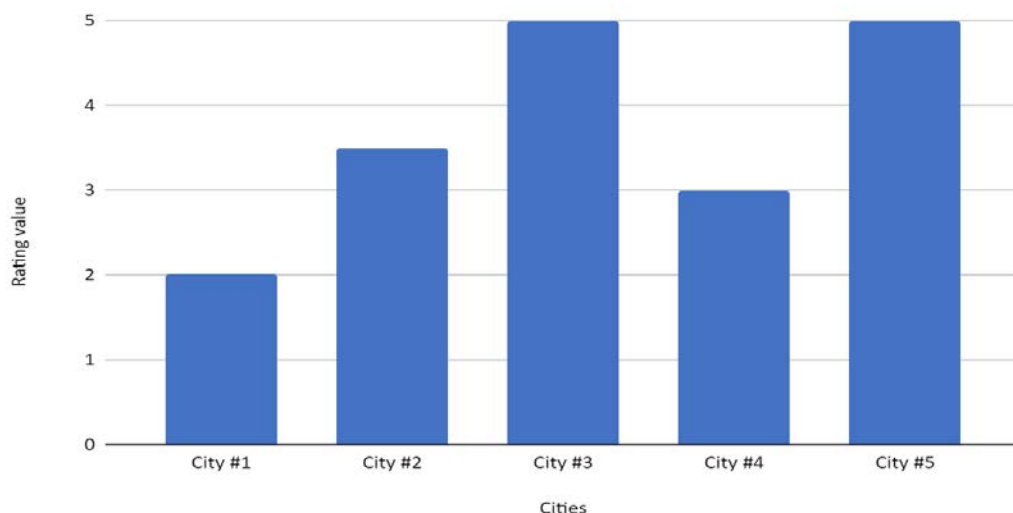


Figure 32. The new cities' perceptions on the value of SynchroniCity for the local government and decision makers in their city (Scale of 1-5). (T6.4 data collection)

The following responses describe the perceived value:

“The project helped us provide interoperable infrastructure that opened a whole set of opportunities for further integration and use of the city data.”

“It has definitely been an eye-opener towards what’s possible working with IOT and made it easier to convince the decision makers in our municipality to take further steps into the (locally) unknown (but elsewhere successfully implementation) of IOT projects.”

“Having in mind that one of the project’s aims was to investigate the potential of the service that relies on the support of relevant city bodies and local government, project played crucial role in defining the roadmap and evaluating the potential of the solution, both from business and technical perspective.”

5 IoT Infrastructure Development

This chapter looks at how the IoT infrastructure was developed during the project. It shows the creation and consumption of open data sets during the Open Call pilots and the integration of the pilot companies in the SynchroniCity ecosystem. It also describes how the aspects of privacy and the number of IoT connected devices were developed during the project. In addition, perceptions of the quality of open data and interoperability are presented. This chapter reports the following indicators: The level of data protection by the city; Number of IoT connected devices implemented during the project lifecycle; Number of open data sets in use; The extent to which the quality of the open data produced by the project was increased and; The extent to which the project has increased interoperability between infrastructures.

5.1 The Level of Data Protection by the City

This KPI refers to the level of data protection by the city. This was evaluated by whether the RZs performed the PIA (Privacy Impact Assessment).

Four of the RZs implemented the PIA. Those four cities that did not implement it had several reasons. The reasons for not implementing it were, that the pilot implementation did not require a PIA or the authentication and authorisation systems were not in place. One argument related to the delay of the pilot, which postponed the plan to implement it, while another was linked with legislative reasoning.

5.2 Number of IoT Connected Devices Implemented During the Project Lifecycle

In 13 Open Call pilots, new hardware IoT devices were installed in the piloting cities (Table 10). The number of devices installed (M2) was 1694 (D4.5 Technical Validation of the SME projects). This number does not include any other devices from other programmes or projects which may be connected to the solution.

Table 10. Number of IoT devices (D4.5: technical validation of the SME projects, table 70)

City	# IoT Devices	City	#IoT Devices
------	---------------	------	--------------

Bezana	15	Porto	175
Bilbao	5	Santander	90
Calatayud	100	Antwerp	442
Donegal	15	Carouge	199
Dublin	200	Eindhoven	11
Edinburgh	6	Helsinki	37
La Nucía	15	Manchester	216
Novisad	76	Milan	52
Palencia	15		
Tampere	25	TOTAL	1694

In the final pilot report (M6), the Open Call pilots reported that altogether, the number of IoT devices connected with their solutions, was 2509. This number includes devices from other programmes or projects which have in addition to the SynchroniCity devices, been connected to the pilot solutions. The average per Open Call pilot was 167 IoT devices, with a minimum number reported being three and the maximum being 800 IoT devices connected.

In addition, the number of entities can be looked at. Entities refer to e.g. roads, bus stops that report information. D4.5 Technical Validation SME Projects reports these numbers and shows that the number of available SynchroniCity compliant entities was 236589 (for partial validated entities the number being 267056) after the Open Call. The total number of entities and their validation (all the data models and cities) can be followed at <https://validation.services.synchronicity-iot.eu/table/>. When writing this report, the update based on the validation report shows the number of entities being 544764, of which 492506 SynchroniCity validated (downloaded 12 Dec, 2019).

5.3 Open Data Sets

This indicator refers to the number of open data sets in use. The number of available different types of data sets according to SynchroniCity data models after the Open Call was 43 and the number of available data sets according to SynchroniCity data models, including those duplicated in several RZs was 159. The number of data sets that are shared by two or more RZs was 30 after the Open Call. Table 11 shows these numbers and the increment during the Open Call.

A further investigation in the data sets created and consumed provides understanding about the level of integration. When looking at the Open Call pilots, open data sets were created and consumed differently across the pilots as Figure 33 illustrates.

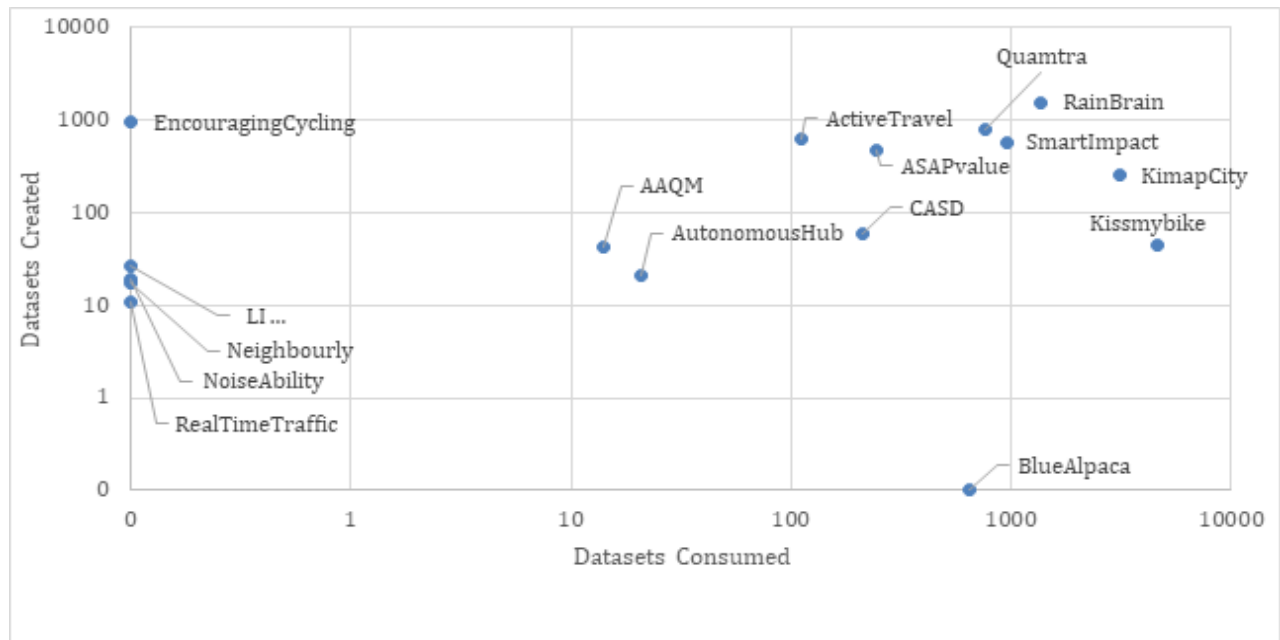


Figure 33. Datasets created and consumed (D4.5: technical validation of the SME projects)

This shows different level of integration, which is further shown by the following categorisation by WP4 (D4.5 Technical Validation of the SME projects).

- **Minimum integration:** Fulfils Open Call minimum integration criteria. They generate data sets in at least 2 pilot cities, but the performance of the solution doesn't have a strong dependency of SynchroniCity framework.
- **Medium integration:** The performance of the solution depends on SynchroniCity framework, as it consumes data from at least 2 cities.
- **High integration:** The pilot has brought new cities to SynchroniCity, deploying in them new SynchroniCity instances. The performance of the solution depends on SynchroniCity framework, as it consumes data from at least 2 cities.

The figure below shows that eight of the Open Call pilots reached a medium integration level, five a minimum and, three a high integration level.

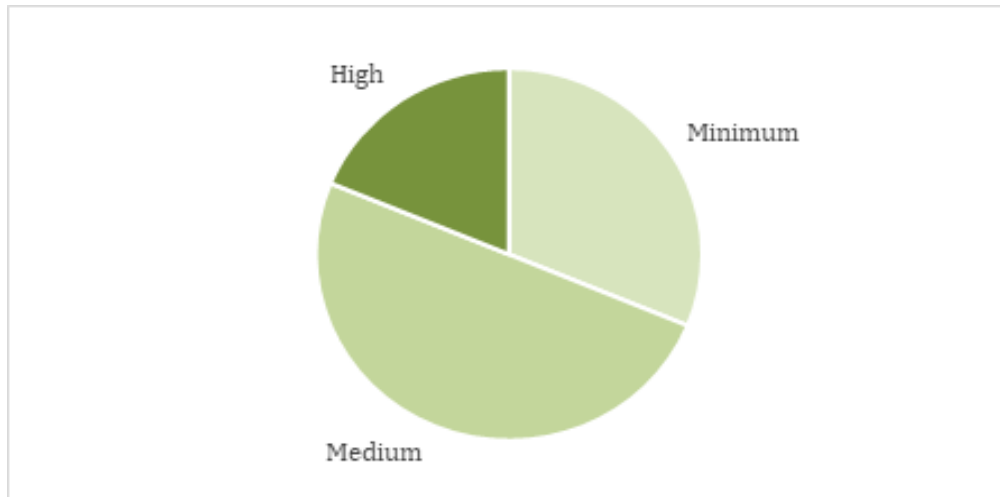


Figure 34. The level of integration in pilots (D4.5: technical validation of the SME projects, Figure 5)

Table 11 summarises the number of open data sets and their increase.

Table 11. Open data sets validated (D4.5 Technical Validation of the SME projects)

#	KPI	Description	Before Open Call	After Open Call	Increment	Increment %
1	SynchroniCity data sets	Number of available different types of data sets according to SynchroniCity data models	38	43	5	13,16 %
		Number of available data sets according to SynchroniCity data models, including those duplicated in several RZs	80	159	79	98,75 %
2	Data sets shared	Number of data sets that are shared by 2 or more RZs	16	30	14	87,50 %
3	Entities	Number of available entities (including partial validated entities)	195646	267056	71410	36,50 %

		Number of available entities (full SynchroniCity compliant)	194778	236589	41811	21,47 %
4	SynchroniCity cities	Number of cities with a NGSI interface exposing data sets according SynchroniCity data models	8	21	13	162,50 %

5.4 Perceived Quality of Open Data

This indicator refers to the perceived quality of the open data. The following descriptions reflect the Open Call pilots' perspectives on the quality of open data. According to the Open Call pilots' responses, 57 % of the pilots evaluated the quality of the open data used to be 4 / 5 or higher. Furthermore, 81 % of the Open Call pilots evaluated the quality of the open data produced to be 4 / 5 or higher.

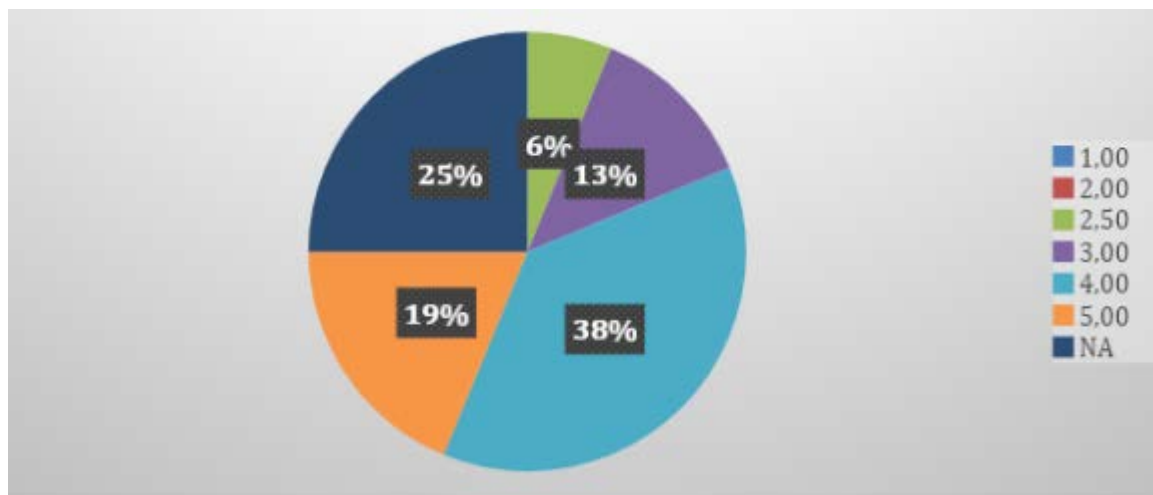


Figure 35. The pilots' perceived quality of the Open Data used in the Open Call pilot projects (scale of 1-5). (SynchroniCity M6 final pilot reports)

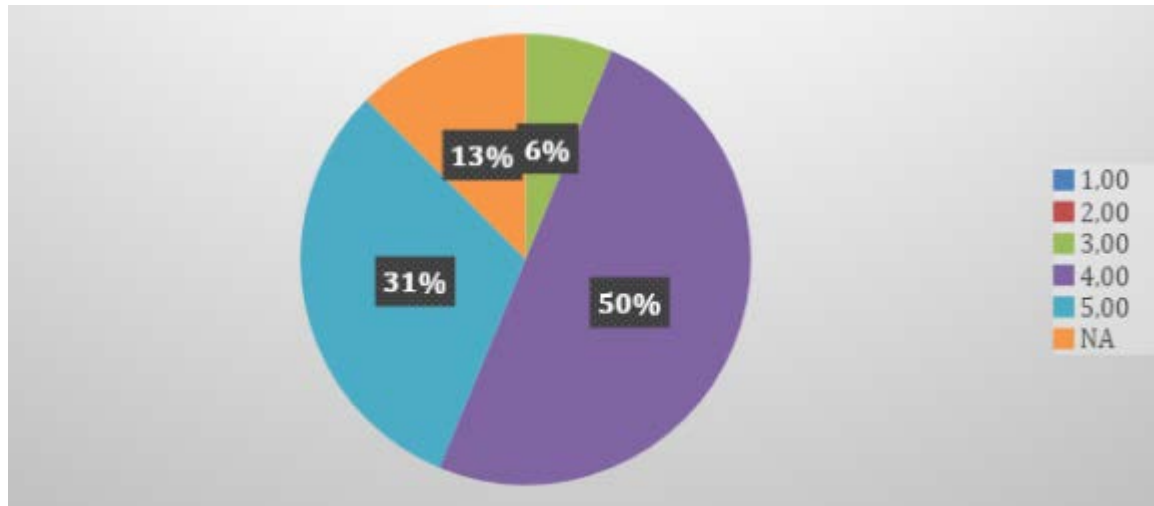


Figure 36. The pilots' perceived quality of the Open Data produced in the Open Call pilot projects (scale of 1-5). (SynchroniCity M6 final pilot reports)

5.5 Perceived Improved Interoperability

A qualitative evaluation of the perceptions of the improved interoperability was collected from the different actors in the project, that is, the RZs and the new cities as well as the Open Call pilots. The issue was asked from the RZ leaders in the final Monitoring Framework at the end of the project and from the Open Call pilots in the final reporting template. A separate inquiry was sent to get the new cities' perspectives. Their evaluations are shown in the figure below.

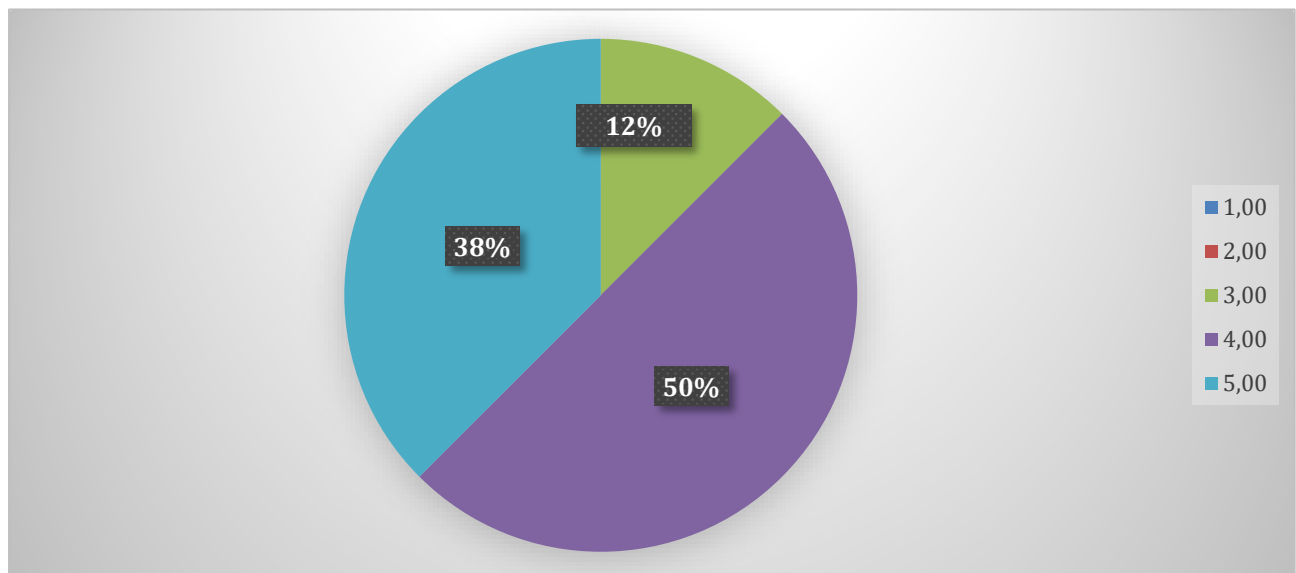


Figure 37. The rate of the Open Call pilot projects' improved interoperability (scale of 1-5). (SynchroniCity M6 final pilot reports)

In the final reports, 88 % of the Open Call pilots considered the rate of the improved interoperability to be 4 / 5 or higher. The average rating was 4,25/5. Furthermore, the new cities were asked to evaluate

the improved interoperability between infrastructures (visualized below, in Figure 38). At the time of writing, the final monitoring framework information, that is, the perceptions of the RZs were not yet available.

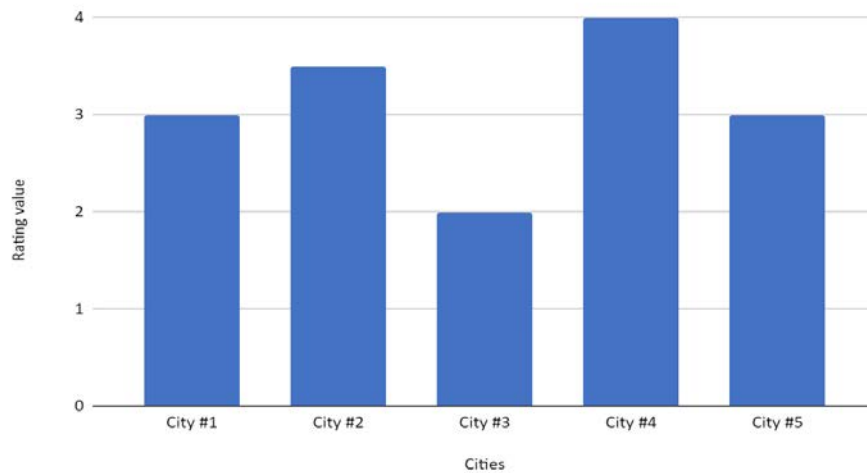


Figure 38. The feedback evaluations from the new cities on the improved interoperability between infrastructures (scale of 1-5).

6 Summary

The indicators looked at were grouped by the three overarching aims of the project. The first set of indicators looked at what kind of ecosystem was built during the SynchroniCity project, the second focused on the validated services and their use and the third on the IoT infrastructure development. Table 12 summarizes the indicators that were presented in the previous chapters. Overall, the indicators show positive results in terms of the impact created. For most of the indicators, the expectations were reached or exceeded. With some of the indicators, there were challenges to measure with the changes taken place during the project. Due to changes in the project realization, some of the initial expectations or measures were not valid anymore (Awareness impact, Co-creation). Instead, new means for evaluating the impact were developed.

Table 12. Summary of the evaluation report indicators

Indicator	Expectation	Realized
Awareness impact	n/a	Number of Open Call applications (133) with 45 new cities exceeded the expectations (100)

Co-creation (Participatory governance)	n/a	Co-creation tasks satisfactorily accomplished (62,5% of the Internal pilots, 37,5% of the Open Call pilots) Improvements to the solutions made during co- creation by adding or changing features (80% of the respondent pilots)
SME involved	100	227 applied to join through the Open Call 38 actively involved in pilots
Partners' engagement	200	123 partners involved Increase in the number of partners High growth in IoT partners
Local job creation	60	37 jobs created
New follower city members/interested	8	36 cities interested to join in the Open Call 13 new cities in the selected pilots
Service implementation	20	All 16 Open Call pilot services with 50 deployments passed validation 8 validated Atomic Services, total 15 Atomic Services with 25 RZ applications
Citizen Centred	350000	Open Call pilot service users: 57500, users mostly org. users
Replication potential	Number of replicated services: 4	16 Open Call pilot services replicated in at least two cities 8 validated Atomic Services adopted in at least two cities
Perceived value for the end users and citizens involved	70% satisfied	88% of the Open Call pilots with user satisfaction rate 4 or higher

Perceived value for the local government and decision makers involved	70% satisfied	RZs: 63% value 4 or 5.
Data privacy	PIA implementation: 8	4/8 RZs implemented the PIA
IoT connected devices	Number of IoT connected devices implemented: 10000	1694 devices installed during the pilot phase 236589 full SynchroniCity compliant entities available after the Open Call, 492506 at the end of the project
Open data sets	Number of open data sets in use: 70	43 different types of data sets according to SynchroniCity data models 159 available data sets according to SynchroniCity data models, 99% increase during the Open Call phase 21 cities with a NGSI interface exposing data according SynchroniCity data models
Quality of open data	65%	87% rated the produced open data with 4/5 or higher 57% rated the used open data with 4/5 or higher
Improved interoperability	The extent to which the project has increased interoperability between infrastructures	88% rated the improved interoperability with 4/5 or higher

7 SECTION II: PIU

This Performance In Use (PIU) Framework, the impact assessment methodology, focuses on the measurable change of deployed IoT solutions and will be discussed in detail in Section 7.2. The PIU Framework is tailored to the deployments that impact the end users directly, whether it be the citizens or city operations staff. While project level impact is measured through things such as key performance indicators and meeting certain targets and objectives, at a deployment level the focus is on the measurable change or effect the technology deployment has had on the user and citizens at large.

7.1 Applying the PIU to SynchroniCity

The PIU was used to review both an internal pilot service and a market-ready pilot service. The initial atomic pilot service reviewed was both a multi-modal navigation app and parking app for Santander city. The development of the app was directed and led by several project partners. The purpose of this work was to develop both map-routing and parking spot location identification using the framework. However, after gaining insight into the nature of the internal pilot services, it became apparent that:

- the user interfaces were light-touch/beta versions
- they would likely only be tested by a small group of users
- there was a possibility those services would not be deployed to citizens at all and would remain internal technical tests.

At the time of carrying out an assessment, there was uncertainty surrounding the timeframes of whether the Santander multi-modal navigation app would be deployed to users with time to undertake an assessment, as it was still in testing and development phase. Therefore, the decision was made earlier in the process to undertake just the initial discovery phase of the PIU. This included providing both impact mapping and a comprehensive recommendations document. The impact map is included in section 7.2, while the Recommendations document has been included in Appendix 2.

Realising that the potential for these ‘first-round’ Atomic Services, may not be piloted in the near future or perhaps only piloted to a smaller user group, the PIU team decided to review the Open Call market-ready solutions. Upon review the PIU team discovered that whilst these pilot solutions all make their own contributions to overcoming these challenges for cities and their citizens, the team needed to determine where a measurable change could be detected within the short 6-month pilot period. This proved challenging as to screen these shorter-term Open Call pilots, a longer period of data collection – ideally up to a year – is needed to fully assess the impact and ensure a robust assessment.

Having reviewed all the Open Call pilots, three Open Call pilot groups were selected as suitable for a PIU impact assessment. These were *Neighbourly*, *Real Time Traffic Data with energy savings on streetlights* and *Quamtra Smart Waste Management*. They were selected with time constraints, data collection, deployment timeline, availability of partners’ data and resourcing all taken into consideration. However, it became apparent that due to the timeframes and deployment delays, that piloters would not be able to collect sufficient data early enough to carry out the PIU impact assessment analysis.

As those in the innovation space often hear, innovation deployments carry some inherent risk, and here this was coupled with challenges of management of multiple parties involved in each process from SMEs to technical partners to city officials. Problems with the initial deployment phase led to significant delays and thus to the availability of crucial data. Given the unavailability of pilot-specific data, it was agreed that this report should provide an overarching framework for carrying out impact assessment on IoT deployments of large-scale innovation programmes such as SynchroniCity. Readers will find in this report key principles and concepts underlying robust impact assessment. The intention is that through this report SynchroniCity contributes to the IoT resource base and guides future programs in conducting robust assessment of their solutions’ impacts.

The following section overviews the PIU framework and its three phases: discover, measure and analyse.

7.2 What is PIU?

The Performance In Use (PIU) framework is an impact assessment framework which has been developed by Future Cities Catapult, (FCC, now known as the Connected Places Catapult, CPC),² to

² Connected Places Catapult is the new name of Future Cities and Transport Systems Catapults, as of April 2019

undertake impact assessment for urban innovation projects. The framework builds upon international standards and was developed in partnership with leading academic institutions³. It is intended to guide practitioners to both prospectively appraise potential impacts of planned interventions; and retrospectively evaluate the actual impact and effectiveness of deployed solutions. The PIU considers three main aspects to be investigated: economic, social and environmental. Figure 39 below outlines some example metrics measured within the three pillars of the PIU framework.

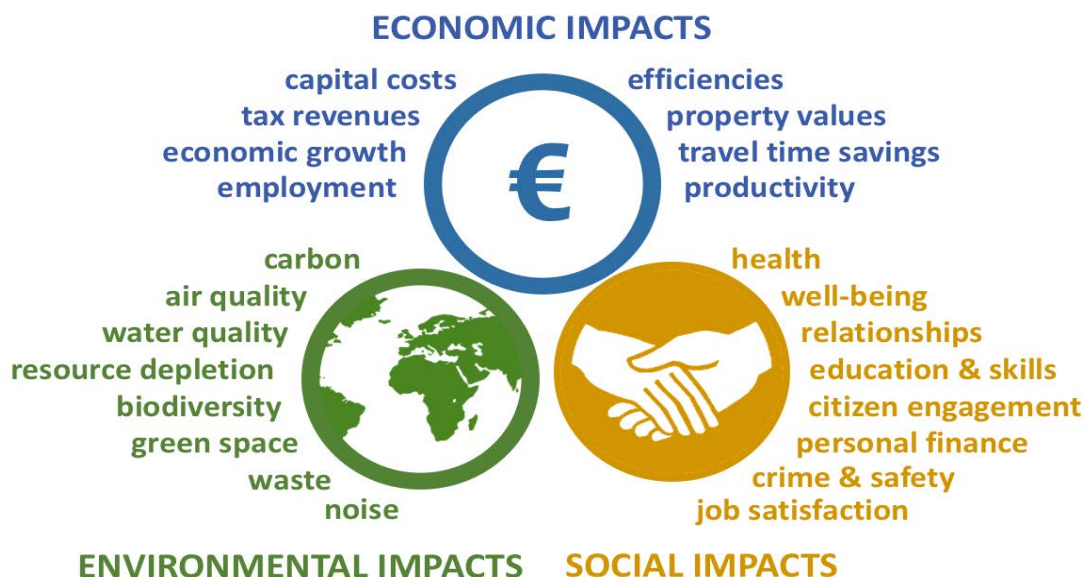


Figure 39. Example metrics measured within the three pillars of the PIU framework.

Intended as a rapid implementation guide for practitioners, this framework serves as a starting point for assessing the impact of urban IoT developments. Instead of covering every topic in depth, the PIU presents a general framework. Although developed primarily with small-to-medium-scale pilot projects in mind, principles presented in the framework can be applied to projects of any size and scope.

A top priority has been to keep the PIU impartial, unbiased, and apolitical. PIU focuses on urban technology deployments that are novel and where impacts are emerging or hard to identify, maintaining flexibility. It is a high-level framework presenting principles and guidance that allow users to appraise potential impacts or evaluate actual impacts of urban technology deployments with economic, environmental and social impacts. It also offers step-by-step guidance on how to conduct an impact assessment for proposed or deployed urban technology services, enabling assessors to identify suitable metrics to measure outcomes and baseline conditions.

With every technology deployment, how the technology is being optimised to create impact across these areas should be considered. Both the potential benefits and dis-benefits, as well as intended and unintended consequences should be included in the analysis. As discussed in the introduction, PIU refers to the framework and tools pertaining to the impact assessment on the IoT solutions, rather than the impact assessment of the SynchroniCity project-as-a-whole.

PIU includes three main stages in assessing IoT solutions: discover, measure and analyse.

The first phase is discovery, see section 7. During this discovery phase, the assessor examines how each IoT solution is developed and how it will solve city-wide problems and achieve strategic objectives. The key activities of this discovery phase are:

³ Including the London School of Economics, King's College London, Southampton University, Oxford University and Glasgow University.

- **Triangular Triage of the problem-solution-desired outcome:** a strategic stakeholder engagement process that connects the demand (the municipality) and supply (the company) sides of the market to ensure technology is developed and refined according to the needs of the customer (cities and their citizens).
- **Impact mapping:** a process that uses the problem-solution-desired outcome process, but follows a more linear diagrammatic structure, which illustrates how activities lead to outputs, through to immediate outcomes and longer-term impacts.
- **Horizon scanning and literature review:** horizon scanning helps understand the state-of-play of existing market solutions and how previous technology has been able to fill the gap in the market or overcome barriers to certain societal challenges. Undertaking a literature review to review leading and seminal academic papers on the areas requiring impact analysis are important in this phase.
- **Recommendations:** this is an iterative process and as such the practitioner undertaking the impact assessment at this stage may return to the IoT company with questions and/or revisions that challenge their product's functionality or use. This will be with an aim to maximise the utility to better meet outcomes which lead to positive longer-term impacts. Considering potential scale-up opportunities at this stage may be important to understand wider-reaching benefits when considering a small company among a larger city or cities context.

The second phase of a PIU assessment is **measurement** (see section 8). During the measurement phase the assessor will develop the methodology according to the IoT solution before carrying out any assessment. Developing the methodology will include scoping the work, deciding which metrics are most appropriate and other ethical considerations. Carrying out the work will include collecting data from an established baseline and will include collecting the IoT solution's created data or other data which is generated as a consequence of the solution.

The measurement phase includes the following activities:

- **Screening and scoping:** establishing the breadth and depth of the analysis.
- **Choosing appropriate metrics:** this includes determining direct and indirect impacts as well as understanding how metrics are developed to measure the outcomes.
- **Determining methodology and data required:** this includes ethical considerations, establishing a baseline and determining data type.

This section also outlines some example metrics measured within the 3 pillars of the PIU framework: economic, environmental and social.

The third phase is **analysis** (see section 9) and it includes considering all the data which has been collected, employing appropriate methods to carefully investigate the IoT solution and its impact. This will involve data cleaning, econometric and statistical analysis and presenting findings. These findings should be synthesized, and certain impacts should be integrated into a report. The final report should use language suitable for the reader. For city administrations ensuring a balance of non-technical language both from an econometric and IoT point of view it is recommended to ensure greater readability and understanding. The analysis phase includes the following activities:

- **Conducting the assessment:** investigating additionality and attribution and determining the net effects of the service.

- **Scaling-up and integrating impacts:** extrapolating findings to apply to a wider scale deployment, either across a city or multiple cities, and standardizing units of measurement across impact areas.
- **Communicating impacts:** recording, reporting and sharing results with stakeholders.

7.3 Who is PIU for?

Successfully measuring the wider societal impacts of IoT deployments requires key skills in research design, statistical analysis, economics, environmental economics and social science. These skills ensure that any reporting on impacts captures the 'triple bottom line' and that pilot studies can be designed to report with confidence that the changes detected are attributable to the intervention.

Typically, those conducting the impact assessment will therefore be economists, environmental economists, environmental scientists or social scientists. For very small and basic interventions, it may simply be enough for someone with skills in statistical analysis to take the guidance in this report and conduct a basic impact assessment, although there are risks that without the theoretical background in the above fields, key concepts will either be left off, misapplied or misinterpreted. For that reason, it is recommended that future IoT programs using this guide ensure their teams have sufficient skills to apply PIU in the context of a theoretical understanding of economics, environment and social science.

Additional stakeholders that may find the guide useful include:



City officials – including mayors, governors, legislators. The PIU can help city officials better understand the positive and negative impacts of their large-scale IoT programmes, thereby helping them to make more informed policy and procurement decisions



Investors – private and institutional investors. The PIU will help investors understand the full lifecycle of impacts arising from IoT deployments in greater detail, giving them vital confidence in return on investment, thereby de-risking any future investment decisions.



Small businesses – developers, service providers, system integrators. The PIU helps SMEs enter the market by improving their overall offer to investors, for example by articulating their impact and thus sharpening their business case.



Citizens – residents and stakeholders who are affected by the innovation. The PIU gives due consideration to the views, perspectives and concerns of citizens, thereby helping to maximise positive impacts, minimise negative impacts and boost the project's acceptability.



Research institutions – universities, non-governmental organisations, researchers, funders, advocates and the academic community at large. The uniformity and consistency of the PIU method can improve researchers' understanding of the likely impacts of IoT deployments.



Development institutions – international financial institutions and other actors with a keen interest in urban development. The PIU's standard methodology for assessment can help these organizations make more informed decisions across sectors and countries.



Programme managers – of large-scale IoT deployments. This report sets out the key concepts underlying the PIU as well as specific considerations unique to IoT deployments, with the intention to guide allocation of resources, skills and time.

7.4 Why is PIU needed on IoT Solution Deployments?

In recent years, technological innovations have profoundly altered the way cities function and how citizens interact with city systems. New products and services proliferate at the intersection between

smart sensors, real-time data and a smartphone-savvy citizen-base. In transport, we now expect on-demand access to ride-shares. In housing, we can be remotely alerted to security threats via an app. In the public realm, we can take a picture of faulty street assets and have artificial intelligence (AI) detect the asset type, geotag the location and submit an alert to the council for repair.

IoT, open data and AI are opening the path even wider for more ambitious innovations designed to improve the lives of city dwellers and make cities truly 'smart' – whether they are citizen-facing or behind-the-scenes in the municipality. These innovations can help create economically thriving, clean and green cities that are inclusive and accessible. Many such ideas already exist, but they often exist in their infancy as prototypes, yet to reach scale or struggling to articulate the societal benefits of their unproven technology. They face significant barriers such as poor market co-ordination that hinders technical standards, fragmentation of regional and local data assets that hinders the creation of value from data, and lack of buyer confidence in harnessing new technologies, in part through poor information exchange.

Such lack of clarity hinders city leaders and decision-makers from making informed decisions on which innovations to procure due to a lack of understanding of the impacts on urban systems, citizens and the economy. With the world population forecast to reach 6.6 billion in 2050 in urban centres alone^{4 5}, it is imperative that cities are empowered to use technological advances to solve the pressing common problems they face, problems that touch on transport, employment, education, health, energy, waste management, clean air, climate change and more.

Projects like SynchroniCity have the ambition to clearly and transparently communicate the impact of IoT technologies by establishing a large-scale, cross-border IoT marketplace and setting the groundwork for an evidence base on the wider positive and negative impacts. This report sets out a framework for providing that evidence base, based on FCC's PIU framework. It has been tailored here for IoT solutions, to provide future innovators a building block for understanding and communicating the positive and negative impacts of their deployments.

Impact assessment is useful for IoT deployments as an appraisal tool, as outlined further below. It is important to understand, and where possible estimate, the potential impacts of deploying a certain IoT service. The positive impacts of trialling a new technology need to be measured against any negative impacts and, crucially, the technology needs to be designed with strategic objectives and the 'end-user' in mind, which in the case of SynchroniCity is the cities and their citizens. This avoids unnecessary deployments of technology or poorly designed functionality or usability of an IoT device or solution.

Impact assessment is also useful for IoT deployments as an evaluation tool as it allows cities to measure the impacts of a service and estimate these into the future should the service be rolled-out at scale. This could be across either different municipality functions or geographical locations within the city. Publicly accessible impact assessments also allow neighbouring and comparable cities to explore the benefits of adopting similar IoT solutions in their own cities.

7.5 When to conduct PIU

The PIU impact assessment process should ideally be implemented at the beginning of a project's conceptual phase. Early involvement maximises the chances of identifying the full range of impacts, supporting better baseline data collection while helping to determine whether or not to keep the project going. Impact assessment can be used to prove (i.e. find evidence of the success of) and/or improve (i.e. make changes to) an intervention, and can be applied at any time during the project lifecycle and, as mentioned above, either as:

⁴ <https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html>

⁵ <https://www.un.org/development/desa/en/news/population/world-population-prospects-2019.html>

- **Ex-ante appraisal:** before an intervention is made or completely defined, in order to inform decisions about initiating a project, resulting in measurable benefits and/or costs to the public, or
- **Ex-post evaluation:** after an intervention has been made, so as to analyze a project or intervention retrospectively at a time of completion, conclusion or revision.

Both appraisal and evaluation offer useful insights. While appraisals use assumptions and data which can be a proxy, evaluations always aim to use actual data generated by the project itself. These documents can then form the evidence that companies, cities or other organizations need to prove the value or worth of a certain IoT deployment. This can be useful when applying for funding, seeking investment or engaging a city's procurement process.

The next section gives an overview of the first phase of the PIU: discover.

8 Phase 1: Discover

8.1 Triage Triangle: Problems-Solutions-Desired Outcomes

This Triage Triangle is used to diagnose certain city problems, design solutions and ensure they meet desired outcomes. Importantly the process should be iterative as refinements are made throughout each stage. Following the Figure 40 below one can step through a conceptual way to view how the service meets the city's objectives. It can be used to sense-check that an IoT solution is doing what it should do to meet user needs and expectations.



Figure 40. Triage Triangle for problems, solutions and desired outcomes

Often identifying the core desired outcome is difficult with city administrations as there are many stakeholders placing different emphases on differing objectives. However, in the next section of the discovery phase it is important for assessors to understand clearly the desired outcomes of the project, even if they are understood only in more broad terms or at the city strategic level.

Furthermore, it is important to know from a city their primary objectives and whether some might be more important than others. This is particularly key if objectives cross over or contradict when it comes to the impact mapping stage. For example, a city may have objectives to both increase city

attractiveness and decrease traffic congestion. Therefore, an app which maps out the best route for car parking spots may increase city attractiveness but, depending on how it is planned, it could also have the unintended effect of increasing car usership and therefore increase congestion.

The following table outlines the pilots' self-reported immediate and long-term/scaled-up impacts of their IoT solutions. These reported impacts were collected in the final M6 reporting, which occurred after the pilot deployment period. The pilots were asked which of the following impacts the solution had started to achieve during the pilot period or aimed to achieve in the longer term, including scaled-up effects. Scaled-up effects are the estimated effects of multiplying the outcomes of a deployment with the associated users (extrapolating the findings), in the hypothetical case that the solution is deployed at a wider scale, whether across a city, multiple cities or nation-wide.

Table 13. Self-reported impacts & expected impacts of pilot solutions⁶

Percentage of pilots who reported the selected impacts of their pilot solution			
Economic, Environment & Social Impacts	Immediate Impacts	Longer-term or scaled-up effects	Either immediate or longer-term/scaled-up effects
Economic			
Reduced operating costs for the municipality	25%	69%	88%
Improved service efficiency for municipality	38%	63%	88%
New market-ready solution created	69%	31%	88%
Increased competition in your market	38%	31%	69%
Travel time savings	6%	56%	63%
Reduced congestion	6%	50%	56%
Increased local spend in the economy	6%	50%	56%
Increased tourist attractiveness and spend	0%	56%	56%
Other	13%	19%	19%

⁶ Note that the final column percent percentages do not equal the sum of the first two because both immediate and longer-term impacts selected twice were combined as one.

Environmental			
Reduced carbon emissions	19%	56%	75%
Reduced energy demand	19%	38%	56%
Reduced waste production	0%	38%	38%
Improved air quality	25%	69%	81%
Improved noise pollution	0%	56%	56%
Improved access to green space	0%	38%	38%
Other	13%	19%	25%
Social			
Improved education	6%	25%	31%
Improved mental health	6%	31%	31%
Improved physical health	13%	44%	50%
Improved citizen participation in government	25%	25%	50%
Improved inclusivity for marginalised groups	0%	19%	19%
Improved accessibility for lesser abled people	6%	19%	25%
Reduced crime or improved legal compliance	6%	6%	13%
Other	0%	13%	13%

Of the economic impacts, improving service efficiency, creating a market-ready solution and reducing operating costs were most commonly cited as initial or expected impacts. Interestingly, nine Open Call pilot groups reported that their solutions either in the long run or if scaled-up would increase tourist attractiveness and spend. Of the environmental impacts, the most commonly cited are improved air quality, reduced carbon emissions and energy demand. Interestingly, nine Open Call pilot groups reported that their solutions either in the long run or if scaled-up would improve noise pollution. Of the social impacts, improving mental and physical health, and improving citizen participation in government

were most commonly cited as initial or expected impacts. Improved physical and mental health were mainly cited as scaled-up or longer-term impacts.

Figure 41 shows the results outlined in Table 13. The figures show that economic and environmental outcomes were targeted across the pilots, which also reflects the higher response by the pilots to the challenges surrounding sustainable mobility and environmental concerns. It also highlights the importance most pilots placed on a number of the economic outcomes to be achieved.

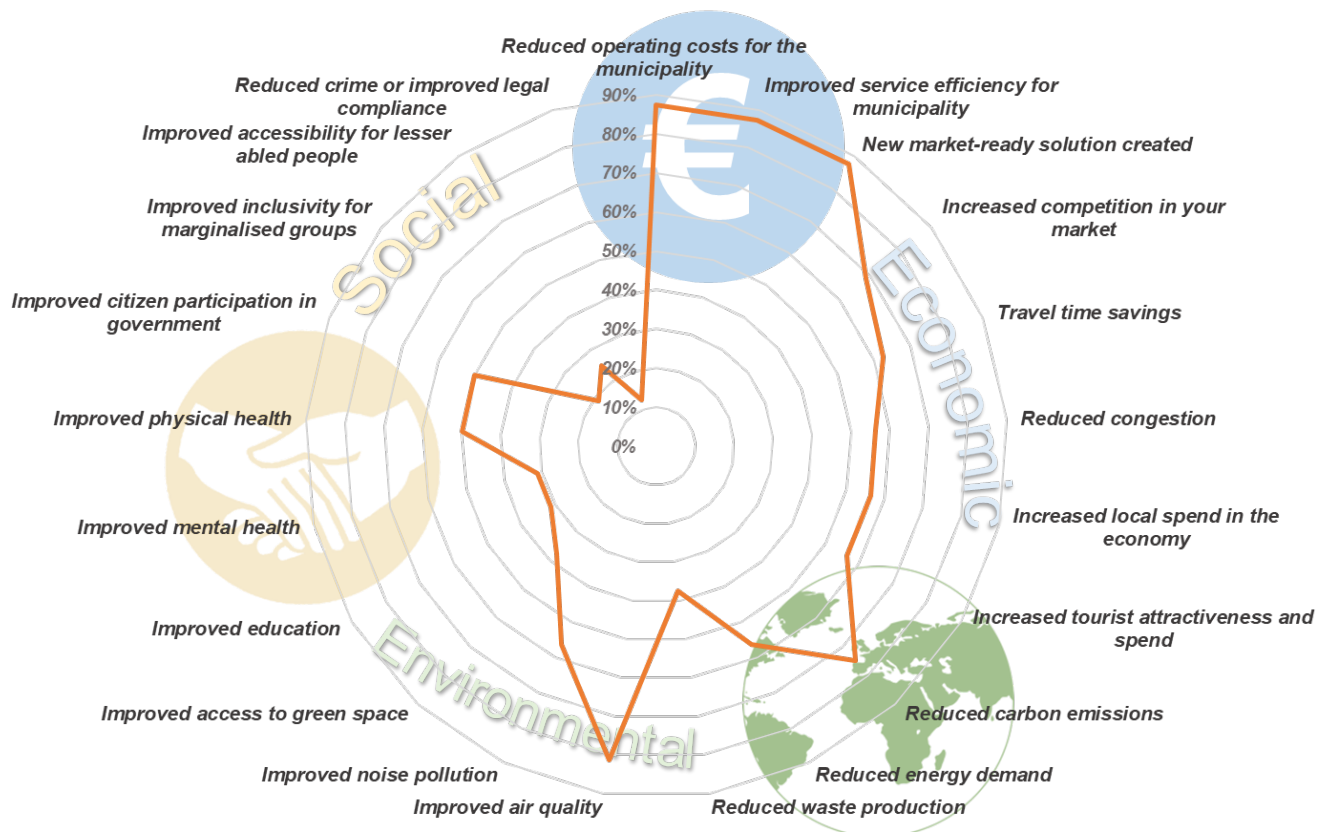


Figure 41. Percentage of pilots that self-reported specific immediate and expected long term impacts

8.2 Impact Mapping

What is an impact map?

Many pressing challenges facing cities today are by nature complex and long-term. Climate change resilience and healthy, active populations are two examples of ambitions that have numerous causal factors at play – so attributing any change to a specific intervention needs to be thoroughly backed by clear logic as well as robust data analysis.

The purpose of impact mapping is to set this logic out in a means suitable for stakeholder participation and communication, providing the opportunity for assumptions to be revealed and challenged constructively. A core part of impact mapping is the logic model – this model serves as a systematic and visual means of presenting the underlying pathways connecting the activities of the proposed intervention to the expected impacts. While ‘impact mapping’ refers to the wider process of identifying,

engaging and communicating with stakeholders, the 'logic model' is a single, visual document showing the flow of activities that result from the intervention.

A logic model has five key elements that are chains in the logical flow:

- **Problem/Context**

A description of the problem(s) the IoT deployment is trying to solve, or the gap in the market. This may also include a description of the environment and local social, political and economic characteristics of the setting, as well as a socio-economic profile. For example, descriptions of challenges in waste management, access to employment, active transport or wayfinding for people with disabilities.

- **Inputs**

A description of the key financial, human and material resources required for the IoT solution and the activities performed to turn those resources into outputs. For example, the number of hardware engineers, training materials or software developers, or the activities of manufacturing smart sensors, designing training materials and deploying an app to smartphone app stores.

- **Outputs**

A description of the assets or products generated, services delivered, processes changed, users gained, and participation generated – for example, the number of smart waste management sensors deployed, training workshops delivered, cycling facilities built or downloads of a wayfinding app.

- **Outcomes**

A description of the anticipated short- and medium-term results of the deployment. They are the changes affecting people, the environment, or the economy that the project seeks to achieve as a result of putting one or more outputs in place – for example the resulting changes in capabilities, skills, cyclist counts, citizen perceptions on autonomy and independence etc.

- **Impacts**

A description of the anticipated broader and longer-term results of the deployment. They occur later on, often indirectly, and lead to the resolution of project goals. For example, improved council service efficiency, reduced unemployment, improved citizen health and wellbeing etc.

See Figure 42 for an example template. Outcomes and impacts can be treated as a single column for higher level logic maps, potentially more suitable for smaller pilot deployments.

Impact mapping can be an invaluable activity as a project develops, with benefits in:

- Co-developing a shared vision of the project
- Convening stakeholders around that common vision
- Revealing assumptions for constructive critique
- Building the case for attributing societal change to the IoT solution
- Articulating the project's value to potential investors, procurers and others
- Identifying what data is needed to assess the impact

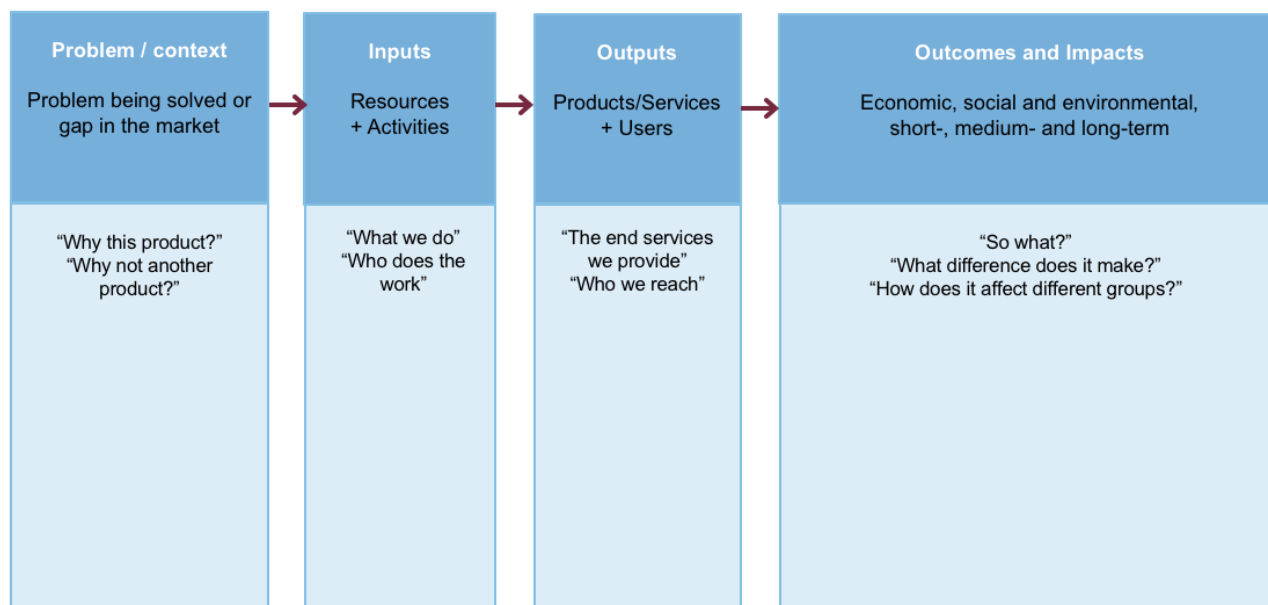


Figure 42. A blank logic model template, here with the Outcomes and Impact columns merged for simplicity for smaller pilot deployments

How to Conduct Impact Mapping

Ideally, impact mapping should start as early as possible before a project is deployed, but it can be useful at any stage in the project lifecycle. Proportionality is important here – very small deployments might not require resources to be spent following every step in great detail, whereas larger deployments may benefit from doing exactly that. That decision will rest with the program managers and conductors of the assessment, based on an assessment of deployment scale, who is relying on the assessment outputs and for what purpose. The steps are, in order:

1. Define the project and its context

This is about investigating and describing the story of the place and community affected, including economic, environmental and social factors. It is important for the assessor to understand the defined project objectives and approaches in simple terms, through reviewing existing documentation, consulting with members of the solution project team and possibly visiting the area. The assessor should assume the perspective of an 'interested outsider' or member of the public in order to start considering potential unforeseen or unintended consequences.

2. Identify stakeholders

Impact mapping is a collaborative process – consider all individuals and groups involved in the project or affected by its implementation, including vulnerable stakeholders. For example, the project might have potential unintended negative impacts on people in particular sub-groups (women, young people, seniors, low income families), or might not adequately embrace sub-groups that are harder to reach through digital solutions. The final list may include funders, policy makers, developers, partners, local authorities, staff involved in management and delivery, and end users or their representatives. Identifying stakeholders promotes a better understanding of their objectives, interests and needs, as well as shedding light on the relationship dynamics (e.g. conflicts of interests, power influences) that exist between them.

3. Hold 'logic model' workshop

Invite a select group of key stakeholders to a workshop with the goal of drawing up a model of how the intervention works, explaining that this in turn will help in the design of an effective evaluation strategy. Some recommended steps include:

- i. First, ask participants to describe the context (the place and the community), its problems and all the issues the intervention will address, as well as considerations about the social, political and economic context of the intervention. Note these in the 'Problems / Context' box on the far left of the logic model (see Figure 43).
- ii. Next, invite participants to express the overall and ultimate intended long-term impacts of the intervention. Note these in the 'Impacts' box on the far right of the logic model.
- iii. From here, participants can take one of 2 approaches:
 - a) If the aim of the workshop is to brainstorm what interventions to undertake in order to achieve clearly defined objectives and impacts, then participants ideally work backwards in order of 'Outcomes', 'Outputs', 'Inputs', identifying the necessary preconditions to drive what they have identified in each case. This approach is useful to brainstorm solutions without any pre-designed interventions in mind.

Explain the difference between inputs, outputs and outcomes (see descriptions above under 'What is an impact map?') and invite participants to share views on what kind of *Outcomes* are needed to drive the long-term *Impacts* they previously discussed. Note these in the 'Outcomes' box.

Next, invite participants to share views on what kind of *Outputs* the project could produce and explore how these drive the *Outcomes* previously discussed. Note these in the 'Outputs' box.

Then, invite participants to share views on what kind of *Inputs* the project requires in order to produce the *Outputs* previously discussed. Note these in the 'Inputs' box.

- b) If, however, the aim of the workshop is to validate the expected impacts of a clearly defined solution, then participants ideally work forwards in order of 'Inputs', 'Outputs', 'Outcomes', identifying the consequences of each step. This approach is useful to confirm if an intervention is likely effective in causing the desired impact.

Explain the difference between inputs, outputs and outcomes (see descriptions above) and invite participants to share views on what *inputs* are expected as part of the defined solution. Note these in the 'Inputs' box.

Next, invite participants to share views on what kind of *Outputs* are expected as a result of the *Inputs*, asking 'so what?' throughout the process. Note these in the 'Outputs' box.

Then, invite participants to share views on what *Outcomes* are expected as a result of those *outputs*. Note these in the 'Outcomes' box.

There are several important considerations to bear in mind when applying the steps above. Some common ones are listed here.

Throughout the workshop, a skilled facilitator should be on hand to ask probing questions that uncover each step's consequences and necessary preconditions, reveal hidden assumptions, identify enablers and inhibitors, and test the logical flow. An important note is to include unintended as well as intended consequences, both positive and negative. For example, an IoT-based service that weighs household waste and charges by the kilo may have the intended positive impact of reducing overall household waste generation, but also an unintended negative impact of disproportionate financial burden on lower-income families who live in areas lacking access to affordable fresh food and thus consume products with more packaging – and so produce more kilos of household waste. Thus, it is important to consider how the intervention might have potential unintended negative impacts on people sub-groups (women, young people, seniors, low income families etc.) and/or not adequately embrace sub-groups that are harder to reach with digital solutions.

It is a good idea to link or group inputs and outputs that relate to different kinds of outcomes – this is very relevant in meetings with developers as it may help in finding gaps between desired outcomes and planned activities. Consider also discussing what 'success' at each step would look like.

Finally, be aware that different stakeholders may be able to contribute different amounts to each chain in the logic flow (e.g. residents may know more about local context, while developers may have a clearer idea of project outputs). There is no 'correct' logic model, nor is there only one 'accurate' model for a given IoT solution. A logic model is a visual representation designed to help us find our way, not a detailed representation of reality. Although challenges may present themselves in reaching a consensus about desired outcomes and how these will be achieved, group discussions are helpful precisely because they elicit conflicting ideas about how the intervention should or might work. They also help to ensure everyone's views are represented in the evaluation plan, which in turn boosts interest in the evaluation results.

How to present the results of impact mapping

Ensure the key information is captured in a way that is complete and communicable to non-specialists. The following is a proposed outline for communicating an impact map:

Table 14. Proposed outline for an impact mapping report

Section / Chapter	Content
Project purpose	Describe the project so that it can be understood by a non-specialist. Consider all aims – social, economic, environmental, technological, commercial. Relate to regional policies or strategies.
Setting and current situation	Describe the local area and its communities in terms of social, economic and environmental factors. Use primarily collected data as well as secondarily available data such as local statistics.
Project stakeholders and affected groups	Identify who is involved in conception, development and implementation of the project, who will be impacted, and who will be most obviously affected by impact aims.
Logic model	Describe the logic model, as well as the method and participants behind it.

Relevant impacts	Summarise all identified impacts, intended and unintended, highlighting those that are material (relevant and significant).
Assessment questions	Delineate principal assessment questions.

How to Use the Results of Impact Mapping

Once impact mapping is complete, three key activities are unlocked:

- **Establishing a set of evaluation questions to answer.** The underlying causal logic identified through the mapping is one way of establishing a set of hypotheses for testing through data collection. For example, to test the hypothesis that citizens will be motivated to take up active commuting if smart cyclist hubs provide safe storage.
- **Identifying data sources and assessment methods.** The evaluation questions and hypotheses facilitate the identification of what data is needed to test them, and what assessment methods are the most feasible in terms of accuracy and resources available. For example, one method may be to make a comparison between the cycling rates among one residential area provided with smart cycle hubs and another area without.
- **Identifying evaluation metrics.** Impact mapping can help to establish a set of evaluation metrics, for tracking and reporting on the change in value attributable to the intervention. For example, an X% reduction in road traffic at junction Y by Z date, or an X% increase in physical activity within Y group of people by Z date.

High Level Example: SynchroniCity Pilot Quamtra for their Deployment in Porto, Portugal

Below is an indicative example of the type of content to include in an impact mapping report, using Quamtra's smart waste management solution as an example. This is not intended to be a full report given the reasons given in "7.1 Applying the PIU to SynchroniCity". Based on full data being available such a report would have individual chapters for each heading and explore the subject in much greater detail.

Table 15. SynchroniCity pilot Quamtra for their deployment in Porto, Portugal

Project purpose	Quamtra is a smart waste management solution. Their aim on SynchroniCity is to equip local authorities and their waste management partners with data and tools that allow them to optimize their collection routes and reduce the frequency of collection. This is achieved (in this Porto pilot) by: • fitting 100 waste containers with smart sensors that are able to detect and report on fill levels • deploying a web-based analytics and data visualisation tool to assist in static and dynamic route optimisation, as well as provide real-time alerts of container fires or vandalism.
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Setting and current situation

The city of Porto is Portugal's second largest city and the most populous of the northern region with 215,000 inhabitants in 2017, accounting for 15.8% of the nation's GDP. Textiles, manufacturing, commerce and fishing are all important industries.

Annual expenditure on waste management per inhabitant is high compared to the rest of Portugal at €110,338 per 1,000 inhabitants compared to the national norm of €43,807 in 2017 – more than double. Porto also generates more waste per inhabitant, about 36% more than the national norm.

Significantly less selectively-collected waste is sent to landfill in Porto compared to the national average, as seen in Figure 42a.

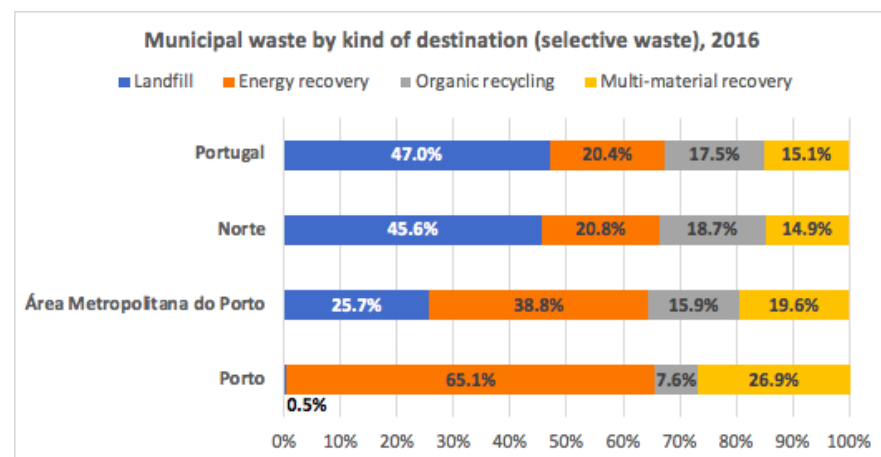


Figure 42a: municipal waste by kind of destination (selective waste only), 2016. Source: Instituto Nacional de Estatística

The population density within Porto is 5,181 per km², typically 55% female, and the population size is subject to a slight year-on-year increase, partly driven by inwards migration. Given Quamtra aims to optimise routes and help decongest local traffic, air pollution is an important consideration. Portugal as a whole has relatively good levels of urban population exposure to air pollution, as can be seen in Figures 42b and 42c. These figures show that the Portuguese average for concentrations of 2 important air pollutants, PM_{2.5} and PM₁₀, fall well below the EU standard and at or below the World Health Organisation annual standard.

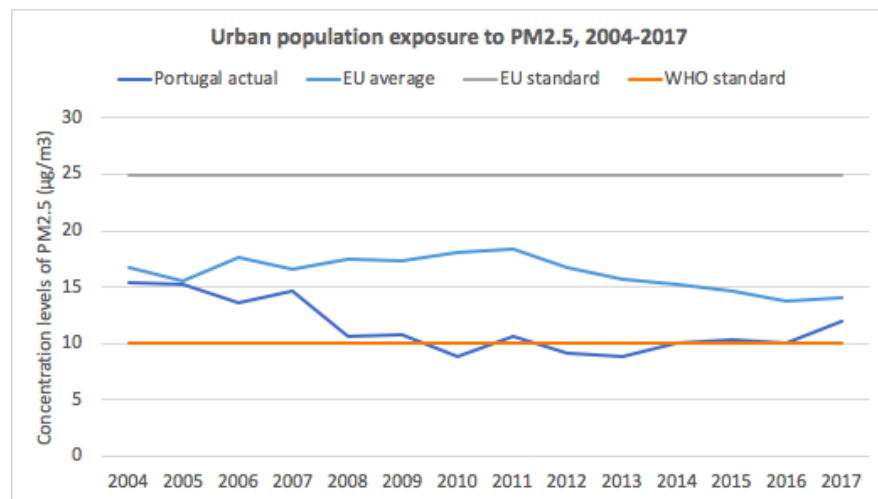


Figure 42b: urban population exposure to air pollutant PM2.5, 2004-2017.
Sources: Eurostat, World Health Organisation

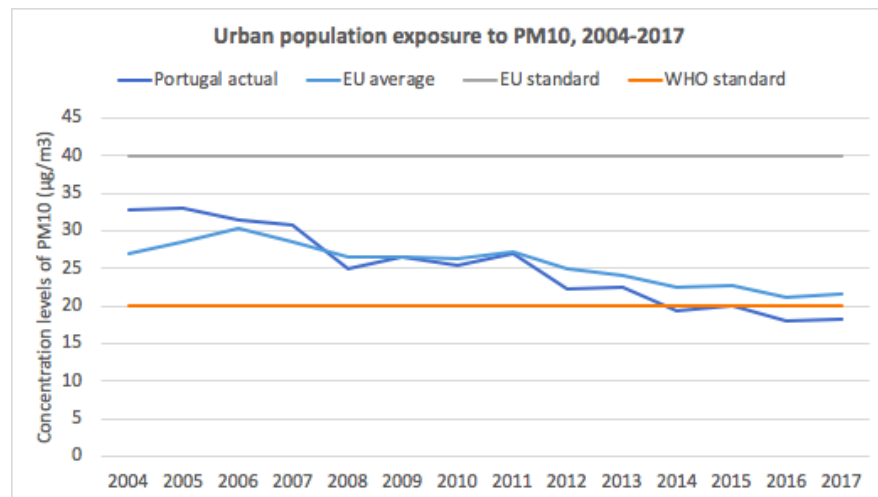


Figure 42c: urban population exposure to air pollutant PM10, 2004-2017.
Sources: Eurostat, World Health Organisation

For the intervention, 100 waste containers will be fitted with Quamtra sensors along the routes being piloted (approximately 36 km in length and with mixed land use).

Sources: Instituto Nacional de Estatística, Eurostat, conversations with Quamtra

Project stakeholders and affected groups

The main stakeholders identified include:

- Wellness Telecom
- Municipality of Porto Waste Operations Department
- Waste collection services contracted by Porto
- Citizens and businesses of the collection area
- Visitors to the collection area

Logic model	See Figure 43 for Quamtra's logic model. Note that this version splits the outcomes into 2 separate columns, those for short-term and those for medium-term, because this was the clearest way of capturing the logical flow and logical bundling of outcomes.
Relevant impacts	Impacts identified included: Economic • Lower municipality costs due to lower fuel costs, improved time management and lower civil liability costs from vandalized containers • Diversified skills in municipality due to a broadened employee skill base in analytics • Lower business and citizen costs due to less congestion (not expected to be material at the pilot's scale). Environmental • Lower carbon emissions due to lower vehicle emissions from optimized routes • Improved recycling rates due to recycling containers having more capacity from avoided overflow. Social • Improved job satisfaction for municipality workers due to a broadened skills base in analytics • Improved municipality service efficiency due to improved time management • Improved municipality service quality due to improved handling of container overflow • Improved citizen health and well-being due to less air pollution, noise pollution and odour from the optimized routes
Assessment questions	Evaluation questions The principal assessment questions were thus identified as: To what extent does the Quamtra solution improve: • municipality expenditure on waste collection? • the municipality Waste Operations department's employee skills base? • business and citizen costs? • carbon emissions of waste collection? • recycling rates? • job satisfaction for municipality workers? • municipality waste collection service efficiency? • citizen health and well-being, including perceptions on noise pollution and odour? Several of the impacts identified are driven by a common factor: the distance the waste management vehicles drive per month to collect waste from the sensor-fitted containers. Therefore, the primary hypothesis was that the Quamtra solution reduces the vehicle kilometres travelled per month in collecting waste from the sensor-fitted containers. Data sources and assessment methods

	Data sources were identified to answer these assessment questions and test the hypothesis. In the next section, section 8, these data sources are discussed in more detail. The assessment method identified was to collect pre-intervention and post-intervention data, as well as to establish a control area and an experimental area for the counterfactual (see section 9.1 on determining net effects for details on these methods). For subjective impacts on perception, wellbeing and skills, the methods identified included surveys, workshops and interviews. Goals In addition to the above, Quamtra already had goals to reduce operational costs by up to 35% and for the municipality to achieve return on investment within two years.
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Sources: European Commission⁷, Eurostat⁸, Instituto Nacional de Estatística⁹, World Health Organisation¹⁰

8.3 Horizon Scanning and Literature Review

Horizon scanning is an activity undertaken to understand the state-of-play of existing market solutions and how previous technology has been able to fill the gap in the market or overcome barriers to certain societal challenges. A literature review is a search and evaluation of publications relevant to the intervention's aims, taking place before deployment. The objective is to improve the likely success of the intervention by capitalizing on existing knowledge in the field and adapting the solution or intervention design where appropriate. This is of importance to IoT solutions that aim to initiate a change in behaviour, as literature reviews can add insights from behaviour change theory, economics, environmental science, social science and more. See Appendix 1 for details.

8.4 Recommendations

Following the horizon scanning and literature review, it is recommended to structure findings in terms of recommendations, so that they can easily be discussed with or used by the project team. It may not be possible or desirable to incorporate all recommendations, for example due to time and budget constraints. See Appendix 2 for recommendations made to the multi-modal navigation app and parking app atomic service in Santander. Whilst these recommendations were not able to be incorporated due to the time and budget constraints, they still highlighted information that future parking and route-planning apps may seek to take advantage of in driving bigger impacts.

⁷ <http://ec.europa.eu/environment/air/quality/standards.htm>

⁸

https://ec.europa.eu/eurostat/search?p_auth=I4XKyU5i&p_p_id=estatsearchportlet_WAR_estatsearchportlet&p_p_lifecycle=1&p_p_state=maximized&p_p_mode=view&_estatsearchportlet_WAR_estatsearchportlet_action=search&text=particulate+matter

⁹

https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=352363098&PUBLICACOESmodo=2

¹⁰

https://apps.who.int/iris/bitstream/handle/10665/69477/WHO_SDE_PHE_OEH_06.02_eng.pdf;jsessionid=AD7D8E58E0BBCFF57D2F58954CFBEECE?sequence=1

Extent of impacts: the impact mapping exercise normally clarifies which impacts are considered most likely and whether there are any key concerns or objectives identified by stakeholders. IoT technology deployments running in a pilot program such as SynchroniCity present challenges in impact assessment which need to be addressed in the screening stage. Pilot programs, as the name suggests, are not guaranteed to run for a substantial time period meaning data creation and availability of data could be difficult. Also, if a deployment is running in a testbed or substantially small geographical area, the impact will likely be too small to ensure robust results. However, some impacts may be measurable and in using a scaled-effects approach, impacts could be estimated. A scaled-effects approach involves scaling up a technology deployment from the deployment zone to the whole city or a greater region. This concept is used across many other fields when estimating the benefits of wide-scale adoption of services. However, while this might be appealing for businesses to pitch their solution, without appropriate consideration to the context of scale-up the estimates may be unreliable. To avoid this, employing sensitivity analysis and a range of estimated benefits is more appropriate.¹¹ This is discussed further below in the final Phase: Analyse.

Cost Effectiveness: in understanding the skills available and likely extent of impact, the assessor or budget-holder may also need to balance this with the costs involved. While smaller start-ups may not have the means to undertake a detailed impact assessment, a high-level analysis could ensure they are able to use the analysis in the future, for example, to secure investors' capital or use in an application for public funding.

Scoping is about understanding the spatial and temporal boundaries and resourcing available to undertake impact assessment. For each IoT deployment one should consider the parameters and constraints of the following focuses.

Spatial: what is the geographic location of your deployment and how will this define your analysis? Answering this question will determine whether the analysis will look at local, regional or national outcomes. This will help understand what data is needed, be it primary or secondary data and also whether a robust level of analysis is possible or feasible given these constraints. It also helps determine whether you will need to include scaled-up effects and how this will be realistically demarcated. For example, an app which maps the accessibility of routes for less-mobile people being trialled in one neighbourhood, is highly localized. The expected terrain and accessibility likely differ considerably in other cities but could be quite similar in the surrounding neighbourhoods. Therefore, the spatial boundaries may be the local neighbourhood and scale-up effects appropriate only to estimate across the city.

Temporal: what time period will the impact assessment cover? As part of determining a suitable temporal boundary, the assessor should obtain or produce a detailed project timeline. For shorter pilot periods the impact assessment period will likely be more difficult to determine as it will depend on how long after the deployment period the users will gain benefit. Then the assessor may consider whether annualized effects are appropriate, which accounts for seasonality and uses existing data to smooth averages over a yearly period.

Resources: who and what resources are available to conduct the impact assessment? Along with skills availability as outlined above, it is also essential to consider the availability of staff, data and other resources. Early, thorough planning which gives due consideration to the resources needed leads to far more effective impact assessments. It is particularly important for each assessor of the IoT deployment to understand:

- Project attributes: including geography, data collection methods, and availability of contributing resources

¹¹ Her Majesty's Treasury, 2018, The Green Book: Central Government's Guidance on Appraisal and Evaluation, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

- Design of the evaluation: including the amount of time required to analyse and draw conclusions from data, and the technical expertise required for working with particular topics
- Requirements of reporting: including time spent preparing reports, presentations, events and other vehicles for sharing findings externally.

In Figure 44 below the first picture shows an example of an imbalance between using a more resource intensive approach and the usefulness of the findings, while the second picture shows the example of a more balanced approach with resources and usefulness being weighed accordingly.

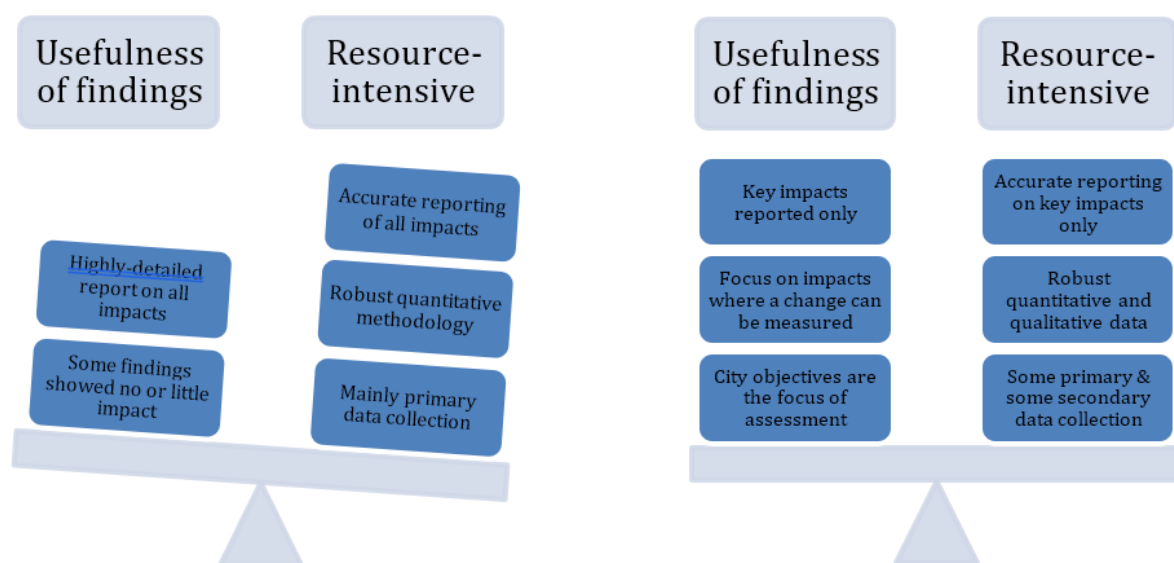


Figure 44. Comparing the balance between and usefulness

9.1.2 Choosing Appropriate Metrics

A set of metrics and measurements should be developed for each dimension identified and selected by the screening process. The term metrics should be understood as an overarching or umbrella term for things that can be measured whether it be outputs, outcomes or impacts. Outputs – for example the number of users of a service – drive the outcomes, in this case the increased number of users of a service. Outcomes then drive the impacts, in this example the increased service provision across the city. This is a basic illustration, but it is important the assessor makes a clear distinction. The assessor should consider the triple bottom line and consider all possible impacts within the economic, social and environmental dimensions. In terms of the impact mapping exercise above, the list of outcomes should directly be linked to impacts.

All impacts should be understood as either direct or indirect:

- *Direct impacts* are those that are the immediate consequences of the interaction of an activity with an environmental, social, or economic component, without intermediary effects. An example of a direct impact is the bicycle hire revenue from a bicycle share program.

- *Indirect impacts* are produced as a result of a chain of impacts or complex pathways. Indirect impacts may be described as secondary or tertiary impacts (this PIU guide treats both as indirect impacts without differentiating between the two). In a bicycle share scheme example, an indirect impact might be increased fiscal income for the city as a result of local shops seeing improved revenues due to an increase in customers (the direct impact) using nearby bike share stations.

Assessors should consider both direct and indirect impacts to the extent that they fit within the scope of the analysis (see section 8.1.1 on Scoping above). The metrics suggested by the following 3 sections do not represent the sum total of what is relevant or appropriate, as projects may span a wide range of technologies and impact types. The impacts that bear consideration are those that fit the project's objectives and context, and the priorities identified by stakeholders.

At all times during the assessment process it is important to remember that impacts can be both positive and negative. Care should be taken to ensure that the process is balanced, that it considers the (non-financial) costs of the project as well as the benefits, and that it follows logically from the impacts identified during impact mapping.

It is important that the assessment considers any unintended impacts, for example those vulnerable to any negative effects, as well as who might be best able to take advantage of the positive impacts. For example, moving an existing service online may lead to an increase in users and more positive experiences for those users. There may also be people who do not have internet access or who lack the skills needed to access the new service online – for this group the transition to online provision will impact negatively on the user experience. Both groups have been affected, but in different ways – the latter group may not have been the primary focus of the project's planning stages, where technological development and implementation are likely to have been foregrounded.

9.1.3 Understanding how Metrics are Developed to Measure Outcomes and Impacts

Each technology solution will have different objectives and therefore different user features to enable the service to meet these objectives. The key to understanding the metrics which are important to employ in the data collection process is understanding how each output aims to meet a short or long-term objective.

Outlined below are some of the metrics which could be used in terms of each of the Open Call challenge areas of which the open call pilot groups responded. The description of the service is linked to the challenge area and city objective.

Table 16. Metrics corresponding to different city challenges

Challenge area	Example City objectives	Description of example service	Example metrics
i) Climate change adaption	Reduce energy waste, thus reducing cost and carbon emissions.	Smart street lighting that adapts its brightness to the volume of traffic on the street, using a combination of sensors, analytics and IoT-enabled streetlights.	Kilowatt hours consumed by streetlights over a suitable period (e.g. 4 weeks). Conversion factors can be applied to understand the carbon and cost savings.

ii) Encouraging mobility as a service	Increase mobility among people who are less able due to physical disability.	A new app which is deployed to provide citizens information on the accessibility level of streets, sidewalks and public transport stops in a city.	One metric to examine would be increased use of the routes provided in the new information service of the app. This could be collected through survey data e.g. questions on the frequency and ease of use of these streets.
iii) Encouraging non-motorized (active) transport	Increase the number of cyclists and the proportion of active travel modes used in citizen trips, thus improve citizen activity levels, well-being and health.	Secure, photovoltaically-powered docking stations for cyclists to store their bicycles or charge their e-bikes in public spaces.	Number of cyclists observed using strategic cycleways; citizen perceptions on safety in leaving their cycle in public docks and on viability of bicycle travel; active trips as a proportion of total trips, etc. These could be collected for example through a mix of observation, surveys and travel diaries.
iv) Increasing citizen engagement in decision making	Improve awareness and education about waste contamination and proper recycling. Decrease the amount of waste contamination and increase the amount of recycling	A cross-domain smart platform which engages citizen data and city data about approaches to recycling and waste disposal.	Some metrics which would be used would be the user engagement with the app, including number of downloads and time spent on the app. Data pertaining to the levels of recycling should be collected before and after the app is released for those who have the access to the app (experimental group), and then additionally levels of recycling should also be collected from those users who do not have access to the app (control group).
v) Reducing air and noise pollution	Reduce congestion, air pollution and noise in the city centre.	A citizen-facing app for drivers that predicts which car parking spaces are likely to be available closest to their destination and offers route-planning features to complement/substitute their journey with public transport, rental bikes and walkable routes.	Kilometres travelled by mode over a suitable period (e.g. 4 weeks), showing how travel behaviours change across private car, public transport, bicycle, walking etc. Conversion factors can then be applied to determine the savings in carbon emissions, air pollution etc.

A more extensive list of the relevant metrics for each of the three impact areas – economic, environmental and social areas – is included further below in sections 8.2, 8.3 and 8.4.

9.1.4 Determining Methodology and Data Required

In general, only data that contributes to analysis of the impacts should be captured – valuable resources or participants' time should not be spent collecting irrelevant information. Care should be taken to be consistent in terms of the spatial and temporal characteristics of data captured and deployed. Where such consistency is not possible, the assessor should be transparent about the substitution of data, stating the source and rationale for the replacement dataset.

Figure 45 shows the data required and identified at the impact mapping stage of Quamtra's smart waste solution. The data for the Outcomes 'Less congestion', 'Less odour', 'Improved street aesthetics', and 'Broadened employee skills base in analytics' are excluded as they would have been outside the scope of analysis, however they could be included if they were key focus areas of the city.

Data required (objective data)

Quamtra, SynchroniCity

"Pre- and post-intervention" = data for the deployment area and an identical 'control' area; ideally for 1-2 years before the intervention and 4 weeks after the intervention; daily / weekly / monthly (Grey text = metric repeated)

Outcome	Metric	Unit	Single figure only	Pre- and post-intervention	Source
Lower fuel costs	Distance driven for the collection routes	km		✓	Quamtra
	Fuel cost to the municipality, including discount	€/litre	✓		Quamtra
Improved time management for waste team	Time spent driving the collection routes	hours		✓	Quamtra
	Time spent planning the collection routes	hours		✓	Porto Waste Operations
Improved time management for street cleaning team	Number of container overflows per month (or day or week etc)	# / month (or day or week etc)		✓	Quamtra
	Number of container overflow complaints per month	# / month		✓	Porto Waste Operations
	Time spent cleaning overflowing waste containers	hours		✓	Porto Waste Operations
	Number of containers burned or vandalised	#		✓	Quamtra
Lower civil liability costs	Maintenance costs per vehicle per X km	€		✓	Porto Waste Operations
Lower vehicle maintenance and replacement costs	Lifetime of average vehicle	km or years		✓	Porto Waste Operations
	Civil liability costs per burned / vandalised container	€ / container		✓	Porto Waste Operations
Lower carbon emissions and air pollution	Distance driven for the collection routes	km		✓	Quamtra
	Average vehicle speed (if known)	kph		✓	Quamtra
	Vehicle type	rigid / articulated		✓	Quamtra
	Vehicle fuel type	diesel / petrol		✓	Quamtra
	Vehicle weight	tonnes		✓	Quamtra
	Vehicle engine size	litres		✓	Quamtra
	Vehicle Euro Standard	I / II / III / IV / V / VI		✓	Quamtra
	Vehicle speed on route	kph		✓	Quamtra
	Vehicle make	-		✓	Quamtra
	Vehicle model	-		✓	Quamtra
	Vehicle year	year		✓	Quamtra
	Fuel consumption rate of the vehicle	litres/km		✓	Porto Waste Operations
	Time of waste collection	hh:mm		✓	Porto Waste Operations
	Average vehicle speed (if known)	kph		✓	Quamtra
	Vehicle type	rigid / articulated		✓	Quamtra
	Vehicle fuel type	diesel / petrol		✓	Quamtra
Less noise pollution	Vehicle weight	tonnes		✓	Quamtra
	Vehicle engine size	litres		✓	Quamtra
	Vehicle Euro Standard	I / II / III / IV / V / VI		✓	Quamtra
	Vehicle speed on route	kph		✓	Quamtra
	Vehicle make	-		✓	Quamtra
	Vehicle model	-		✓	Quamtra
	Vehicle year	year		✓	Quamtra
	Waste container fill levels by container	%		✓	Quamtra
More recycling containers / capacity	Waste container fill levels by container	kg		✓	Quamtra
	Number of container overflows per month	# / month		✓	Quamtra

Figure 45. The data requirements and sources identified by impact mapping Quamtra's smart waste management solution.

9.1.5 Ethical Considerations

In respect of data collection that may be required for impact assessments, particularly when investigating social impacts, ethical issues are often similar to those arising from a research project. There are several areas of ethical conduct to consider carefully when interacting with individuals. The key principle here is to avoid causing harm or confusion. Individual data collected should be made anonymous and aggregated to avoid any privacy issues and ensure compliance with local legislation such as the EU's General Data Protection Regulation.

9.2 Economic Impact

The economic impact of a smart city solution can be far reaching. From the micro-level of reducing operating costs within the council to the macro-level of increasing tourism attractiveness of the regions, cities are concerned with how to maximize the positive economic impacts for citizens and the economic areas they operate within. Arguably, there is no outcome that does not impact the economy of the city region whether it be immediate or in the longer term. However, for this PIU assessment framework economic impacts focus on the added value in euro terms, plus the count of new jobs or new products and services.

Some categorization of impacts can be a useful start, and an assessor may want to establish whether impacts are direct or indirect or on a macro or micro level. Drawing the line of categorization can be difficult as sometimes some groups will benefit while others could receive a 'dis-benefit'. The overlap with social and environmental metrics is common due to different measurements being derived from one metric. This is particularly the case when city objectives have a dual mission. For example, a city may have an objective of reducing personal car use congestion through increased car sharing schemes. The number of cars on the road during peak hour may be one metric, however this could then be used to derive other impacts, such as increased travel time savings for commuters (economic impact), with decrease in carbon emissions (environmental impact). Regardless of which objectives a city is aiming for, there will always be an exhaustive list of metrics which can be used to measure economic outcomes. Some of these have been included in the list below in Table 17.

Table 17. List of economic impacts, their description and units of measurement

Economic impact	Description and expected benefit	Unit of measurement
Gross value added (GVA)	The contribution of an intervention to the economy, or the increase in value in the economy due to an additional product or service being provided. Gross value added is measured by different methods, one of which is product price minus intermediate consumption.	€/year
Employment	This is a simple measure of the number of jobs either created, lost or supported. This can be	Count

	difficult to measure with accuracy.	
Tax revenue/ expenditure	This is the revenue gain (or loss) from total tax income. This can be due to changes in sales, new policies, or improved enforcement. At a municipality level other fees and charges, particularly those which are a percentage of a total could be measured similarly.	€/year
Sales revenue	This is an increase in total product or service sales. This could be due to demand changes such as increased tourism.	€/year
Capital cost	These are the fixed and often one-off expenses such as machinery or physical assets. Decreases in capital costs could be due to reduced material or efficiency gain such as reduction of rework.	€
Operating cost	These are the expenses which are variable dependent on the number of units produced or services provided and are usually understood annually. This could be both at a corporate or 'personal' level. Corporate – from efficiency gain such as via automation; personal – from avoided costs such as lower insurance premiums due to improved safety.	€/year
Property value	The increased value of land and building. This could be due to factors such as improved connectivity, improved safety or increased local amenity.	€
Travel time saving	The time saved in travelling from point A to point B. A shorter commute time means more economic or leisure activities, both of which have value.	Hours and/or €/year

Productivity	This is the change in output for the same input costs or change in input costs for the same output. This is measured differently across countries and could be measured as output per worker, output per hour, or output per job.	€/%/year
Increased product choice/quality	Increases in product and service choice, improving citizen wellbeing and also creating greater competition for the market.	Counts of: • products in market • providers in a region • businesses responding to a tender

As stated above in section 8.1.2, economic impacts can be:

Direct impacts – for example decreased operating costs may be the direct impact of an IoT solution which integrates city service data, as three operating systems may be combined to one.

Indirect impacts – for example due to the new IoT solution integrating city data after 6 months, productivity begins to increase across the city council.

In some economic impact assessment frameworks (particularly for larger scale infrastructure projects) the direct and indirect economic impacts take on different definitions based on the location of the study area. The economic model for large-scale infrastructure often uses an input-output model that differs from the approach described in this framework, which focuses more on the smaller or pilot scale, and on the nature of the advanced urban innovation sector.

Economic impacts can be at a micro or macro level of impact, and this too may differ depending on the region or context of the assessment:

Micro-economic level of impact is a focus on supply and demand at the company or municipality level – for example, operating costs decreasing due to more efficient waste collection, or council staff being upskilled due to new technology

Macro-economic level of impact is a focus on what national or regional outcomes are being achieved, often expressed at a per capita level to understand citizen impact. These are often difficult to measure and/or realized over a longer time period. For example, improved national tourism expenditure due to increased local city attractiveness, or increased work productivity due to more efficient public services.

For IoT deployments initially the service provided by the new solution could have some microeconomic impacts to consider, say from the point of view of the municipality. For example, reducing operating costs is a direct business effect which may be measured in the first months following the implementation of a smart waste solution. However, after a year of productivity gains across the waste department and those departments which deal with the waste department, as well as other private waste and recycling providers, productivity improvements across the city have a wider indirect effect. While it would be difficult to state that small scale impacts would result in macroeconomic impacts, if municipalities collectively were to introduce the same or similar IoT solutions across the country and they had similar positive impacts, over time macroeconomic impacts would result.

Once all the potential economic impacts have been identified, an assessor can then shortlist an optimal number of impacts to include in the assessment. Once again, as outlined in the previous section in Figure 44, resource-intensiveness needs to be balanced with usefulness. The number of impacts to be measured should be based on:

- Expected impacts – what results is the project expected to deliver? Which policy objectives is the project intended to address?
- Available data – will the assessors be able to collect primary data (e.g. by surveying potential users to assess their willingness to pay), or have access to secondary data (e.g. historical economic activity in the area of interest)?
- Available resources – will the expected value of the data reasonably exceed the expected cost of collecting it? How many metrics and economic analyses can the impact assessment budget support?

After the short list has been compiled, the assessor then needs to design an appropriate methodology. This will include how to collect data, establishing a baseline and then to collect the data from the IoT solution's intervention. This is discussed further below in Section 8.5.

9.3 Environmental Impact

A city's environmental quality is a vital driver of its health and prosperity. The quality of air, water and green space are all components of citizens' physical and mental well-being, which are cornerstones of a productive workforce. Cities are increasingly aware of the growing public sentiment on environmental issues, driven in large part by awareness of climate change and urban air quality, but also extending to noise levels, waste, circular economies and beyond.

An IoT project's total environmental impact is derived from:

1. The impact 'embodied' in equipment/sensors;
2. The ongoing impacts caused by the use and maintenance of such equipment, and
3. The impacts that result from changes caused by the project.

It is important to include direct as well as indirect impacts, and negative as well as positive impacts (see section 8.1.2 for details). Table 18 shows example impacts of a smart parking solution that detects available parking spaces and directs drivers to them via an app, with the aim of enhancing mobility and reducing travel time associated with finding a parking space.

Table 18. Example impacts of a smart parking solution.

Type of impact	Positive	Negative
Direct	Vehicles drive shorter distances when seeking a parking space, reducing air pollution and lowering carbon emissions	Energy is used in the manufacture and installation of sensors, adding carbon emissions
Indirect	Parking spaces have better occupancy rates, meaning fewer parking spaces need be constructed. As a result, city land can be used for alternative, higher value uses	The improved parking service actually encourages drivers to make more car trips, adding air pollution and carbon emissions

In addition, take a lifecycle view: this means taking into account all pollution and resource-use across the supply chain in the production, use and maintenance of equipment/sensors, as well as the changes caused by later operation of the deployment. Life-Cycle Assessment (LCA) enables an estimation of the cumulative environmental impacts resulting from every stage in a product's lifecycle, including the activities associated with producing background resources, manufacturing, transporting, using and disposing of that product. In many cases the manufacturer will not have performed an LCA on its own equipment, in which case the need arises for an assessment of whether there are appropriate known items to use as proxies, or whether the item of equipment is unlikely to have a sufficiently significant impact to warrant estimation.

The main environmental impact categories for urban-based IoT services are as follows, although this list is not exhaustive:

Table 19. The main categories of environmental impacts for assessment of urban-based IoT services

Impact categories	Description	Units of measurement
Acidification	Acidification of water and soil	H+ equivalents
Air pollution	Air pollutants emitted in domestic and commercial premises that are harmful to human health and damaging to flora, fauna and structures	Weight of CO, NOx, PM2.5, PM10, SO2
Energy demand	Consumption of energy	kWh
Eutrophication	Oxygen depletion as a result of nitrogen and phosphorous deposit into freshwater or marine environments	PO4 equivalents
Greenhouse gas (GHG) emissions	Global warming potential of greenhouse gases released into the environment	Weight tonnes of CO2 equivalents (tCO2e)
Green space	Total land occupied by green space, which has an associated impact on habitat and biodiversity	Area (ha)
Land occupation	Total land undergoing use change, total land occupied to support the product system assessed	Area (ha)

Noise	Intensity and duration of noise levels over time	Decibels (dB)
Waste	Waste generated, by key waste types	Weight (tonnes)
Water consumption	Net freshwater taken from the environment minus water returned to the same watershed at the same quality or better (net change)	Volume of water
Water quality	Change in the ecological or chemical status of an above- or below- ground water resource	Qualitative rating change

Once the environmental impacts to be estimated have been identified, a methodology needs to be chosen and adapted to quantify those impacts. Detailed exploration of all methodologies is beyond the scope of this document, but a selection of methodologies is shown in Table 20. The methodology should be selected based on available data, materiality and additionality of impact, and available resources. There may be different levels of detail involved in the workings of these methodologies that are more or less appropriate to different cases.

Table 20. A selection of methodologies to be applied in environmental impact assessment

Environmental impact	Metric	Calculation methodologies
Air pollutants	Weight of CO, NO _x , PM _{2.5} , PM ₁₀ , SO ₂	Calculation methodologies typically take the form of using information on change in use of emissions generating devices combined with available emissions factors. This can range further in complexity, with more detailed information on emissions during operation (e.g. cars at different speeds) and also with analysis on the atmospheric dispersion of emissions. The method chosen should depend on the likely scale of the change in emissions. For projects occurring within the EU or within a legal air quality framework, it may be appropriate to take into account limit values, the legal standards and objectives for different pollutants, and assess whether the project results in an improvement or negative effect that brings an area above or below a limit value.

Energy demand	kWh	Assessments of changes in energy use are typically the multiplication product of the change in power consumption and time. However, care must be taken to incorporate other sources and to consider potential secondary and tertiary effects (e.g. increased device battery usage).
Green House Gas (GHG) emissions	tCO ₂ e	There are several media through which GHG emissions can be measured and the methodologies for calculating them are broadly the same. Activities that result in direct changes in emissions, such as running an engine, are determined and then multiplied by an 'emissions factor' that relates the activity to the generation of GHGs. Sometimes intermediary steps may be required, such as converting to fuel usage, in order to utilize known emission factors. Emissions can be indirectly generated through the use of material resources, where emissions are generated in the production, transportation and manufacturing of materials. Once again, the technique requires determining the change and the use of emissions factors.

9.4 Social Impact

IoT deployments can also influence individual and collective wellbeing.

Whilst there is no single agreed definition of 'wellbeing', it can be viewed as a positive physical, social and mental state and not simply the absence of pain, discomfort or incapacity. It requires that basic needs are met, that individuals have a sense of purpose, that they feel able to achieve important personal goals and to participate in society. It is enhanced by conditions that include supportive personal relationships, strong and inclusive communities, good health, financial and personal security, rewarding employment, and a healthy and attractive environment. This definition echoes the World Health Organization's definition of health as 'a state of complete physical, mental and social wellbeing'¹², while also stressing there are contextual factors that influence wellbeing.

Social impacts are locally defined and project-specific, and so any list of potential social impacts should be viewed as a guide rather than as a definitive checklist. In this section, we offer examples of different social impact dimensions to help assessors arrive at the most relevant metrics for their IoT service, such as the following:

Table 21. Social impact dimensions aligned with the European Commission's Quality of Life indicators

Impact dimension	Description and example metrics
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¹²World Health Organization <https://www.who.int/about/who-we-are/constitution>

1. Material living conditions	Includes income levels, risk of poverty and housing conditions. Such material resources can often be transformed into wellbeing in line with each individual's preferences and capabilities.
2. Productive or main activity	This addresses gainful or recompensed work, such as paid or unpaid work (for example caring for family or volunteering) and other activity statuses (for example studying or retirement).
3. Health	Health contains both subjective and objective measures of physical and mental health, including healthy life expectancy, disability, satisfaction with health, depression and anxiety.
4. Education	Covers the stock of human capital in the labour market and levels of educational achievement and skills, such as percentage of people with no qualifications, percentage of those not in education, employment or training, and human capital. Could include any experience that has a formative effect on an individual.
5. Leisure and social interactions	The time that individuals spend outside their main productive activities, including the extent and type of individuals' relationships with their immediate family, friends and the community around them, as well as satisfaction with leisure time, participation in arts or cultural activities and sporting activity.
6. Economic security and physical safety	Economic metrics include difficulties in 'getting by' financially and satisfaction with household income, whilst physical safety metrics include rates of crime and violence and measures of both real and perceived physical safety.
7. Governance and basic rights	Establishment and implementation of civil society, rule of law, human rights and accountable government. This includes participation in civil society, trust in institutions and views about interactions between countries. Indicators include trust in national government and voter turnout in general elections.
8. Natural and living environment	This includes the interactions individuals have with the environment, as well as the adverse effects they may have on ecosystems and biodiversity. Measures reflect having a safe, clean and pleasant environment, such as noise-free residential and work environments or easy access to nature and green spaces.
9. Overall experience of life	Including individuals' feelings of satisfaction with life, whether they feel their life is worthwhile, and their positive and negative emotions. Personal wellbeing measures are grounded in individuals' preferences and take account of what matters to people by allowing them to decide what is important when they respond to questions.

A number of social indicators are established by governments around the world. The European Commission has established a set of Quality of Life indicators.¹³ This list is not exhaustive, and other dimensions and indicators can also be used. For example, measuring the domain 'Leisure and Social Interactions' might mean investigating attachment to place, sense of community, or levels of urban accessibility for people with disabilities.

Assessments can use both subjective and objective indicators. Subjective indicators use ratings provided by individuals about their perspectives, attitudes, feelings, beliefs, preferences, and desires (e.g. an individual may be asked to rate job satisfaction). Objective indicators do not require individuals' responses – for example the number of citizens engaged in a city decision-making process. Objective indicators are not more 'accurate' than subjective indicators. Rather, the distinction between subjective and objective refers to the source and nature of the empirical data used to measure the underlying dimension of wellbeing.

Social impact using big data

Assessing the impacts of IoT deployments suggests that big data (datasets > 1,000,000 rows) can be leveraged to identify changes in human behaviour due to a specific intervention. The formal definition of big data is "data that contains greater variety arriving in increasing volumes and with ever-higher velocity" (Gartner 2001).¹⁴ This means that big data does not only refer to the size of the data set but refers to the changing nature of the data as datasets can become active in real time and deliver a higher level of detail in the quality of observations. Social science has a history of employing large scale models, such as global social models to map traffic flows, land use and development. When we refer to big data to measure social impact, it similarly relates to personal data, population data, spatial data, financial, intellectual, political, psychological, behavioural – and as with traditional methods of measuring social impact from individual-level outcome data, the linkages between these data are complex and largely unknown.

Benefits of Big Data

Big data collected through IoT sensors provides an opportunity to design experiments on a geographic scale that was not possible before. This presents an opportunity to design experiments to test social theories in an ecologically valid setting. Using big data, large-scale experiments do not have to be limited by coarse treatments measured at the population level, but instead increased granular treatment to more specific populations enables a deeper understanding of the social world.

Challenges of Big Data

However, social scientists understand that big data cannot overcome the selection problems that make causal inference difficult. This poses a challenge when measuring the social impact of new urban technologies. For example, when using social media data to measure social impact, there is a disconnect between the researcher and the data input. Furthermore, social data has blind spots where certain groups are not represented, and marginalized communities may be discounted from any analysis. Another challenge for social impact measurement is resultant from the changing nature of big data. We make consequential and untestable assumptions to compress data into some measure, either by filtering data to identify the relevant streams of information, or by aggregating data to identify the right temporal scale or spatial resolution. These assumptions affect the inferences made, and recommendations are given below to address some of these key challenges.

¹³ https://ec.europa.eu/eurostat/statistics-explained/index.php/Quality_of_life_indicators

¹⁴ <https://www.oracle.com/big-data/guide/what-is-big-data.html>

Key recommendations when dealing with Big Data

The computational challenges created by big data mean that sampling is often a necessity, and systematic attention needs to be paid to its impact on analyses and findings. Sampling can be done by the researcher, for example, filtering results based on relevant hashtags or a simple keyword-based search. Alternatively, sampling can be done by the data provider, usually through application programming interfaces (APIs). These do not usually give a full stream of information, more often giving a random sample of all activity. Both researcher sampling and provider sampling may contain bias, and therefore this bias should be recognized when conclusions are drawn.

However, big data can provide the ideal setting to match methods and the characteristics of observations to make treatment and control units comparable. A potential method of sampling to compare treatment and control populations is using a sampling frame chosen by researchers. This enables researchers to target a domain (which could be temporal and spatial) to focus on the relevant stream of data to assess the impact of new IoT solutions, and a control domain that is not impacted. Ultimately, researchers have to make an informed decision on whether “Global” as well as “Local” factors influence the impact of a particular technology and develop a sampling strategy that reflects this.

9.5 Conducting the Assessment

Once metrics have been established, the methodology needs to be planned. Broadly speaking, in this PIU framework, this will include 3 stages: selecting a research methodology, establishing a baseline and collecting intervention data.

9.5.1 Select a Research Methodology

Designing and planning the methodological approach will depend on what metrics have been shortlisted, but it is vital to focus on the link between the intervention of the IoT solution and the measured changes directly linked to the intervention. It can be difficult to establish robust cause-effect relationships within impact assessments because doing so includes an experiment such as a randomized control trial and this can be challenging and costly to implement effectively. Other designs may include experimental, cross-sectional, longitudinal, case study and comparative designs. Some designs may be weaker in terms of causal inference but can still shed useful light on the impacts of IoT solutions.

A SynchroniCity impact assessment would focus mostly on quantitative data, however other assessments could take a mixed methods approach, which combines both qualitative and quantitative data. There are many different research methodologies that can be adopted for assessing impacts, however detailed exploration of these is beyond the scope of this framework.

9.5.2 Establishing a Baseline

After identifying the metrics and finding ways to quantify them, the next step in a PIU impact assessment will be to establish a baseline. Setting the baseline means identifying the conditions before the intervention. The aim is to collect pre-impact data that can be compared to equivalent metrics following the intervention in order to assess the impact. Without knowing the trend or status prior to action it is hard to gauge how much of the observed changes in metric values are due to the intervention. A robust baseline is a critical element when it comes to determining additionality and attribution, themselves key components in rigorous impact assessment.

Depending on the metrics relevant to the identified impacts, there are 2 principle data types:

- **Bespoke/primary data** – For metrics highly specific to the impacts identified in an IoT deployment it is important that developers engage with the impact assessment in the design of which data will be created and become available. Otherwise, it is likely that assessors will lack available data. In these cases, the assessor will need to conduct surveys or primary data research or make use of data outputs from an intervention to establish the baseline. To the extent possible, an adequately long baseline period should be used for the context – 12 months is a good starting point, for example, when a seasonal effect might be expected. Assessors should allow sufficient time for designing and conducting surveys – interaction with stakeholders often takes more time than expected due to privacy concerns and other implementation issues.
- **Available/secondary data** – SynchroniCity presents a great opportunity to harness available open data and all that is being created by different city partners. For many metrics, open data sources may provide the historical data needed to establish the baseline. A frequent challenge in using open data is extracting location-specific data from a database matching the scope of the impact assessment. While economic data such as GDP and household incomes are tracked by many governments, it would be harder to secure similar metrics for the area of a 200-home development. In the face of data that is not at the appropriate scale, assessors can use the available regional data as a starting point and then calibrate further using survey and primary data collection. For social metrics we recommend using previously validated instruments.

The data could be collected through questionnaires, observation, secondary data, interviews, focus groups, and documents as sources of data.

Below, you can see in Figure 46 a graph of how the data is collected over time and the shaded area denotes the corresponding impact which is to be measured.

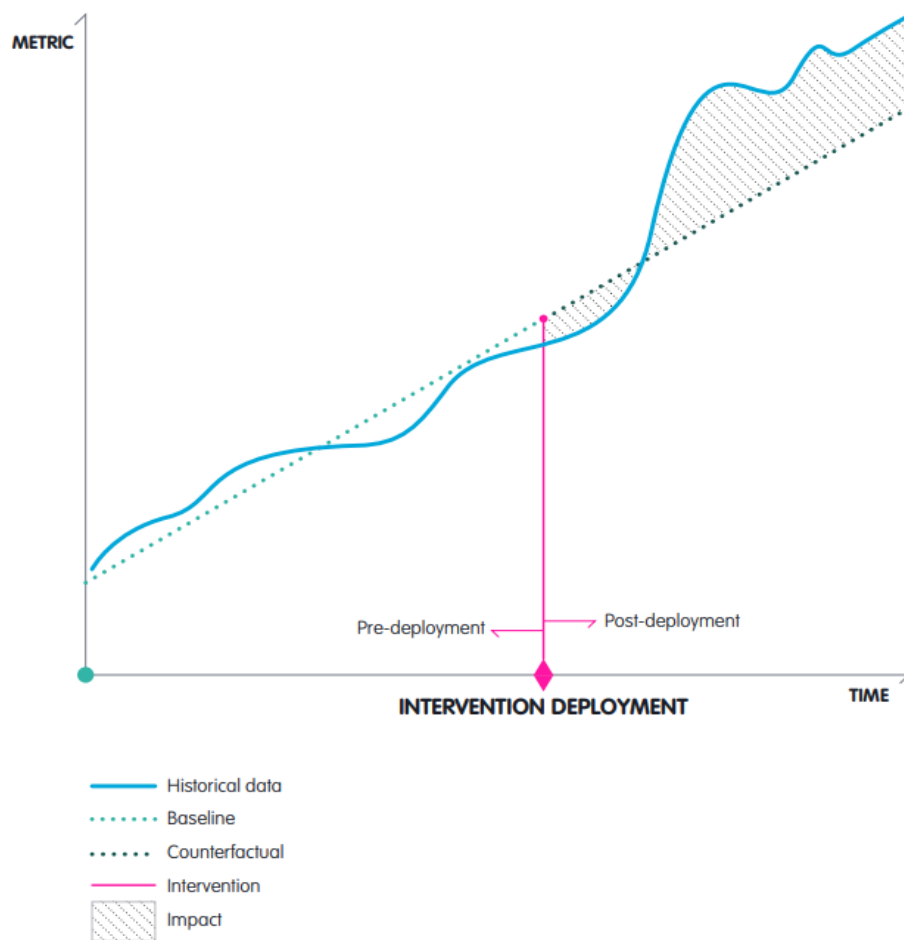


Figure 46. Counterfactual graph

9.5.3 Collecting the Intervention or Experimental Data

Following baseline data collection, the next step is to collect the intervention data. This will be after the IoT solution intervention is in place. The main goal is to determine the solution's effectiveness in delivering the desired outcomes. After this, the next stage is to analyse all the data collected, as discussed below.

10 Phase 3: Analyse

10.1 Determining Net Effects

Once quantifiable metrics have been measured, at baseline and for the intervention, the data collected for each metric should be investigated for additionality and attribution. Only then will the net impacts brought about by the intervention be known.

- **Net impacts** are impacts produced that can be attributed to the project being assessed and not to other factors such as the normal passage of time. Assessors need to account for

additionality, including deadweight and displacement, as well as changes attributable to other factors.

- **Additionality** allows an assessor to determine the net effects of an intervention by removing deadweight and displacement effects from the gross impacts. Deadweight is the condition stakeholders would experience in the normal course of events – that is, without the intervention. Displacement refers to the extent to which the project's effects displace other outcomes (e.g. when a company recruits new staff to support an intervention and so drives up wage rates).

To determine the net effect of the intervention, assessors need to compare the metrics measurement against the counterfactual. Counterfactual describes the hypothetical circumstances of what would have happened had the project not occurred. In theory, the assessor asks the question 'what would have happened to the local context (businesses, environment, communities) if the project didn't exist?' in order to determine the net impacts. In practice, the question is often difficult to answer, precisely because it is hypothetical. Impact mapping with a well-developed logic model or equivalent and a strong counterfactual will strengthen the causal link between impacts and interventions. Other techniques for assessing the counterfactual include:

- **Setting a control group** – a 'randomised' control group or a comparison group
- **Benchmarking from national data or comparable projects** – to compare the effect of the intervention to what normally happens as described by statistics
- **Gathering perceptions** by asking stakeholders directly what they believe would have happened to them if the intervention hadn't occurred
- **Using informed, expert judgement** – ask an expert in the field or from the local area.

The Additionality Guide published by the Homes & Communities Agency of the UK Government provides additional details and further guidance on the workings of additionality¹⁵.

- **Attribution** is about the interactive effects of multiple factors, particularly in terms of deciding which changes are a result of the assessed intervention and which are not. For example, if house prices within a city postcode rise following the installation of smart kiosks locally, how much of the price increase is due to the new kiosks? Other external factors, including prevailing tax policies, regional income patterns, and mortgage rates, can potentially have much larger effects on house prices.

An investigation of attribution helps the assessor single out how much of any increase is attributable to the intervention. It should be noted that determining attribution effects is open to some level of subjective interpretation, and there are often no definitive answers. However, techniques exist to improve the quality of attribution explorations, including:

- **Asking stakeholders directly** to what extent the outcomes have been the result of the intervention (not at all, or a great deal), and to what extent the outcomes have been the result of the intervention in conjunction with other factors
- **Conducting workshops** with representatives of other partners or entities or projects that may also have affected the outcomes in order to apportion respective attributions.

¹⁵ Homes & Communities Agency, 2014. This is not to be confused with the additionality as the principle followed by the European Structural and Investment Funds.

These techniques above, would be combined with the collection of quantitative data to deduce where the IoT solution has had an impact. For example, data collected from sensors on waste containers, which improve and optimize waste collection, would be coupled with asking the waste disposal team before and after about the new solution in place.

From all of this econometric, statistical and data analysis would then be undertaken to investigate the data collected, apply the methodology and calculate net impacts.

Readers can consult *Small Slices of a Bigger Pie*¹⁶ to learn more about alternative techniques for estimating the attribution of a project.

10.2 Scaling Up and Integrating Impacts

Following the assessment of any economic, environmental and social impacts, the next step is to integrate as well as extrapolate findings for scale-up, where appropriate, in the final report.

Firstly, the assessor must decide whether any of the economic, environmental or social impacts can be integrated. Integrating impacts is a key step in bringing objectivity and consistency to the decision-making process in city administrations which are surveying whether a solution may be needed or not for their city. However, carrying out the process of integration is no easy task. Among the considerations and challenges are the following:

- **Different units of measurement:** economic impact can usually be expressed in monetary units which are easily understood by stakeholders and policy makers. It is tempting, therefore, to convert environmental (e.g. CO₂ emission) and social (e.g. level of life satisfaction) impacts into monetary units. While this is possible in principle, there are a number of challenges associated with translating non-monetary into monetary units.
- **Different timeframes:** some environmental and social consequences are long-term effects that won't materialize until many years after deployment. Economic impacts, such as project revenue, can be delivered shortly after operation. How can we usefully compare profound but uncertain long-term effects with immediate and more predictable outcomes?
- **Handling of interactive effects:** how impacts from the 3 dimensions affect and interact with each other is often poorly understood or analysed. While a link between, for example, wellbeing and economic productivity is recognised, enumerating that economic impact may prove challenging or impossible.
- **Risk of double counting:** when the environmental and social impacts of a project are monetized, there exists a risk of 'double counting' if their economic impact has already been included. For example, a project that monetises the environmental benefit of a certain CO₂ emission reduction and the associated fuel saving as an economic benefit will be double counting if the CO₂ emission credit priced into the fuel has already been expressed or captured as an environmental impact.
- **Some impacts may be difficult, or impossible, to quantify or monetize:** these include social wellbeing impacts such as sense of purpose and sense of social cohesion, which are usually considered nonetheless to have an intrinsic value.

¹⁶ New Economics Foundation, 2011

Secondly, the assessor can look to scale-up, where appropriate, the measured impacts of a pilot or smaller-scale project. SynchroniCity has the mission to ensure solutions are replicable and scalable and ensuring that this can be proven with evidence is essential. While pilot solutions may only have small measurable impacts, the real power of reporting is seen when reporting vision is taken to a greater view and reliably forecast across different city departments or across different geographical areas.

Scaling-up impacts will involve the assessor using extrapolation of one impact assessment and applying the impact to another, whether it is another city department or another city altogether. Specifically, scale-up impacts are the estimated effects of multiplying the outcomes of a deployment with the associated users (the extrapolation method), in the hypothetical case that the solution is deployed at a wider scale.

Some of the considerations and processes involved in scale-up reporting include:

Seasonality: the effect which occurs when there are predictable and cyclical changes which influence the results in different time periods over a year. For example, there may be more city bicycle hire over the university year by students compared with the holiday period.

Annualising effects: the estimation of the effects of outcomes over the duration of a year using existing data and assumptions, adjusting for seasonality in the data.

Level of replicability: the consideration of how easily the IoT solution can be replicated in its exact form. For example, an accessibility mapping device may have more users in a geographic region with some terrain challenges, hills and many stairways, but may need to be altered in a geographic region where there are fewer terrain challenges.

Territorial division of units: when multiplying findings across cities or countries the assessor needs to consider and decide upon an appropriate unit for scale-up. This could be whether to multiply across similar units of division – for example from one city to another city of similar size – or to base the multiplication upon the population change from a smaller municipality to a greater region.

Comparability of city contexts: similar to understanding the level of replicability of the IoT solution, the assessor must consider how similar each city is that would be suitable for scale-up. An air monitoring sensor device and dashboard system may not be as well received in a city administration that already has many similar monitoring systems. Similarly, a city with 1 million citizens will have a quicker spread of users of an IoT device compared with a city of only 20,000 people.

Sensitivity analysis: this allows the analysis to have a range of values reported in the final stages. This is done by switching values, to give a range between more conservative values at the lower end, up to more optimistic values at the higher end.

All of these considerations for both integrating and scaling-up impacts must be weighed in terms of usefulness and resource-intensiveness as outlined in Figure 45. It may be that there are little resources to conduct a robust scale-up of impacts and therefore a caveat is given explaining the sensitivity of the range given in the forecasted impacts.

10.3 Communicating Impacts

A properly conducted impact assessment is only a starting point for delivering impact through IoT innovations. Increasing the likelihood of successful innovation for all identified outcomes beyond the pilot phase will require finding ways to share the results of the assessment.

Recording and circulating the difficulties and challenges overcome in the process of delivering an impact assessment is an important part of communicating the results. While all results should be presented – whether they are positive or negative – so as to be transparent and unbiased, it should be acknowledged that in order to ensure the results of an impact assessment are communicated effectively assessors should decide early in the process from whose perspective the study will be conducted or 'viewed'.

In order to maximise the output of the assessment we recommend adopting the perspective of the primary audience, which will often be cities and government officials operating within the city space. If the primary audience is not clear, we suggest adopting the perspective of the public – typically the largest stakeholder group. The ‘best’ audience is the one whose use or experience of the result will:

- Support implementation of the intervention
- Inform future decision-making
- Support development of funding and business cases
- Improve intervention delivery.

We recommend that assessment reports:

- Use non-technical language
- Establish an easy-to-follow audit trail, with clear presentation of calculation, evidence bases, data, and supporting assumptions
- Clearly present both positive and negative impacts, as well as the results of the analyses of uncertainty and sensitivities used
- Identify winners and losers as well as the average effect, considering in particular any trade-offs between goals that were identified during the assessment process
- State clearly which methodologies were used
- Give thorough consideration to ensuring compliance with legal restrictions and user privacy regulations where applicable

See Table 22 for a common reporting template for impact assessment. As with the framework as a whole, the format can be adapted to suit the individual project.

Table 22. Proposed structure of an integrated impact assessment report

Section	Content
Impacts and metrics	• Summarize the impacts to be measured • Define the corresponding concepts as well as the selected metrics.
Assessment design and method(s) of data collection	• Describe the research design and method(s) of data collection. Note that the methods chosen should be appropriate for the impacts identified, and not necessarily the same in each case • Describe the setting, the participants, the procedure, the instruments and the analytical strategy.
Results	• Write up the results obtained, using complementary graphs or tables when helpful.
Conclusions	• Discuss and integrate results and provide conclusions.

11 Lessons Learned

Since many urban IoT innovations are pioneering projects, capturing the lessons learned from the impact assessments can be valuable to future endeavours. Over time, a lesson learned may become an emerging good practice, if and when it can demonstrate proven results or benefits.

For recording the challenges faced and overcome, we recommend keeping a log of lessons learned. The log becomes a valuable reference resource for future impact assessments conducted on similar IoT services. The log describes what went well and what was less than optimal – and in so doing it offers

important insights into how to improve the assessment process in the future. See Table 23 for an example for SynchroniCity.

Table 23. An example log of lessons learned, as relevant to impact assessment of the SynchroniCity IoT solutions.

Issue category	Challenges	Consequence	Recommendation
Data collection	The pilot and city being impact assessed suffered delays to their final deployment	Data was not available to be impact assessed in time for analysis	Program planners to ensure sufficient time between pilot deployment due date and final report due dates, to allow data to be collected and impact analysis to be run
Data collection	Atomic services provide early opportunities to impact assess; however they do not deploy fully developed products at scale, are often light-touch/beta interfaces and tested only by a small group of people	Highly unlikely to detect any significant effect	Target the impact assessment on pilots, as they are more likely to be developing full products and services at scale and thus analysis is more likely to be able to detect the effects of the intervention
Intervention design	Not every pilot leads to a direct intervention that can be impact assessed e.g. they may instead be providing sensors, but no behavioural change	Impact assessment not possible on such pilots	Not every pilot will entail a change in behaviour/policy etc., but if impact assessment is desired then at least some pilots will need to involve an actual intervention as well as new technology. SMEs can conduct impact mapping early on to establish a clear view of possible long-term impacts and interventions to achieve those impacts
Resource availability and activity scheduling	July and August are common holiday periods in Europe, meaning that key contacts can often take overlapping holidays over the 2-month period	Activities that can require communication between multiple points of contact may face slow progress during this period – especially relevant for the pilot deployment phase, where	Plan the pilot deployment phase to minimize disruption from the July/August period. For example, a six-month deployment phase could start in October and finish in March – the December Christmas holiday period may give rise to the same problem but is much shorter in duration than the summer holiday period

		communication is required between pilots, city official and others	
Technical language barriers	Different stakeholders in SynchroniCity can use specific terminology or acronyms that are unknown to the other teams (e.g. highly technical language, or communications-specific language etc)	This can lead to uncertainty and lack of clarity on the meaning behind communications and requires time spent clarifying	Avoid acronyms in communications – always use the full spelling for the sake of clarity. Consider compiling short user guides that define common terminology in each team, to assist different stakeholders in navigating communications and documentation (e.g. a guide on software terminology, a guide on hardware terminology, a guide on communications terminology etc.)

12 Next Steps

As smart city deployments proceed in scale, ambition and uptake, cities will find themselves faced with an increasing array of IoT products and services. This makes impact assessments especially crucial so that a clear understanding is available to cities on how those solutions meet city needs and what the longer-term benefits or disbenefits are for the economy, environment and society.

Such an understanding will assist procurement decisions. It may be that an approach will need to be developed to simplify understanding of impacts generated by the vast array of options, and that a common scoring mechanism is designed to allow standardized comparison of solutions against city needs: carbon emissions, transport-related air pollution, waste and circular economy, are a few examples. Such an index is one possible area for future development of impact assessment on large-scale IoT programs.

In general, the trend towards open source real time data brings great potential to strengthen impact assessment through the ready availability of rich data, something that can often present a challenge. We encourage innovators and assessors to make use of such data where possible, building a clear view of both the context and changes attributable to the intervention, and establishing a database of smart city findings.

13 SECTION III: Conclusion

This report focused on impact evaluation (as part of Task 6.4 Impact evaluation). The aim of the report was to evaluate the impact of the project (Section I) and to provide tools for evaluation the impacts of IoT deployments (Section II). Impact evaluation was done with a selection of indicators that were set in the beginning of the project. The indicators reflected the Synchronicity objectives, that in this report were compacted in the following: 1. Ecosystem building, 2. Services and the value created and, 3. IoT Infrastructure development.

To summarize the evaluation results according to these aims, we can see the positive results in all the tree overarching aims. SynchroniCity created and replicated services for IoT smart city context. The

infrastructure development enabled the service creation and replication. An ecosystem was grown around the SynchroniCity initiative, to co-create the digital single market.

Further, we can see that SynchroniCity created value at the different digital levels. As argued by previous literature, the 4 digital layers of the digital architecture provide sources for value creation in IoT ecosystems (Yoo et al., 2010; Turber et al., 2014), suggesting that value is created on 1) device layers (physical layers such as hardware and logical capability layers such as operating system), 2) network layers (physical transport layers such as cables and logical transmission layers such as network standards), 3) service layer, and 4) content layer.

Generating value in IoT smart city ecosystem deals greatly with data and the amount and quality of open data is one of the key issues. However, as Abella et al. (2017) argue, releasing the data is not enough. The real value for citizens and society comes through the services delivered (figure 47).

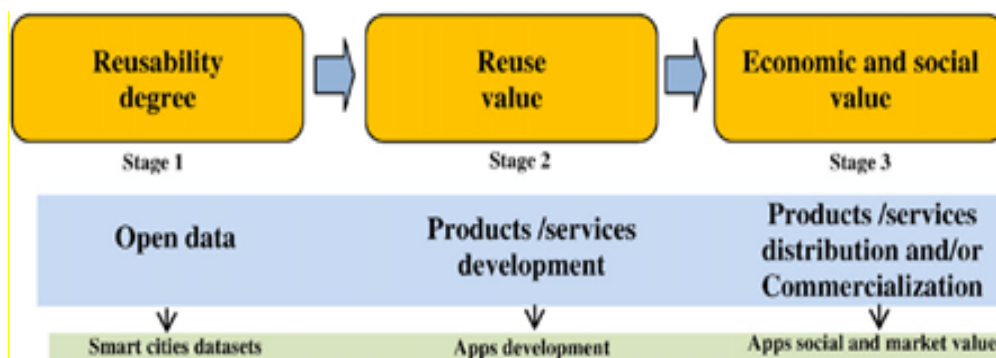


Figure 47. Model of value creation by the reuse of data in smart cities (Abella, 2017)

Abella et al (2017) suggest that for improving the quality of citizens' life, cities can nurture and optimize the ecosystems and agents that reuse their data to create innovative services. One of the major impact SynchroniCity shows is exactly this nurturing. Previous research has shown that for IoT ecosystem value creation, in addition to Ideators and Designer, ecosystem partners in the role of Intermediary are needed (Ikävalko et al 2018, table 24). Initiatives such as SynchroniCity can act in this role and support the evolvement of the ecosystem by intermediating the knowledge flows and relationships in the ecosystem. As the project is finishing, the plans of OASC to continue in this role suggests sustainability for the drive initiated by SynchroniCity.

Table 24. Service exchange roles in IoT ecosystems (Ikävalko et al., 2018)

Role	Definition
Ideator	Bring knowledge about own needs to the ecosystem. One-way knowledge flows. Providing input for service innovation.
Designer	Mix and match existing knowledge components in the ecosystem. Reciprocal knowledge flows. Developing service innovation.
Intermediary	Intermediate flow of knowledge and relationships in the ecosystem. Multi-way knowledge flow, orchestrating service innovation.

We can see from the activities of SynchroniCity that it is not just a project that ends. The ongoing development and dissemination work carried out (e.g. the continuing further development of the atomic services) show that the work with building the single digital market continues.

Further, the PIU framework and tools provided in this report offer a practical methodology for future impact evaluation. It has been demonstrated that the internal pilots addressed a wide spectrum of indicators across economic, environmental and social categories. The most common benefits expected by the pilots were about delivering economic value to municipalities in the form of lowered operational costs and improved service efficiency. Key environmental issues – of increasing concern to citizens and local authorities alike – were also addressed, from carbon emissions to air quality and waste generation. Social issues were also targeted and can perhaps be expected as indirect benefits of the improved service efficiency and improved environment, although this could also be an opportunity area for municipalities to encourage more direct action in future IoT programmes.

Crucial to those future IoT programmes is the need to build impact assessment, as suggested by the PIU in Section II, into their activities at an early stage. By convening pilots, municipalities and other stakeholders around a common vision of the city's needs, the intended impacts and the proposed service, the solution can be refined. These activities help to ensure focus on how the service can best achieve its intended economic, environmental and social benefits, as well as measure the resulting benefits and communicate its results. This enables cities to gain clarity on the effectiveness of their procurement; funders to gain clarity on the returns to their investments; citizens to gain awareness of the positive outcomes in their city; and pilots can use the evidence to access new markets and funders. A practical and scientifically robust approach to measurement, such as the PIU in Section II, is an important factor in assembling this evidence base and improving the impact of future IoT programmes

● Appendices

Appendix 1: Literature review and reiterative recommendations

A literature review is a search and evaluation of publications relevant to the intervention's aims, taking place before deployment. The objective is to improve the likely success of the intervention by capitalizing on existing knowledge in the field and adapting the IoT solution or intervention design where appropriate. This is of importance to IoT solutions that aim to initiate a change in behaviour, as literature reviews can add insights from behaviour change theory, economics, environmental science, social science and more.

Literature reviews can draw on numerous sources, including academic and industry content. They will commonly include research findings or discussions of theory, and thus help to fill gaps in the knowledge of the development team or suggest areas for further exploration in future iterations.

Depending on the type of literature and the methodologies they applied, different publications may carry different weight. Generally speaking, those with the highest levels of evidence and critical appraisal should be prioritized as they are likely to be more scientifically robust. As an example, consider a 'hierarchy of evidence' as is common in evidence-based medicine (see Figure 48).

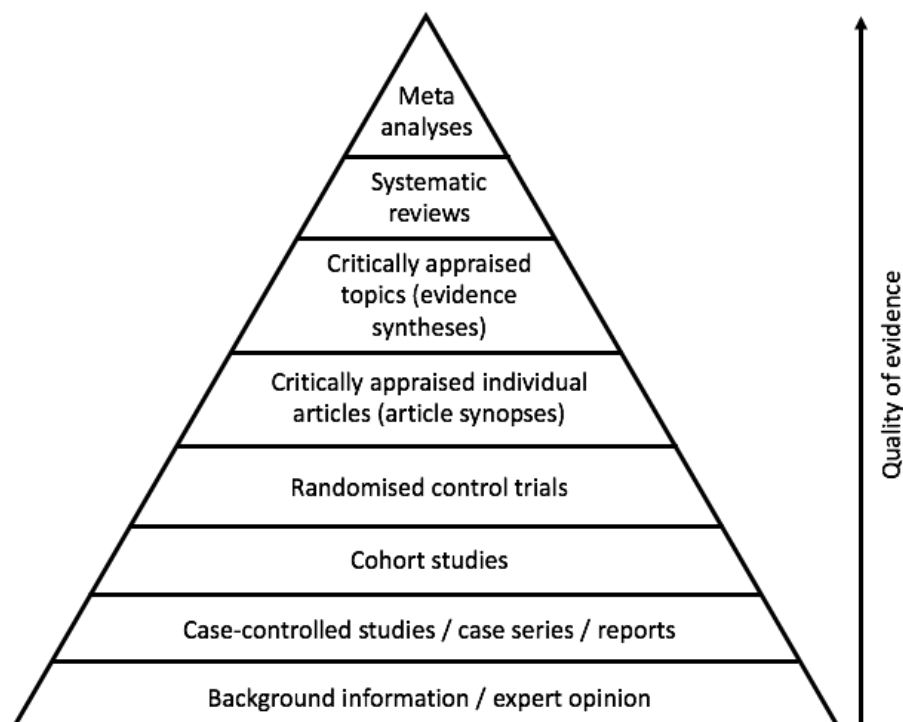


Figure 48. An example hierarchy of evidence for literature reviews¹⁷

¹⁷ Based on EBM Pyramid and EBM Page Generator (2006), Trustees of Dartmouth College and Yale University. Produced by Jan Glower, David Izzo, Karen Odatto and Lei Wang.

Definitions:

Meta-analysis: a systematic appraisal and summary of all relevant studies that uses quantitative analysis to summarize the results.

Systematic review: a systematic appraisal and summary of all relevant studies.

Critically appraised topic: evaluation and synthesis of multiple research studies.

Critically appraised individual articles: evaluation and synopsis of individual research studies.

Randomized controlled trial: a research design that assigns subjects to 2 or more groups, at least one receiving an intervention and one not, and then comparing the results.

Cohort study: research designs that identify different groups (cohorts) of subjects who either did or did not receive intervention and observe the outcomes.

Case-control study: research designs that identify subjects who have an outcome of interest and subjects who don't, and then retrospectively identify the frequency of exposure to draw a relationship.

Background information/expert opinion: this can include reference materials, textbooks and general information.

When performing literature reviews, it is recommended to structure findings in terms of recommendations, so that they can easily be discussed with/used by the project team. It may not be possible or desirable to incorporate all recommendations, for example due to time and budget constraints. See Appendix 2 for recommendations made to the multi-modal navigation and parking app atomic service in Santander. Whilst these recommendations were not able to be incorporated due to time and budget constraints, they still highlighted information that future parking and route-planning apps may seek to take advantage of in driving bigger impacts.

Appendix 2: Recommendations given to the parking and navigation atomic service app in Santander



Synchronicity: Santander Park&Move and Multimodal Navigation Apps: Key recommendations based on literature and preliminary data findings review

Thanos Bantis, Chris Taylor and Susannah Stearman – Future Cities Catapult – 11 December 2018

Thanos Bantis, Chris Taylor and Susannah Stearman – Future Cities Catapult – 11 December 2018

Future Cities Catapult has undertaken some preliminary research in the impact assessment mapping process. This process aims to provide early insights in order to better ensure the success of interventions as well as continual refinement of activities to meet the programme's objectives.

Our economists, social and data scientists have reviewed the current academic literature and provided recommendations based upon previous studies and research. Furthermore, the primary data collected from the car park sensors has been interrogated at a high-level to provide feedback and recommendations to improve the app's functionality.

This is provided as a working document with recommendations as a starting point to challenge, raise questions, and collaborate on, rather than a rigid prescription. It is recognised that the intervention is a pilot and therefore some of these recommendations may be difficult to implement within the current scope of the project and more appropriate for commercial stages of app development.

The main section below outlines eleven recommendations, literature review tables and sensor data analysis and graphs. Note recommendations 2-11 assume recommendation one will be implemented.

Key recommendations

User interface

1. Both the multimodal and parking app should be merged together

The intervention should consider merging the car parking app with the routing app. Research suggests commuters/travellers are less likely to take the car if they know parking availability is unlikely. If this is the case, they may take an alternative form of transport which could be provided in the same app. Having the apps as two separate apps makes it more difficult for the user and the user might possibly not download both apps. Behavioural studies on 'nudge' theory suggest that if given more options, such as public transport alternatives, people may change their behaviour and take public transport routes instead of the car.

2. The app should include a cost estimate

The intervention should include a cost estimate including public transport and a comparison of cost to drive (average petrol) plus cost of parking. Highlighting that cycling and walking are free could also incentivise behaviour.

3. *The app should include a time estimate comparison with other factors*

As in recommendation point two, people are incentivised by time saved. They are also influenced by other factors such as 'ease' as found in one parking study (in the literature below). If alternative routes could be provided with time as well as details of how many legs¹⁸ or transfers in each journey, they can weigh up the time, the ease (or stress), and cost of each journey. Other factors such as 'rain-safe' options for walkers and cycling or kilojoules used by your walking or cycling, could be included and compared.

4. *The app should provide peak time information to the user and nudge drivers to park in less congested streets or at different times*

Based on the preliminary sensor data collected, the busiest times for parking are between 8.00am and 9.00am, 10.00am and 11.00am and 4.00pm and 5.00pm. During the busiest times, the app could direct drivers to an alternative street. The app could suggest that the driver is more likely to find a parking space with a short walk to their destination. The literature suggests that nudge theory can be influential in changing behaviours, so giving other options that are either less stressful or take less time could change drivers' behaviour.

5. *The app should include more information in the calculation of the parking probability estimate besides historical data*

Historical information on parking availability can provide an indication of parking patterns for the locations where parking sensors are available, however the ratio of available/occupied spots overlaps to an extent for different areas (Figure 51). As such, ranking and prioritising potential areas for parking can be challenging due to the small differences in historical patterns. Including ancillary data (such as congestion levels, temporary road closures etc.) could remove uncertainty and provide more robust suggestions to drivers.

6. *The app should be able to provide real time updates of the status of recommendations and adjust the suggestion accordingly when parking availability changes*

The combined functionalities of the parking and multimodal app should be able to provide a seamless experience to the user. To that extent the app should provide real time information on the status of the recommendation while the user is en route and adjust the route/parking suggestion accordingly. For example, the app should be able to recompute the suggestion with a live update if the first recommendation is no longer applicable (e.g. the parking was taken while the user is en route). This is important since the duration availability of parking spots per hour of day is uneven and can range for few minutes to several hours (Figure 52).

7. *The app should communicate the suggestions in a clear way*

Sorting the available recommendations and communicating the results in a meaningful way to the user is important, as it is generally harder to assess the optimal parking suggestion between the different options, particularly when the difference between the probability estimates are within prediction error margins. Communicating probabilities should be avoided as they are generally hard to interpret by a lay person without any additional context.

¹⁸ A 'leg' is a segment within a journey. If you take a bus, then change to another bus, and then take a short walk to your destination, this would be considered three legs in your journey.

8. *The app development should prioritise the use cases for high impact users*

Different groups of people will respond differently to the app, making it more or less effective. Interventions are most effective amongst these groups, so we recommend prioritising use cases for them:

- i.* drivers with strong habits (drivers who travel often and rarely consider alternative modes of transport). For example, commuters
- ii.* drivers with strong moral motivations to reduce car usage
- iii.* new residents to Cantabria.

Observed data from the app

9. *The app should observe user behaviour to allow detailed impact analysis and future recommendations*

Capturing information about the user, compliant with GDPR, will allow a more detailed impact assessment to be performed and give recommendations on how future interventions can be most effective. E.g.

- Observed data collection: distance, duration, frequency. Split by transport mode (including for multimodal journeys), weekday vs. weekend day, driving vs. parking time
- One-time user input: gender, age, primary travel reason, attitudes towards sustainability
- 'Per journey' input: number of people in car (if using car).

Recommendations not specific to development

10. Prioritise download amongst users who can make the most impact

Different groups of people will respond differently to the app, making it more or less effective. Interventions are most effective amongst these groups, so we recommend prioritising download amongst:

- Drivers with strong habits (drivers who travel often and rarely consider alternative modes of transport). For example, commuters. Advise local businesses and business forums of the app
- Drivers with strong moral motivations to reduce car usage. Advise green societies, NGOs and eco-tourism boards of the app
- New residents to Cantabria. Advise house move agencies and government registration bodies of the app.

11. Ensure pilot has enough users for the research to be statistically significant

To ensure statistically significant impact assessment, surveys require a sufficient number of people. Ideally, there would be 400 users in the experimental group (using the app and being surveyed), and 400 users in the control group (being surveyed but not using the app). It is unlikely this number of respondents will be obtained within the timeframes and budget of this project, but the more users there are the more robust the analysis will be. Could the following organisations encourage all their staff to take part in the app user testing and surveys?

1. University of Cantabria
2. Santander City Municipality
3. Santander port workers
4. Torrelavega City Municipality
5. Local business networks
6. Facebook advertising
7. Other local business associations
8. Other Academic institutions

Below is a trade-off matrix as an example to consider where recommendations lie in the trade-off between impact and effort required to undertake the task required. Below this, literature review tables and data analysis are provided in the appendices.

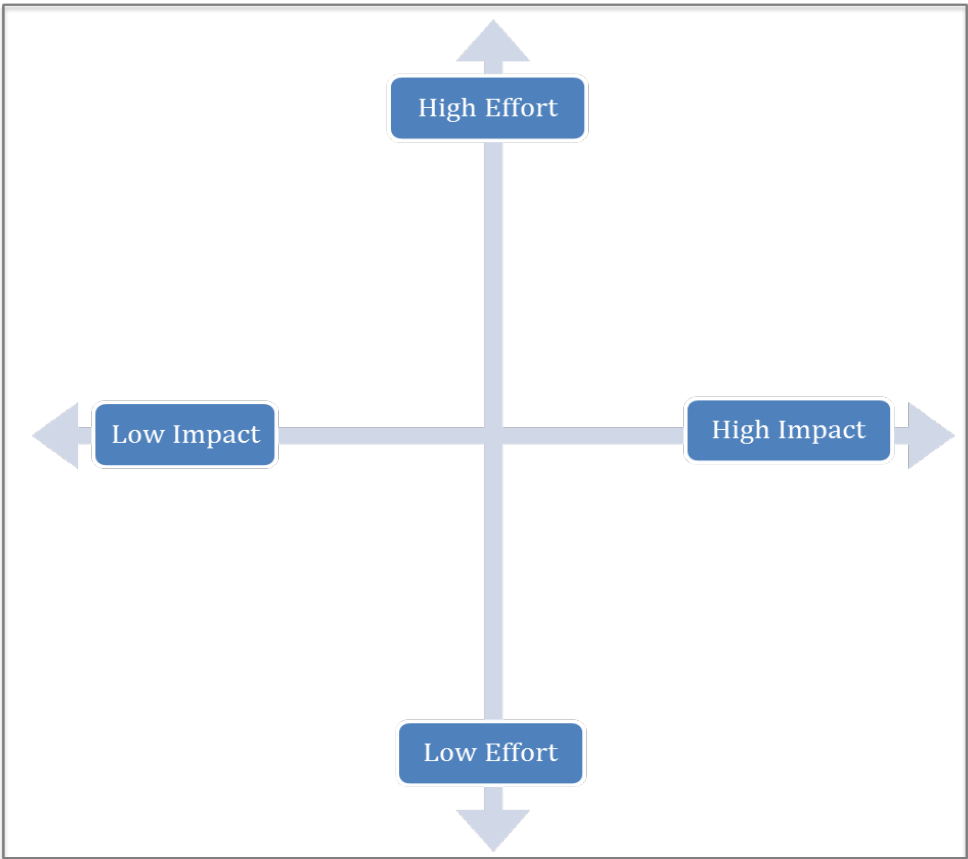


Figure 49. Trade-off between impact and effort required to undertake the task required

Recommendation one has been plotted with high effort and high impact.

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Part 1: Literature review tables

The economics of car parking

Table 25. The economics of car parking

Source & Details	Relevant points	Implications/suggestions for intervention:
The Impact of Parking Pain in the US, UK and Germany by INRIX Research, Graham Cookson, Bob Pishue, July 2017 INRIX Report - car parking	17,968 drivers in US, UK, and Germany from 30 cities - Survey results average a time of 9 minutes searching for a parking space - Behavioural decisions based on knowledge of parking – 34% much more likely to drive if parking was available, and 19% a lot less likely to drive if parking was NOT available (p.37) 27% said if they knew parking was available it would make no difference to their decision to drive. 24% said if they knew parking was NOT available that it would not impact their decision. However, the remainder of respondents were impacted by receiving information regarding driving - Security followed by ease were the main drivers of parking location preference, with proximity and cost also being recorded, however less influential - Total country cost for UK was estimated at £981 per driver per year, this included £733 in parking search costs, £209 in overpayment costs and £39 in parking ticket costs - Driver behaviour is clearly affected by information, which is also good news for congestion prone cities. More than half of drivers claim that they are less likely to drive to their destination if they know that parking isn't available. Parking information is therefore key to both demand management and parking space optimization' (p.41).	- The net of those that would not be influenced by the knowledge of parking availability is approx. 74% – implying that knowledge of parking spaces does impact behaviour - Possibility to derive/develop a model for parking costs for Santander based upon the methodology for UK and Germany - There is a case for the intervention as knowledge of parking impacts behaviour. 'Parking information is ... the key to both demand management and parking space optimization'(p.41) - The intervention should consider merging both the car parking app and routing app as commuters/travellers are less likely to take the car if they know parking availability is unlikely, and may thus take an alternative form of transport. - Ease was ranked as the second driver of parking location preference also making a case for the intervention - The intervention could consider other factors such as security, cost and proximity for the user.
Europe's Traffic Hotspots: Measuring the impact of congestion in Europe by INRIX Research, Graham Cookson – 30 Nov 2016.	- Methodology developed for congestion - Proxy for bottlenecks = when speeds drop to 65% of the reference speed, and stays below 65% causing 120 seconds of delay, if it remains below 75% of the reference speed the bottleneck will not be cleared (p.4) - Month of September used and then x 12	- Congestion is a cost to the economy. There is a case for the intervention if it aims to lessen congestion in Santander city centre and along the main beach parking places - Suggestion: intervention to aim to lessen congestion

Report – traffic congestion, methodology	• Impact factor = avg. max duration (minutes) * avg. max length (km) * no. of occurrences (per month) • Economic cost of congestion £0.29 per minute	• Similar methodology could be used to establish baseline and then a post evaluation (however note seasonal adjustment required) • Bilbao similar Spanish city to Santander – possibility to derive an impact factor per capita to be used in Santander • €22m is the estimated economic cost to the city by 2025, using 2016 world population figures • (~345,000 persons means a €64 per capita) • Need to understand the methodology timeframe more. This is a 10-year projection from 2016-2025. Possible follow up with INRIX to learn about methodology in detail.
The future economic and environmental costs of gridlock Cebr, London 2014	• Cost of congestion per individual car commuting household in US \$ projected for 2020 is in the UK US\$1,788, in France US \$1,888, in Germany US \$1,755 • Costs to households total direct (value of fuel and time wasted) and indirect (increased cost of doing business) forecast for UK 2020 is US\$25,430m, France US\$25,448m, Germany US\$37,341m. City level cost to households in Stuttgart, 2013 actual US\$3,170m	• Congestion is a cost to the economy. Similar to above article. Suggestion: intervention to aim to lessen congestion • Possible methodology to take household level of Stuttgart and transform into per capita for 2013
Getting the Prices Right, Gregory Pierce & Donald Shoup (2013) Journal of the American Planning Association, 79:1, 67-81, DOI: 10.1080/01944363.2013.787307 https://doi.org/10.1080/01944363.2013.787307	• Study on parking optimisation in San Francisco • Drivers display rational inattention when looking for parking and comparing prices, and believe they are saving energy and time by driving direct to locations • Drivers have an inelastic demand for parking • Tourists (and other drivers) remain unaware of price variations • Educating even a few on parking options can assist with producing open spaces.	• Education on car park pricing can lead to behaviour changes • Suggestion: include information on prices for parking and/or for different transport use i.e. average cost of driving your car and parking, compared with alternative public transport or cycling use
Parking: Issues and Policies, Ison,	• Providing information on parking on its own may actually promote driving and	• Parking information on its own may increase driving and

Mulley, and Shaw, 2014, Emerald Publishing Limited	come with a 'net traffic increase' thus parking must be seen as a part of a 'bundle' associated with car use (p.414) • Parking choice (ch 6) – concludes individual parking choice decisions are multi-faceted and influenced by a number of factors. More research is required in this area. Individual differences are determined by trip purpose (influencing time constraints and destinations), varying levels of knowledge of parking options, and using technology such as parking websites, navigation systems or dynamic parking guidance information.	increase traffic, implying objectives of traffic alleviation are not met • Suggestion: apps to include parking information with other public transport options together • The drivers behind parking choices are not clear but could be determined with greater understanding about the purpose of the trip • Suggestion: undertake research to understand the trip purposes of those commuting and travelling into Santander.
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Economic activity of high streets and town centers

Table 26. Economic activity of high streets and town centers

Source & Details	Relevant points	Implications/suggestions for intervention
Understanding High Street Performance: Executive Summary – December 2011 Department for Business Innovation and Skills	• 'Key Performance Indicator – footfall. Footfall is the key to understanding a place. The measurement of footfall should gauge the number and frequency of visitors to the area defined locally as the high street or town centre, not just visitors to shops or particular attractions • It needs to measure seasonal variations, and variations at different times of day – is the high street used only during traditional working hours, or does it also have an active night-time and weekend economy? Importantly, footfall is not just a reflection of retail strength, although of course this is likely to be a key driver, if not the key driver. Other uses can be critical footfall drivers, such as public services (a health centre for example) or major businesses (with employees using the high street to come and go). A footfall indicator would therefore require a set of locally chosen sub-indicators,	• Footfall should be a part of an economic assessment of high streets • The intervention should consider the footfall tracking e.g. geofencing or geo-mapping/location. The city centre could be geofenced and triggered whenever a device enters it, which will count as a new anonymous footfall data point • This metric will also assist with medium term impact as footfall could be measured and compared across different periods.

	including: length of stay, number of places visited, and frequency of visits' (P.21)	
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Routing alternatives

Table 27. Routing alternatives

Source & Details	Relevant points	Implications/suggestions for intervention:
'Durham's Plan to 'Nudge' Drivers Out of Cars' by Bliss, L., City Lab news https://www.citylab.com/transportation/2018/10/durhams-plan-to-nudge-drivers-out-of-cars/574264/	- Nudge theory of behaviour science to incentivise motorists into changed behaviour surrounding public transport - Enriched information relevant to the commuter could assist in changing their decision to more optimal choices e.g. savings in gas money, weight loss potential and time saved.	- To change personal behaviour towards using public transport the app can highlight personalised routes which include public transport and/or cycling options - Other options such as savings in gas money could be provided on the app through using a simple average calculation based on estimated kilometres.

Behaviour change incentives

Table 28. Behaviour change incentives

Source & Details	Relevant points	Implications / Suggestions for intervention
Can we reduce car use and, if so, how? A review of available evidence, by Graham-Rowe, Skippon, Gardiner, Abraham (2011)	- Interventions found to be successful that used incentives to reinforce behaviour change. However, behaviour reverts once incentives are removed - Congestion reduction interventions may be susceptible to behaviour rebound effects, i.e. the greater efficiency encourages greater use (Herring and Roy 2007) - Economic disincentives found to reduce rebound effect. (Jakobsson et al, 2002) - Research typically measures these outcomes, indexed to single occupant over 1 day/week/month:	- Offer drivers economic incentives (e.g. parking subsidies/free parking etc.) for frequent use of the app. The app can use geolocation to check drivers follow the advised route and reward them for it - Consider economic disincentives to reduce the rebound effect (e.g. reduce the parking subsidies/free parking if average mileage rises from week to week) - Ask the user to select the type of journey they are making (e.g. leisure, work, school run, university, tourism, other). This data can help learning and guide future iterations of the app

	- o Distance travelled - o Number of car trips/frequency of car use - o Time spent in a car - o Modal shift: walk/cycle/bus/train/car-pool • Travel Feedback Programmes provide tailored information to drivers on their travel patterns and knowledge and skills to use existing non-car travel infrastructures. (Brog 1998; Fuhi and Taniguchi 2005). Such interventions are typically more effective when combined with campaigns that raise awareness of real improvement in public transport options (Department for Transport, 2007). • Interventions found to be more effective with: 1. Drivers with strong habits (Eriksson et al, 2008) 2. Drivers with strong moral motivations to reduce car use (Garvill et al 2003) 3. People who have recently moved to the area and are yet to establish travel habits (Bamberg, 2006) • Carbon conversion is more accurate when we know the fuel type.	• Include immediate and aggregate personal travel feedback as a feature of the app. Benefits to user: increased awareness of own use, motivation and ability to plan faster and cheaper routes. Benefits to Santander: increased impact. Combine with comms campaign raising awareness of the quality of public transport • Target these users: 1. Drivers with strong habits (e.g. commuters, local shopping routines etc). Users could self-select if they have strong habits, e.g. daily commute, (could also be identified through GIS) 2. Drivers with strong moral motivations to reduce car usage (e.g. from green societies, NGOs, eco-tourists) 3. Recent movers to the area • Users self-select if their vehicle is petrol/diesel/LPG/electric
Perceptions of public transport travel time and their effect on choice-sets among car drivers, van Exel and Piet Rietveld (2010)	• A main barrier for modal change among car drivers is the distorted perception that alternatives are not viable, in particular with respect to travel time (but also cost) • If perceived public transport (PT) travel times were more accurate a substantial number of car drivers would include PT in their choice set	• Present information to drivers about the cost, duration and convenience of alternative modes for their trip, to challenge existing perceptions and lead to consideration and use of these alternatives.

	• However, actual changes in behaviour might be much smaller, due to some participants deliberately overestimating public transport travel time as a form of justification for their car use.	
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Sustainable travel habits and gender

Table 29. Sustainable travel habits and gender

Source & Details	Relevant points	Implications / Suggestions for intervention
Polk, M., (2004). The influence of gender on daily car use and on willingness to reduce car use in Sweden. <i>Journal of Transport Geography</i> , (12), 185–195.	• Significant relationship found between sustainable travel patterns and gender. Women found more willing to reduce their car usage and have more positive attitude towards reducing the environmental impact of travel modes than men • Polk concluded that researchers must consider gender as a factor in attitudinal research on car usage.	• Consider targeting female drivers, as research shows they are more likely to adopt sustainable travel patterns.
Curtis, C & T. Perkins, (2006). <i>Travel Behaviour: A Review Of Recent Literature, Impacts of Transit Led Development in a New Rail Corridor</i> , Perth. Department of Urban and Regional Planning Curtin University.	• Women found to be more likely to adopt sustainable travel behaviours than men.	

Mode change to active transport

Table 30. Mode change to active transport

Source & Details	Relevant points	Implications/suggestions for intervention
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Shifting from car to active transport: a systematic review of the effectiveness of interventions (Scheepers et al, 2014).	Intervention tools categorised by (Hoogerwerf & Herweijer, 2008) • Legal • Economic (subsidy, reward system, penalty) • Communicative (written materials, behavioural tools) • Physical (e.g. architectural adjustments, providing bicycles). Some interventions that combine the above have a significant effect. They typically include: • Limiting parking spaces • Increasing parking charges • Improving changing facilities for walkers and cyclists • New secure cycle storage • Subsidised bicycle purchase schemes • Car-sharing schemes • Free public transport services • Discounted season tickets on public transport.	The app will have greater impact if combined with economic, communicative and physical tools such as those listed opposite.
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Other articles:

Measuring the Economic costs of traffic congestion

<https://ieeexplore.ieee.org/document/7980471>

Part 2: Analysis of data from sensors

The following graphs are based on the car parking sensors in Santander City Centre with data collected between May and August last year (2018-05-09 to 2018-08-1). The original dataset was sourced by placing requests on Santander's smart parking API (http://datos.santander.es/api/rest/datasets/sensores_smart_parking.json) every minute and storing the dataset in a NoSQL database. The API's response consisted of information such as location of the sensor, a timestamp when the status of the sensor was last updated, the status of the sensor (occupied/free) as well as sensor ID.

The resulting dataset was then used to provide insights on the parking habits of drivers for the areas where sensors are installed. Figure 50 below (Santander city API) shows the location of the sensors:



Figure 50. Locations of the parking sensors source by Santander city API

To gain an indication of the parking flux at street level, the sensors were grouped by street location, resulting in 8 categories. Next, for the whole data sourcing period, the number of times the parking status was reported occupied versus free were calculated for each time of day. Finally, the ratio between these frequencies was taken as a proxy of parking availability ranging from 0-1 (free/occupied). Figure 51 below shows the mean variation of the ratios together with the variance:

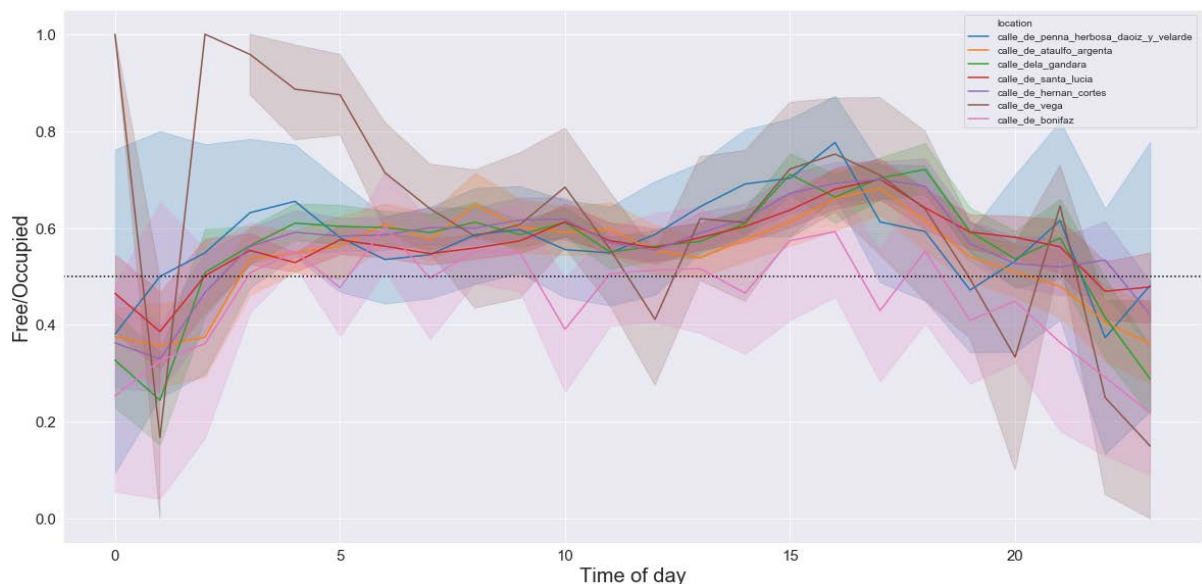


Figure 51. Ratio of free versus occupied spots for different areas.

As can be seen, the different area categories follow a similar trend throughout the time of day, and parking occupancy generally fluctuates around 0.6, indicating that 60% of the time the sensors were

observed they reported occupied status. There are slight deviations in the middle of the day where Bonifaz and Vega streets are less occupied. The clear overlap of the occupancy levels of the sensors makes the generation of a confident parking recommendation using historical data challenging, as more information is needed to differentiate between parking availability for those areas.

Furthermore, the total duration cars spend parked at a spot is an important attribute that is likely to influence any availability recommendations based on historical data. To get an insight on the total duration a parking spot remained occupied, the following metric was devised:

- For every sensor, check whether the occupancy status had status: occupied. If so, store the sensor's status update time
- Move to the subsequent record in the dataset and check whether the occupancy status remains: occupied. If so, move to the next record. If not, calculate the duration between the timestamp of the first occurrence of occupied status and the last occurrence of occupied status
- Store the total duration for the date/time of the first occurrence of occupied status
- Repeat the process.

This will produce an indication of how likely it is for a parking spot to remain occupied in the future, given the current timestamp. Figure 52 illustrates the variation of duration of occupancy per day of week and time of day.

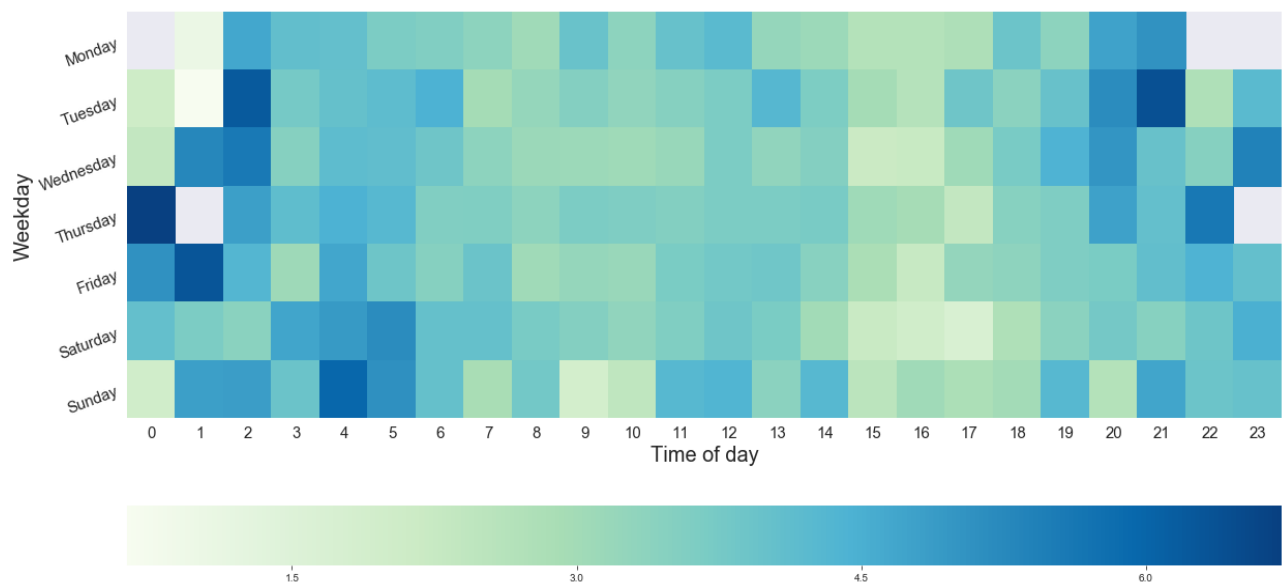


Figure 52. Duration of parking remained occupied by day of week and time of day

As it can be seen, durations of occupancy vary significantly throughout the week/time of day. In particular, parking turnover is more frequent in the morning/afternoon indicating that drivers who park at those hours tend to do so for shorter periods of time. This is likely to have an impact on parking recommendation for those hours, as the confidence of proposing a parking spot that will remain free by the time the driver has reached his/her destination is smaller.

Appendix 3: Example of London Bootcamp Feedback

Overall, how much did you enjoy the bootcamp? (out of 100).	Do you feel ready to start your pilot?	Are you confident with the reporting process for SynchroniCity?	Are you confident with how to project will be governed?	Please give us a short quote if you think the event was a success.
90	Yes	Yes	Yes	The event was very well-organized and we enjoyed it!
85	Yes	Yes	Yes	Great event and loved having the chance to get everyone in the same room together.
85	Yes	Yes	Yes	All in all, this was an amazing event with great information sharing, and positive energy. I hope that we can continue this onward in the post Synchronicity era
86	Yes	Yes	Yes	This will be a hell of a ride and I like it.
89	Yes	Yes	Yes	great organisation and usefull networking
75	Yes	Yes	Yes	Out of all the smart city events I have been, this one was very professional, well-organised, and very relevant to solve the usual challenges of rolling-out smart city projects.
100	Yes	Yes	Yes	SynchroniCity Bootcamp was a fantastic introduction to the Large Scale Pilot programme. It was great to have the opportunity to meet other pilot groups and cities, as well as spend time together as a Pilot Group. The talks and expo sessions were invaluable for helping us to prepare our pilots and the SynchroniCity team created a very constructive, collaborative and energetic environment for us all. Thanks to
80	Yes	Yes	Yes	Thanks for running an engaging and interesting event!
90	Yes	Yes	Yes	Cities as a platform is powerful idea. The bootcamp was a big step towards aligning the many elements of this
80	Yes	Yes	Yes	The event clarified all the remaining issues on the table
90	Yes	Yes	Yes	The bootcamp was a great start for a promising pilot phase
90	Yes	Yes	Yes	Great organization, and scope understood to the necessary detail. Good atmosphere, and veru useful networking.
79	Yes	No	Yes	The bootcamp was very practical and useful
77	Yes	Yes	Yes	The bootcamp has been a first step, and I think that it is very important, because you meet all people, and you may solved doubts. And you also may share with them: ideas, project,
100	Yes	Yes	Yes	Excellent organisation and very motivating
80	Yes	Yes	Yes	SynchroniCity is the fuel to enhancing city value through federation, data sharing and interoperability.

Appendix 4: M3 Open Call Pilots Interim Report Template

SYNCHRONICITY

Interim report

Note that this report could be subject to minor modifications. The final template will be provided to the SME pilot leads before the submission deadline.

Pilot Title

Date Submitted:

SME Pilot Lead Name and Organisation:

SME Pilot Group Partners:

Pilot Cities:

Name of the Journey Mentor:

TRL of your solution at the beginning of the pilot:

This report will cover:

- General aspects
- Technical environment
- Standards
- Impact evaluation/KPIs
- Lessons learnt

Remember:

Submit by emailing helpdesk@synchronicity-iot.eu stating that you have finalised the document. Include the following attachments:

- Financial Claim Form. A payment of a maximum of 35% of the funding will be released within 30 days from approval of all documents via email.
- Any other additional documentation that you consider important.

If you have any questions please contact your journey mentor or the helpdesk.

SynchroniCity Interim report

GENERAL ASPECTS OF THE PILOT

1. Short summary of your pilot for publication by SynchroniCity and/or European Commission.
2. Provide an overview of the progress towards the objectives of the pilot according to your workplan, including any milestones and achievements identified. Explain and justify what has changed in your experimentation process compared to your initial plans. Consider general, technical and ethics & privacy activities.
3. Describe the co-creation activities that you have performed until now. Mention the stakeholders you have engaged with and explain what you have learnt from engaging with them.
4. Describe if your pilot has had fruitful interactions with other SynchroniCity pilot projects or with the other Large-Scale Pilot projects. What was the nature of this interaction?
5. Provide an overview of the main communication activities that your pilot has carried out (presentations at events, conferences, press releases, blogs, publications, etc.).
6. Next steps, risks and mitigations of your pilot project
7. What are the steps your pilot team has taken or planned to ensure that your solution can continue after the SynchroniCity project has ended?

TECHNICAL ENVIRONMENT

This is just a general overview of the scope and the technical contents of this section. A more concrete structure will be provided before submission deadline, based on SME deployments and M2 reports results. Please, don't take this as the final template.

8. Data used in each Pilot City

CITY	Data	Data type
City 1:		
City 2:		

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9. Data created in each Pilot City

CITY	Data	Users of data
City 1:		
City 2:		
City X:		

10. Explain the experience of integrating your solution into the SynchroniCity framework, indicating barriers and problems found and solutions adopted, if any.

11. Explain if you have used any existing Atomic Services in your pilot project or if your pilot project has created new Atomic Services. Which ones?

12. If in your pilot there is a New Pilot City, please provide the following information:

- a. What are the actions that the city has taken to implement the SynchroniCity framework and your solution?
- b.

STANDARDS

13. Which of the following standards have you and/or your city been using?

ETSI ISG CIM	
ETSI NGSI-LD	
ITU-T SG20/FG-DPM	
OAUTH2 industry standard protocol for authorization	
DCAT-AP	

14. For each standard you used/are using, please provide a summary of how you worked/ are working with your city to implement the requirements of the standard and a summary of

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the lessons learnt (e.g. what worked well, what worked not so well and tips you have for others looking to use the standard)

15. Were there any other standards that your pilot uses that would benefit from more widescale adoption? If so, please provide details.
16. Do you think there are any gaps where additional standards would help deployment of your project e.g. interoperability, process standards, common good practice guidelines for deployment etc.

IMPACT EVALUATION and KPIs

1. What is the number of users of your solution? Indicate the number per pilot city.						# of users
	City 1:					
	City 2:					
	City 3:					
	City 4:					
2. Who are the users of your solutions?						% of users
	Citizen					
	Start-up or SME (<250 employees)					
	Large company (>250 employees)					
	Public sector organization Other, which? _____					
3. How satisfied are the users of your solutions? (1=not satisfied, 5= very satisfied)?	1	2	3	4	5	
4. What is the number of IoT devices that you connected with your solution?	172					
5. What is the number of Open Data sets you used and produced?						# of Open Data sets
	Used					
	Produced					
6. How would you rate the quality of Open Data used (1=low -5=high)?	1	2	3	4	5	
7. How would you rate the quality of Open Data produced (1=low-5=high)?	1	2	3	4	5	
8. To what extent has the project improved interoperability (1=low -5=high)?	1	2	3	4	5	

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9. What is the number of local ecosystem partners involved (indicate the number per city) e.g. companies, creative hubs, citizen organisations, etc.?		# of partners (type of partners)
	City 1: Bordeaux	
	City 2: Carouge	
	City 3: Seongnam	
	City 4:	
10. Of the partners involved, what is the number of SMEs?		
11. What is the number of jobs created as direct outcome of your pilot?		

Provide open comments on the above impact evaluation and KPIs that you consider worth mentioning.

- a. Please, enumerate also other KPIs that you may have considered to track the progress of your project.
- b.
- c. Which effects do you (or other institutions relevant for your pilot) foresee that your solution will have in technical, economic and societal terms?

LESSONS LEARNT

THREE MAIN LESSONS LEARNT	
1	
2	
3	

Appendix 5: M6 Open Call Pilots Final Report Feedback Template

SYNCHRONICITY

Feedback to the Final Report (Month 6)

Project Title	[Pilot name]
Lead Applicant	[Pilot lead name]
Cities	[to copy from the final feedback report]

Summary

Your M6 final report status is **'approved'/'pending'** the following requirements.

Questions, comments and outstanding requirements:

General: No action /Outstanding Action

City: No action /Outstanding Action

Financial: No action /Outstanding Action

Financial

Approval of your costs claimed is pending the below action point:

- Lead partner – [cost category].

Version of the document

V.1

References

Articles & Research papers

Abella, A., Ortiz-De-Urbina-Criado, M., & De-Pablos-Heredero, C. (2017). A model for the analysis of data-driven innovation and value generation in smart cities' ecosystems. *Cities*, 64, 47-53.

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Bosch, P., Jongeneel, S., AIT, H. M. N., & Airaksinen, M. (2016). CITYkeys indicators for smart city projects and smart cities. <http://nws.eurocities.eu/MediaShell/media/CITYkeystheindicators.pdf>

Cebr (2014). The future economic and environmental costs of gridlock. London.

F. Cirillo et al., "Atomic Services: sustainable ecosystem of smart city services through pan-European collaboration," 2019 Global IoT Summit (GIoTS), Aarhus, Denmark, 2019, pp. 1-7.

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Cookson, G. (2016). Europe's Traffic Hotspots: Measuring the impact of congestion in Europe by INRIX Research - Report – traffic congestion, methodology.

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Curtis, C & Perkins, T. (2006). Travel Behaviour: A Review Of Recent Literature, Impacts of Transit Led Development in a New Rail Corridor, Perth. Department of Urban and Regional Planning Curtin University.

Graham-Rowe, Skippon, Gardiner, Abraham (2011). Can we reduce car use and, if so, how? A review of available evidence

Huovila, A., Bosch, P., & Airaksinen, M. (2019). Comparative analysis of standardized indicators for Smart sustainable cities: What indicators and standards to use and when?. *Cities*, 89, 141-153.

Ikävalko, H., Turkama, P., Smedlund, A. 2018. Value Creation in the Internet of Things: Mapping Business Models and Ecosystem Roles. *Technology Innovation Management Review*, 8(3): 5-15. <http://doi.org/10.22215/timreview/1142>

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Mulley, I. & Shaw (2014). Parking: Issues and Policies, Emerald Publishing Limited

Pierce, G. & Shoup, D. (2013). Getting the Prices Right *Journal of the American Planning Association*, 79:1, 67-81, <https://doi.org/10.1080/01944363.2013.787307>

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United 4 Smart Sustainable Cities. Collection Methodology for Performance Indicators for Smart Sustainable Cities. ISBN: 978-92-61-25231-1 (Electronic version). <https://www.itu.int/en/publications/Documents/tsb/2017-U4SSC-Collection-Methodology/index.html>

Van Exel and Piet Rietveld (2010). Perceptions of public transport travel time and their effect on choice-sets among car drivers.

Yoo, Y., Henfridsson, O., & Lyytinen, K. 2010. Research commentary—the new organizing logic of digital innovation: An agenda for information systems research. Information Systems Research, 21(4): 724-735. <https://doi.org/10.1287/isre.1100.0322>

Project Deliverables

D1.7 Monitoring framework template 2, SynchroniCity, 2018

D1.8 Monitoring framework template 3, SynchroniCity, 2019

D.2.03 “Common methodologies and KPIs for design, testing and validation, CREATE IoT, June 2018

D3.6 Customized IoT service prototypes for lead ref. zones – advanced

D4.3 Technical validation (phase 2)

D4.4 Assessment on the user, stakeholder, replication and market validation

D4.5 technical validation of the SME projects

D5.3 Open call dissemination report

D6.3 KPI Framework

SynchroniCity M0 survey

SynchroniCity M3 interim pilot reports, 2019

SynchroniCity M6 final pilot reports, 2019

SynchroniCity monitoring framework (M18)

SynchroniCity monitoring framework (M24)

Work Packages

WP1. As part of WP1, a monitoring framework was conducted throughout the project to monitor the RZ activities. The monitoring framework collected RZ’s perspectives of the project activities, including the KPIs (D1.7 Monitoring framework template 2; D1.8 Monitoring framework template 3)

WP2. D2.7 Catalogue of IoT devices ready for Smart City platforms integration, SynchroniCity, 2019

WP3. The work package 3 focused on the atomic services. The deliverables D3.3 Suite of atomic implementations - advanced; D3.6 Customized IoT service prototypes for lead ref. zones - advanced; D3.8, Report on reference zones IoT service deployment, provided information for the impact evaluation.

WP4. Work package 4 deals with the validation in terms of architecture, services, user acceptance, market and replication. The deliverables of WP4 contributed to impact evaluation and especially, the deliverables D4.3 Technical Validation (Phase 2); D4.4 Assessment on the user, stakeholder, replication and market validation; D4.5 Technical Validation of the SME projects.

WP5. The activities of work package 5 focused on the Open Call of the project. Its materials and deliverables (D5.3 Open call dissemination report; slide set of the project) were used in impact evaluation. As part of WP5, the pilot reporting collected the pilot perspectives twice during the pilot phase (M3 and M6), including the KPIs (for the templates, see D5.6 Report on the selected SME projects delivery and lessons learnt).

WP6. One of the tasks in work package 6 was communications, the deliverables of which (D6.10 1st Report on Communication, Dissemination and Marketing activities; D6.11 2nd report on communication, dissemination and marketing activities; D6.12 3rd report on communication, dissemination and marketing activities) were used in impact evaluation. In T6.4, the initial framework (D6.3 KPI Framework) served as the initial plan for impact evaluation. A survey for RZ leads was conducted in M18 to get their perspectives on the perceived value. This was later merged into the monitoring framework (see WP1 description). At the London bootcamp, the new pilot companies' perceptions of the firms' business models were collected with a questionnaire (M0). The new cities' perspectives of the project were collected with a questionnaire after the pilot phase was finished (M34). T6.4 also collected information

Internet references

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Datos Abiertos Santander. https://www.datos.santander.es/api/rest/datasets/sensores_smart_parking.json

Other

Institute Nacional de Estadística

Eurostat

World Health Organisation

Numbered references

¹ Following the EU recommendation 2003/361, small and medium-sized enterprises (SMEs) are defined as firms as 1. Staff headcount <250 and 2. Turnover ≤ € 50 m or Balance sheet total ≤ € 43 m (<http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition>).

² Connected Places Catapult is the new name of Future Cities and Transport Systems Catapults, as of April 2019

³ Including the London School of Economics, King's College London, Southampton University, Oxford University and Glasgow University.

⁴ <https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html>

⁵ <https://www.un.org/development/desa/en/news/population/world-population-prospects-2019.html>

⁶ Her Majesty's Treasury, 2018, The Green Book: Central Government's Guidance on Appraisal and Evaluation, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

⁷ https://ec.europa.eu/eurostat/statistics-explained/index.php/Quality_of_life_indicators

⁸ <https://www.oracle.com/big-data/guide/what-is-big-data.html>

⁹ Homes & Communities Agency, 2014. This is not to be confused with the additionality as the principle followed by the European Structural and Investment Funds.

¹⁰New Economics Foundation, 2011

¹¹ Based on EBM Pyramid and EBM Page Generator (2006), Trustees of Dartmouth College and Yale University. Produced by Jan Glower, David Izzo, Karen Odatto and Lei Wang.

¹² A 'leg' is a segment within a journey. If you take a bus, then change to another bus, and then take a short walk to your destination, this would be considered three legs in your journey.