

SYNCHRONICITY

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Executive Summary

This document describes the approach to the concept of validation that will be taken during the course of the SynchroniCity project. First, it describes the overarching principles under which the validation was developed, as well as defining agreed terms to go forward with.

Validation within SynchroniCity is agreed as meaning the process of establishing evidence that provides a high degree of assurance that a product, service, or system accomplishes its intended requirements, and that this will involve the acceptance of fitness for purpose with end users and other product stakeholders.

A set of strategic principles and guiding questions then frame the following descriptions of the types of validation that are taken forward. These areas for validation include:

- *Technical and Functional*
 - *Requirements*
 - *Architecture*
 - *Components and enablers*
 - *Services and applications*
- *User and Stakeholder*
 - *Stakeholder*
 - *User*
 - *Engagement*
- *Replicability*
 - *Architecture*
 - *Services and applications*
 - *SME projects*
- *Market*
 - *Architecture adoption*
 - *Service framework*
 - *Business model*
 - *Market sustainability*

For each of these areas, a general approach is described that will be followed within the associated future tasks. Further, more detail is provided on the activities, objectives and outcomes of each of the criteria.

Overall, the result of the Validation Methodology document is a holistic approach to project validation, highlighting intervention points throughout the project where validation activities are able to provide important feedback to other work packages.

Abbreviations

AAA	Authentication, Authorization and Accounting
API	Application Programming Interface
CPU	Central Processing Unit
D	Deliverable
DSM	Digital Single Market
EC	European Commission
EU	European Union
GDPR	General Data Protection Regulation
GPL	General Public License
GPRS	General Packet Radio Service
IoT	Internet of Things
KPI	Key Performance Indicator
LTE	Long-Term Evolution
LoRaWAN	Long Range Wide-Area Network
MVP	Minimum Viable Product
NB-IoT	Narrowband-IoT
OASC	Open & Agile Smart Cities
PC	Project Challenges
PO	Project Objectives
RZ	Reference Zone
SLA	Service-level agreement
SME	Small and Medium Enterprise
SWOT	Strength, Weakness, Opportunities, Threats
UA	User Accessibility
UI	User Interface
UX	User Experience
VC	Validation Categories
WP	Work Package
WT	Work Task

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1 A holistic approach to the validation methodology

1.1 Introduction

Synchronicity is a project aimed at kick-starting a Digital Single Market (DSM) for cities. This requires a large number of elements to contribute towards making such a concept reality. Among these elements are the design of an Internet of Things (IoT) enabled system, information, process, software architecture which has to incorporate within its design the eventual attainment of the DSM. As well as the architectures, the marketplace mechanisms that are required to make DSM work will have to be put in place.

In order to accelerate the adoption of the DSM by citizens and cities, it is thought that different services will have to be conceived and implemented in the different Reference Zones (RZs) in order to effectively demonstrate the success of the infrastructure and the potential for replication. Citizen-centric design of the services is also an enabler in increasing the likely public acceptance of the project's components and services.

The RZs are acknowledged to differ in many ways and so it is important to ensure that all steps in the project are supportive of the varied contexts. This includes the approach to validation, which will need to assess the project elements according to the different project perspectives.

Validation is intended to ensure a product, service, or system (or portion thereof, or set thereof) results in a product, service, or system (or portion thereof, or set thereof) that meets the operational needs of the user. A set of validation requirements (**as defined by the user**), specifications, and regulations may then be used as a basis for qualifying a development flow or verification flow for a product, service, or system (or portion thereof, or set thereof). This ensures that the product meets the user's needs, and that the specifications were correct in the first place.

The intended validation has been broadly categorised to create a holistic approach to project validation. The categories are:

- Functional: Aiming at assessing the fulfilment of the corresponding requirements based on an iterative approach.
- Technical: Whose main aim is to characterize the performance and behaviour of the different components. As such, a set of metrics have to be identified.
- User perspective: This validation has as main objective to collect the feedback of the user based on his/her interaction with the services, platform and tools.
- Replication: To assess the success that the project decisions have had in being adopted in other zones and cities, both within the project and outside of it; this is a critical aspect of judging the success of the SynchroniCity architecture and applications and cuts across the areas of functionality, technical operations, user feedback, and market value.
- Market: To assess the value-networks and governance of required commercial partners within the project.

In order to ensure that the validation is conducted in a consistent manner across the RZs it is necessary to state in advance the methodology that will be used to generate the validation methods and to present the framework of the validation methods.

1.2 Validation: A general perspective

1.2.1 Strategy

As stated, to develop the validation work package into a clear plan for delivery the first task is to establish the **overall strategy**. Without overarching strategic principles it will be difficult to maintain alignment of the specific activities with both the overall project objectives and the multiplicity of stakeholders and distributed activities in a multi-year programme environment.

A conventional, yet useful, starting point for defining the overall strategic project landscape are the following questions, represented graphically in Figure 1. Systematic answers to these questions should enable us to generate a concise strategic statement to guide and focus all validation activities thereafter.

Figure 1. The systematic questions



- 1) WHAT is the high level problem or challenge that validation is intended to solve?

As stated, validation is conceptually intended to ensure that the components and services that are emplaced as part of Synchronicity have the result of meeting the operational needs of the users, the citizens of the RZs. The two key goals of this activity are to internally ensure that the different components meets the operational needs of the consortium partners in establishing the parts of a DSM, and to demonstrate to external stakeholders that the correct requirements and specifications have been enacted. It is clear that the validation is intended to be part of an effort to establish a rich evidence base that can support other stakeholders, including cities and businesses, to participate in the DSM. There is a public facing role to validation, with outputs being used to help convince new cities or businesses to participate in the SynchroniCity-established market. Internally, validation will help to answer whether the project is progressing against the project challenges and objectives, though this is not the primary purpose.

The validation will need to be sufficiently flexible to work within different city-contexts and with applications across the themes of the project. These themes include adaptive traffic management,

multi-modal transport, and community policy making, which are the themes that were identified at the outset of the project. Moreover, the validation should also cover new themes that will be identified through market and city-engagement over the course of the project.

- 2) HOW will resources / tasks be allocated to accomplish the results and what approaches, processes and workflows will be followed?

The validation task has been divided by category, with technical experts in each area assigned to that validation. This document, recording the methodology, will communicate both internally and externally the approach to be taken.

In each section, information will be provided on:

- What governance structures and operational processes do we need in order to coordinate the validation work across a large, multi-stakeholder consortium of organisations and cities?
- Information management: How will we capture, store, analyse, and communicate the validation results?
- How do we ensure proper strategic alignment of the distributed teams and activities, and also consistency in the assessments?

- 3) WHY is the (validation) solution needed?

A cornerstone of success is to demonstrate through the validation that the new IoT services have been deployed in response to the genuine needs and challenges of citizens and cities - to prove we are building the right things, and that they are being built in the right way.

This process will be conducted across the different project work packages and stages, as outputs from validation will be needed to support the successive steps of the project. Each methodology section will answer:

- What are the drivers for this work and how do they impact the way the work is carried out?
- Do we have a complete picture of all the purposes for which the validation results are being used?

- 4) WHO?

The validation activity will support the work of the different work packages, providing reassurance to those working on the successive project stages that the requirements and specifications set before them are appropriate and completed. Further, the validation activity provides evidence to both the European Union (EU), the European Commission (EC), and to other cities that are interested in joining the DSM.

Validation activity will be carried out by the consortium partners, in particular by technical experts in each validation area, but with support from representatives of the RZs where needed.

As stated, the primary users, and those who derive the most value from validation, are those within the project that can use the validation outputs to determine what additional actions may be required in order to meet the criteria of the project.

- 5) WHERE are the various geographical and logistical locations and how do they have impact on validation?

Validation applies across a multiplicity of services and cities. The core methodology described in the separate sections will be tailored to the specific geographical and service deployments. Indeed, the specific characteristics linked to the different RZs will play a critical role. The specificities of the different ecosystems have to be considered.

- 6) **WHEN** - deals with the various time-based parameters, events, activities and how they will impact the validation activity

Milestones have been set for some of the validation activities, however it is critical to keep in mind that these represent end points, or final reports, however in most of the cases that will be described the validation activities are continuous and feedback into the relevant project area, as discussed later in this deliverable.

1.2.2 Strategic alignment

We can say already that an essential part of the strategy will address the alignment of the validation activities with the overall project strategy. This is conveyed in two main places: Project Challenges (PC) (Figure 2) and Project Objectives (PO) (Figure 3). In addition, the project sets out initial Validation Categories (VC).

Figure 2. SynchroniCity Project Challenges

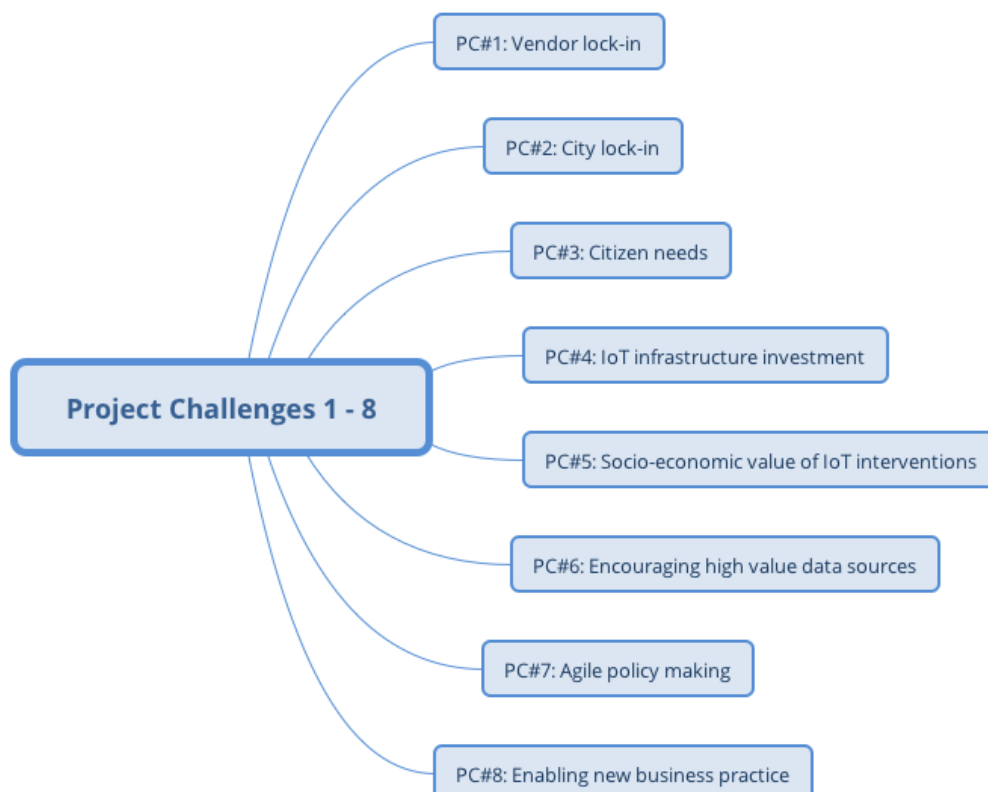
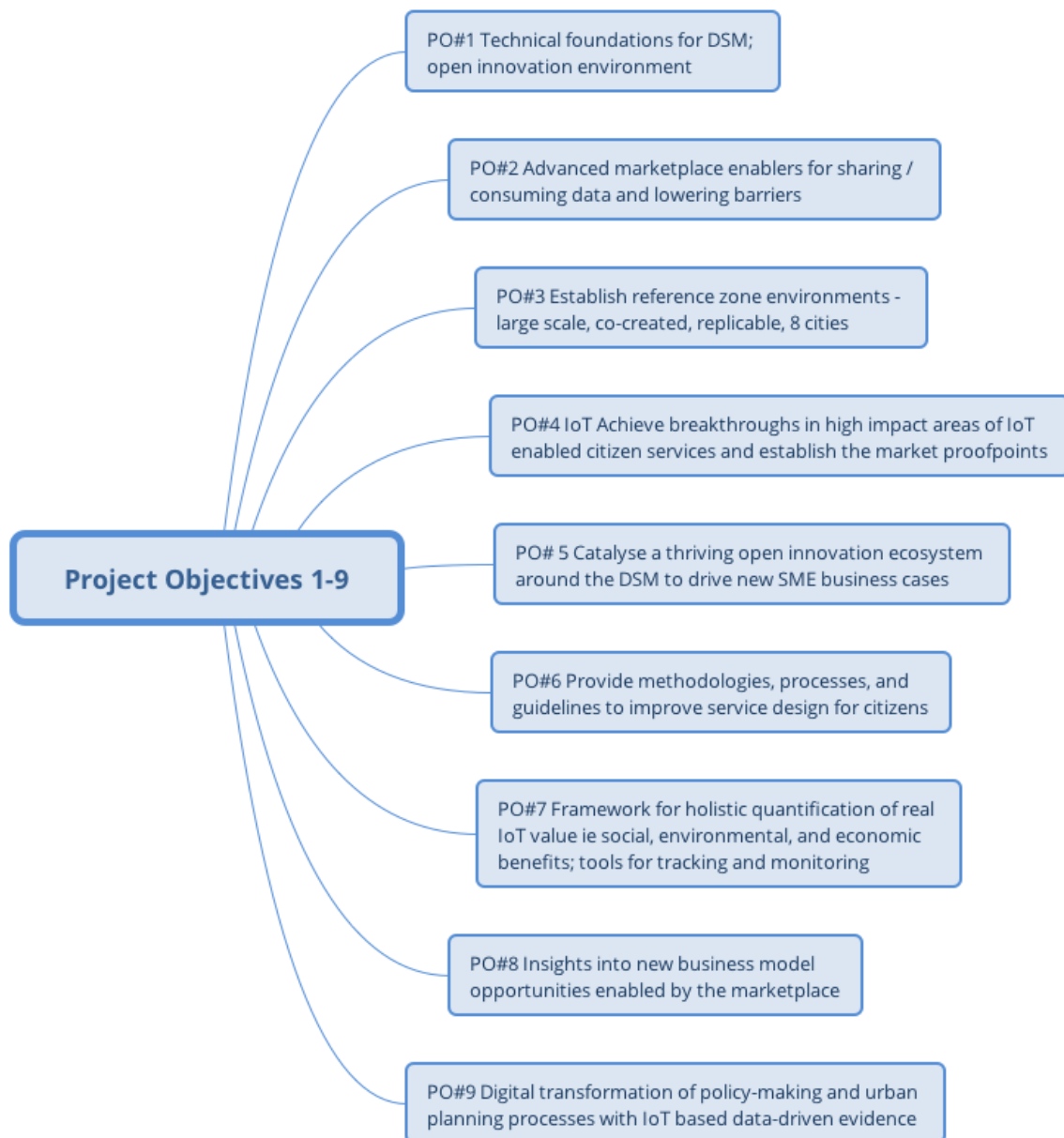


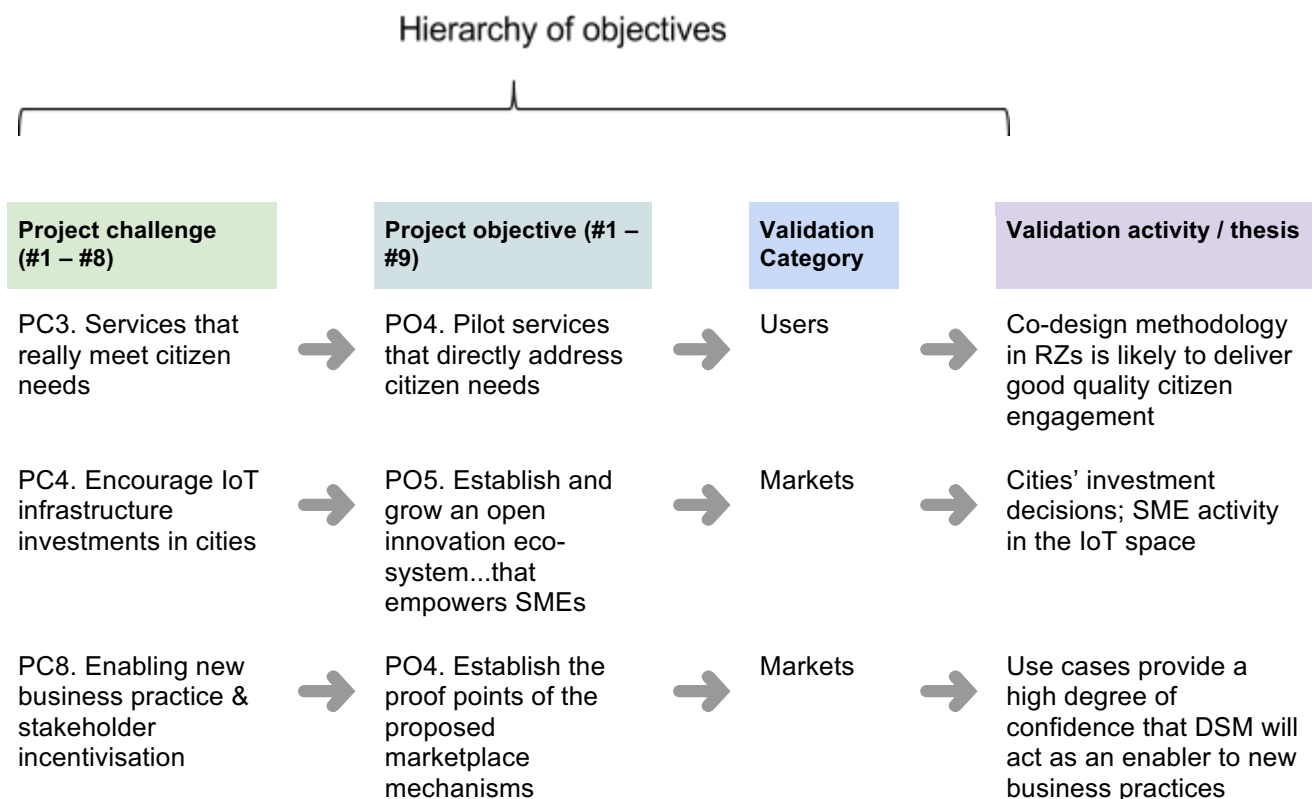
Figure 3. SynchroniCity Project Objectives



By ensuring the validation activities are aligned to these **challenges, objectives, and categories** it will maintain a clear strategic focus and deliver benefits by focussing on the most important and significant outputs, outcomes, and impacts..

Mapping exercise: Figure 4 shows how the specific validation activities are demonstrably aligned with the overall hierarchical strategy:

Figure 4. Objective Mapping Exercise



1.2.3 Holistic validation

A core requirement in WP4 is that the validation is carried out in a holistic way so it will be important for the methodology to establish a clear definition of what a holistic validation entails. Within this document, holistic validation will mean a validation that incorporates **technical assessment** and also include **users; function; replicability; and markets**. “The methodology will rely on a holistic approach taking into consideration that we are not just constraining the validation to technical concepts but also sociological considerations, replication capabilities business models and co-creation attributes.” (T4.1)

1.2.4 KPIs

Project Key Performance Indicators (KPIs) are an important consideration in defining a comprehensive validation methodology as they provide information on areas of the project considered to be important by different stakeholders. It should be noted, however, that these KPIs do not correspond to the individual sections on Technical and Functional validation, User validation, Market validation or Replicability validation. As such, progress against these project KPIs will not form a part of the validation methodologies, except where the project KPI provides valuable information for the especially formulated validation KPIs. The project KPIs available at the time of publication can be found in the Annex. Some project KPIs are particularly interconnected with the objectives of the validations. These include:

- Improved interoperability (Technical, functional)

- Replication potential (Replication)
- New follower city members/interested (Replication)
- Beyond the zone (Scalability)
- Beyond the sector (Replication)

1.2.5 Concise strategy statement

The overall strategic aim of the validation methodology is to provide an initial guide to the principles and methods of the validation to be undertaken across Synchronicity Tasks 4.2, 4.3, 4.4. It is neither necessary, nor desirable, that this be treated as a definitive guide to how these parts of the project will proceed, but rather that it will serve as an initial starting point and to allow other project partners to fully understand the aims of the WP4; further it will provide a jumping off point for the documents and reports developed over the course of WP4. These following reports can refer to the methodologies described within this document, only requiring restatement of methodology where the actual activities differed significantly from those envisioned here.

Our key strategic principles include:

- 1) Be clear on purpose - it is the aim of this document to help fulfil this principle.
- 2) Start with an accurate assessment of today - a core part of each methodology will be to build a picture of what the status of these components of the project are, and explain how that shapes the proposed methodology.
- 3) Create a shared vision of success - this document, through the validation KPIs, will communicate these.
- 4) Define the methods - these will be communicated and explained in the following sections. Differences that occur in practice will be identified in upcoming documents.
- 5) Monitor and report results - associated with each validation type is a report, which will clearly communicate the differences from the proposed methodology, will communicate the results of the validation, and measure against the target validation KPIs.

1.3 Scope

Before commencing the work, we need to define at least two key aspects of the scope:

- What are the essential elements which comprise a validation methodology?
- What specific components will be within the scope of the validation?

1.3.1 Validation methodology scope

- **Methodology** - a general strategy outlining the way in which validation will be undertaken; the theoretical understanding of the methods, rules, practices, principles, qualitative and quantitative techniques, phases, which are required to be applied for the specific validation cases in question
- **Method** - the practical, 'hands-on' steps for carrying out specific validation e.g. the procedures or modes of data collection, how results are calculated, the tools or instruments required, processing and analysis of the data.

Our interpretation is that the scope of T4.1 is primarily concerned with the **methodology** of validation. It is about defining and justifying the overall framework in which existing methods can be employed to achieve the strategic goals of the validation, and defining the justifying the methods as being fit for the purpose of validation. Where further detail can be provided on method, it has been done.

1.3.2 Terminology

Part of developing the scope is to ensure clear definitions of key terminology. This includes an understanding of what we mean by validation, ‘holistic validation’, how validation is different from verification, and whether WP4 includes both validation and verification or is the emphasis more towards one than the other? Key terminology can be found in Table 1.

Table 1. Types of evaluation

Evaluation concept	In WP4 scope?
Validation “The assurance that a product, service, or system meets the needs of the customer and other identified stakeholders. It often involves acceptance and suitability with external customers. Contrast with verification.”¹ Validation asks the question: ‘Are you building the right thing?’ It involves consulting with potential customers and stakeholders hence validation is usually described as an ‘external process’ It is a process of establishing evidence that provides a high degree of assurance that a product, service, or system accomplishes its intended requirements. This often involves acceptance of fitness for purpose with end users and other product stakeholders. Validation can be prospective and retrospective Example: Do the use cases developed in WP1 accurately and comprehensively describe the way stakeholders will need to interact with the DSM? [=meets customer needs)	Yes
Verification "The evaluation of whether or not a product, service, or system complies with a regulation, requirement, specification, or imposed condition. It is often an internal process. Contrast with validation.”² Verification asks the question: ‘Are you building it right?’ It involves conformance to requirements or specifications (rather than customers and stakeholders’ needs) hence verification is usually described as an ‘internal process.’ Verification can be in development, scale up, or production. In development phases verification typically involves modelling or simulating a service or system and then reviewing the results. In production phases verification focuses on ensuring the service or system continues to meet the original regulation, specification, or requirement Example: Does the reference architecture support all the stakeholder use cases defined by WP1? [=conforms to specification] Verification of machinery and equipment (eg IoT hardware) usually consists of design qualification (DQ), installation qualification (IQ), operational qualification (OQ), and performance qualification (PQ)	In part

¹ Project Management Institute, 2017, Project Management Body of Knowledge Guide – Sixth Edition

² Project Management Institute, 2017, Project Management Body of Knowledge Guide – Sixth Edition

Evaluation concept	In WP4 scope?
Impact assessment: Task 4.1 calls specifically for an ‘holistic’ validation methodology, interpreted as one that covers technical, functional, users, stakeholders and markets; the VCs. This is considered to be different from the impact assessment elaborated in the description of PC 5 where it is associated with the longer-term impact assessment of IoT solutions’ potential to address the triple bottom line: social, environmental, and economic.	Not covered
Monitoring (T1.3) “Monitoring is the systematic and routine collection of data during project implementation for the purpose of establishing whether an intervention is moving towards the set objectives or project goals. There are several types of monitoring including: process monitoring, technical monitoring, assumption monitoring, financial monitoring and impact monitoring.”	No, covered by WP1, but will be used by WP4

1.3.3 Scoping activity

A process was used whereby the Synchronicity consortium partners co-created a list of potential validation points. This involved looking through the components, processes and methods that are considered during Synchronicity. These were placed into validation categories and described with detail on likely methodologies, criteria, outputs and the users of the validation results.

This list was then critically reviewed by the Task leaders, divided into those validation types which are considered to fall within the boundary of WP4 and those that are not, based on criteria from the Task descriptions and the potential value of the validation.

This was further developed in order to clarify the potential methodologies of the validation areas. This can be seen in Table 2, Table 3, Table 4, Table 5.

Table 2. Technical and functional validation areas

Criteria			Methodology
Architecture Validation	Architectural system requirements	Decoupled and distributed components	Deployment through modular approach: every component can be replaced easily and with a very limited impact on other components and infrastructure.
		Interoperability and Openness	Support as many agreed open standards as possible for communication, storing and exchanging data.
		Scalability	Easy expansion: adding new nodes to the infrastructure or more resources to existing nodes
		Legacy Compatibility and heterogeneous landscape	The architecture must support/integrate both new and legacy components, while handling different versions of them (reuse of already available resources)
		Resilience to failure and Robustness	Should provide a self-healing system, including redundant links that cover breakdowns
		Performance	Real-time user experience: interaction with the system; discovering new available assets at run time; assets availability (according to service-level agreements (SLAs); 24/7 operation
		Feedback and Monitoring	User feedback channels/management to describe improvements and/or use experience and rate their quality. Advanced usage monitoring functions (statistics, revenue models, technical management)
		Communication interfaces	Handle different communication (standard) protocols/technologies at different communication layers (e.g., Long Range Wide-Area Network (LoRaWAN), IEEE 802.15.4, Narrowband-IoT (NB-IoT), WiFi, Long-Term Evolution (LTE), General Packet Radio Service (GPRS)) and be flexible to incorporate future changes.
	Data management	Data Management Application Programming Interface	Facilitate the reuse of solutions thus avoiding vendor lock-in

Criteria			Methodology
		(APIs)	
		Data Storage Management	Guarantee that data access is performed in accordance with their license, policies of distribution and/or charging, the system should support different data categories based on restriction of their usage such as public or open data, private data and commercial data, while conforming to laws such as the EU General Data Protection Regulation (GDPR).
		Data Models	Ensure the common data models are correctly implemented
		Marketplace	Strict management in terms of validation procedures to be followed, in order to publish or request assets in the marketplace, access policies, business models and federation capabilities
		License	Allow the reuse of existing models and predefined usage licenses
		SLA	Allow definition and management of extensible SLA for data access
	Security and Privacy	Platform security	Accommodate the different needs of specific target scenarios
		Data protection and privacy	Ensure compliance with respect to data protection rules, such as the GDPR
		IoT infrastructure security	Define adaptation policies of these mechanisms in the boundary points while assuring that security remains independent from components
Components and Enablers	Context Data Management		Assess technical performance of components
	IoT Management		Interact with the heterogeneous sets of deployed devices
	Data Storage Management		Interact with heterogeneous sources of data storage
	Marketplace and Asset Management		Support business interactions between suppliers of assets or resources and consumers
	Security, Privacy and Governance		Provide crucial security properties

Criteria		Methodology
	Monitoring and Platform management services	Manage platform configuration and to monitor activities of the platform services
Services Applications and	Human-centric traffic management	Check the implementation of the baseline IoT required services, evaluate the final baseline IoT services and customised services
	Multimodal Transportation	
	Community Policy Suite	

Table 3. User and stakeholder validation areas

Criteria		What	Why	Methodology
Needs and Requirements	Adaptability	Adaptability refers to the service provider response to customer needs, requests and behaviour.	To assess the flexibility and adaptability of the Platform and services to different contexts and needs of the stakeholders (tangibles and service performance).	Co-creation techniques Customer research Discover
	Usability	Usability is a concept in user interface design that refers to how effectively and efficiently a user can interact with a user interface.	To ensure that the end solution/system is easy to learn, efficient to use and pleasant features to increases customer engagement to the product and most of all to the service.	User satisfaction User validation Interface design Focus group, concept test
	User experience	User experience is the emotional response the user has to a service and product.	Focus on a deep understanding of users' needs (values, abilities and limitations) to improve the quality of the user's interaction	Methods: Focus group, user tests, hallway test, online test, prototype user tests and visual performing test..

Criteria		What	Why	Methodology
			with the service and product. In order to be a meaningful and valuable user experience, the information must be useful, usable, desirable, findable, accessible and credible.	Interaction design
	Value co-creation	Value co-creation creates value with, and for, multiple stakeholders through co-creation activities and ongoing interactions leading to an innovative solution. Involve all the stakeholders during the research journey helps fulfil the project with genuine insights of the end users' needs and values.	The implementation of value co-creation throughout the project ensures meaningful interactions and enriched end user experiences. Openness and understanding is needed to work across different sectors and cultures with flexibility, fairness and transparency being essential to the value co-creation process.	Iteration design Co-creation activities Insights validation Research validation Secondary research
Engagement	Empathy	Empathy is defined as a skill to understand and sense other people's feelings and thoughts without having had the same experience. In this context, empathic understanding means to relate to the user by gaining an emotional connection and understanding of certain experiences.	Using this empathic approach is important to relate and get closer to the user, their lives and experiences, not just knowing about the user. This approach will increase the engagement of the user with the product and service develop because it meets the users' needs and expectations.	Research techniques Secondary research Ethnography techniques Deep interviews Diary research technique
	Interaction quality: Trust, Cooperation	Trust and cooperation are 2 main values associated to citizens engagement and stakeholders. The involved actors need to build a trust	To ensure permanence and usage of the tools and solutions from the user's side.	User Validation Stakeholders validation

Criteria		What	Why	Methodology
		relationship with the solution.		
	Co-creation	Co-creation is one of the cornerstones for innovation. Individual knowledge and creativity are not enough to find user-centred solutions to complex problems that most cities face nowadays. Co-creation not only involves all the relevant stakeholders, but it also provokes their creativity by using creative design thinking tools and methods. In this way, co-creation process generate an excellent result for service innovation.	Have a participatory design point of view reduce this risk of failure for the end-product. Ensure the project is internally fulfilling the stakeholder engagement requirement. Ensure that co-creation does not block cities from being able to share projects. Ensure that the project is matching the user needs by involving themselves throughout the co-creation process.	Iteration design Co-creation activities
	Adoptability	Eligibility for quick and sustainable adoption from the Users.	High quality design will be a precondition to the aim of getting widespread citizen adoption of the new services	Adoption validation with minimum viable product (MVP).

Table 4. Replicability validation areas

Criteria		Methodology
Architecture	Specifications	The solution must provide the guidelines to replicate SynchroniCity Architecture
	Degree of implementation	Check the degree of implementation of SynchroniCity Architecture in the RZs: - Adoption of common data models - Authentication, Authorization and Accounting - Northbound, southbound APIs

Criteria		Methodology
		- Data monetisation framework
	RZ's feedback	Collect experiences from the RZs to qualitatively (and eventually quantitatively) assess the design carried out
	Specifications	The solution must provide the guidelines to develop services and application on SynchroniCity Architecture
Service Applications and	Specifications	The solution must provide the guidelines to develop services and application on SynchroniCity Architecture
	Degree of application	Degree of applicability of the service in the RZs
	Feedback from services and application implementation	Collect experiences from the services and applications implementations (WP3) to qualitatively (and eventually quantitatively) assess the design carried out
SME's Projects Integration	Degree of application	Degree of applicability of the project in the RZs
	Alignment with SynchroniCity guidelines	Assess the fulfilment of the main guidelines and architecture specification of SynchroniCity: - Adoption of common APIs - Interoperability with legacy components.
	Small and Medium Enterprise's (SMEs) Feedback	Collect experiences from the SME's projects integration to qualitative (and eventually quantitative) assess the design carried out

Table 5. Market validation areas

Criteria		What	Why	Methodology
Architecture adoption	Market monitoring methodology validation	Validation of the implementation	Verify if the implementation supports all the use cases	Test reports with the users/stakeholders

Criteria		What	Why	Methodology
	Innovativeness of the solution	Innovation level of each service within the different RZs	Ensure that the solution provide innovation to the DSM	Evaluation and compare Positioning map Perceptual mapping (Perceptual mapping that helps visually display the perceptions of customers or potential customers. Mapping the competitive position) Benchmarking (By using this type of methodologies and adding the market research, the team can easily measure the level of innovativeness as well as the level of inventiveness of the solution)
Service framework adoption	Feasibility of business plans	Feasibility validation of business plans	Ensure that the solutions that are created are viable. There is a business plan that will allow the solutions to continue to live, also after the project end date. Validate the profitability, strengths, risk and business opportunity.	Feasibility and financial analysis Business model canvas Financial business plan (financial projection, profit and loss) Investments plan Sales strategy plan
	Broader Market Validation	Assessing the different commercial partners and their role within the different RZs	Verify the level of usefulness and applicability of the commercial solutions developed through the Open Calls and with external commercial partners	Value Network Analysis Stakeholders map
	Time model	Time duration and overlap	Verify that the system life-cycle and times of development, prototyping and implementation	Test reports

Criteria		What	Why	Methodology
			is effective and efficacy	
	Market research and analysis	Gather qualitative and quantitative data on the market niche or market segmentation, in different city sectors.	To understand the acceptability and motivation of the potential customers. Have an overview of the market ecosystem and select where the solution is going to fit, market segmentation	Statistical methodologies Questionnaire
Applicability and potential of the SynchroniCity business model	Business models	Feasibility and applicability of the business models	Verify that the business models envisioned are applicable for all the RZs and are effective in terms of sustainability plans	Expert review, questionnaire with the RZs Strength, Weakness, Opportunities, Threats (SWOT) Analysis
	Go-to-market strategy	Understand the market Market segmentation Target audience	Validate the applicability of the go-to-market strategy Define and selecting a target market to pursue.	Keyword analysis, Google Market Trends, Social chatter Target profile (persona)
	Marketing strategy	Identify all basic, short-term and long-term activities in the marketing field	Identify, anticipate and satisfy customer requirement profitability	Marketing strategy plan (short-term, mid-term and long-term) Digital marketing strategy Communication strategy (offline and online)
	Revenue model	Feasibility of the revenue model	Verify the feasibility of the revenue model to be effective for all the services deployed by the RZs	Expert review, questionnaire with the RZs
Sustainability and replicability	Economic impact	Economic impact assessment	Identify the economic potential impact of the project on the different stakeholders, to	No embedded methodology

Criteria		What	Why	Methodology
			ultimately provide stronger business cases and sustainability of the services developed by the cities with SMEs through the Open Call in WP5	
	Services	Service acceptance in the different RZs	Know the different service acceptances in the RZ and evaluate the implementation of the monitoring strategy	Monitoring Framework Template Methodologies/tools from co-creation process WP3
	Uptake	Various application in each RZ	User / citizen validation (two dimensions: User Experience (UX) / User Accessibility (UA) and perceived impact e.g. user behaviour, quality of life)	Methodologies / tools from WP1 and co-creation process from WP3
	Competitors	Capability of keep pace with competitors	Understand the ability of the project to keep pace with competitors	Methodologies/tools from WP3 and WP6, Likert scale (self-evaluation) Positioning map Competitor analysis and benchmarking
	Human resources	Human resource management oversees various aspects of employment.	To understand the business strategy and operation.	Human resources plan (organizational structure, diagram)

1.4 Guiding Questions

For the development of the validation methodologies, the following guiding questions have been co-created by the project partners. The answers to these will be clearly called out within the validation methodology texts.

- If different parties are carrying out the validation how do we ensure a consistency of approach?
- What is the role for validation at different points in the development lifecycle:
 - o before new services are developed - specifying validation criteria?
 - o during development of new services - consulting on validation KPIs?
 - o after services are deployed - verifying?
- What is our approach to carry out validation across all cities?
- Is the validation an ongoing process or carried out at defined moments in the project?
- This task will be generating a lot of data. How do we manage / store / disseminate / update the data?
 - o How do we make this report or system easily available for all the cities?
- What are the cities already doing in terms of validation and how do we build on top that?

These specific guiding questions are also aligned with the strategic alignment questions.

2 Functional and technical validation

2.1 Approach

This section will focus on defining the functional and technical directives for the validation methodology that will be applied to the core of SynchroniCity framework and addressed on Task 4.2. This will consider the performance validation of the architecture, components and overall services developed within WP2 and WP3, through the verification of the functional and technical requirements set started in WP1³ and evolved according SynchroniCity progress. All these together will support the project's desired DSM outcome, as well as the use cases and pilots defined in WP3.

When addressing functional and technical validation, an iterative approach will be adopted. Hence, the different functionalities linked to the enablers, components, interfaces and services will be assessed. Such assessment will be carried out both at individual level and integrated level, analysing each component performance working alone as well as part of the SynchroniCity framework.

In this line, the first set of outcomes from Task 1.2⁴ provides a list of functional and technical requirements that will be taken as the starting point for the validation methodology to identify **how** to overall validate the SynchroniCity framework. These requirements were complemented and addressed by Task 1.2⁵ to link them with the SynchroniCity Architecture Reference Model and its core components, what represents a first approach to **what** we need to validate from this technical perspective.

Following this approach, functional and technical validation will be split into three evaluation processes, covering different views (detailing what and how) of the capabilities and characteristics of the SynchroniCity framework:

- Architecture validation, focused on the overall requirements and in the framework as a whole, with special interest on standardization, replicability, scalability, privacy and security areas.
- Components and Enablers, that centres on concrete technical aspects and functionalities that guarantee the support of services and applications, as well as provide the tools to develop them on top of the architecture.
- Services and Applications, covering the adaptation of the SynchroniCity services framework to the data formats, APIs, supported standards, consuming options, required by the service market. This will involve required services to exploit SynchroniCity datasets and applications developed on top of the framework and related to the SynchroniCity use cases and Open Calls.

Depending on the scope, the validation process will include all RZs (**where**), as in the architecture validation, grouped by the application areas: context based traffic management, multimodal transportation or community policy suite. These three processes will also identify **who** will carry them out: architecture validation will be led by WP2 partners, assisted by different experts within all RZs, components and enablers verification process will be executed by technical partners, also within WP2, and services will be validated by WP3 involved partners. Overall functional and technical requirements achievement will be validated within each RZ, where SynchroniCity framework will be deployed to support pilots.

³ D1.3 Guidelines for SynchroniCity architecture, SynchroniCity, 2017

⁴ D1.3 Guidelines for SynchroniCity architecture, SynchroniCity, 2017

⁵ D2.1.1 Reference Architecture for IoT Enabled Smart Cities, SynchroniCity, 2017

As the expected outcome, this validation will define the set of components, functionalities, protocols and APIs actually available for the WP5 Open Call process as well as the required framework to develop the SynchroniCity pilots.

The whole functional and technical validation process will be divided in two main stages, following mainly the technical WPs progress and guaranteeing the proper framework for WP5 Open Call and the final SynchroniCity platform objectives:

- During the first stage (M12-M17), the basic functionalities, requirements and components will be analysed and validated, on top of leading cities/RZs architectures. This will provide the basis for the Open Call and a reference for the rest of the RZs.
- The second stage (M25) will validate the evolution of the RZ architectures towards the final SynchroniCity architecture, as well as the services and applications developed to support SynchroniCity use cases and Open Call developments.

2.2 Functional and technical requirements

The functional and technical requirements extracted from first steps on use cases and architecture definition (carried out by WP1 and WP2) refer to the whole SynchroniCity framework, and are not linked to any specific scenario or use case. Therefore, the requirements listed below apply to all instances of SynchroniCity platform and should be accomplished by all RZs and in all deployed pilots. The proper fulfillment and checking of this whole set of technical and functional requirements provides a way to overall validate the whole SynchroniCity framework and will involve all RZ linked partners plus the relevant technical and developer partners.

As already mentioned, Task 1.2 identified an initial set of *functional requirements* emanated from SynchroniCity proposed system use cases, shown in Table 6. These requirements have been described at high level, without defining detailed features or technologies to be adopted for implementation and directly address the SynchroniCity framework core services. Each functional requirement expresses a functionality of the platform that will be directly used/expected by a user (human or external system). A fuller description can be found in the Annex.

Table 6. Functional requirements (initial set)

D1.3 Identifier	Title	Category
SR-LEGACY-02	IoT Devices management	Legacy Compatibility and heterogeneous landscape
SR-FEEDBACK-01	User Feedback collection	Feedback and monitoring
SR-MONITORING-01	Data usage monitoring	Feedback and monitoring
SR-API-02	Publish/subscribe data channels	Data Management APIs
SR-API-03	Asset version management	Data Management APIs
SR-API-04	Resources status notification	Data Management APIs
SR-API-05	Lookup asset	Data Management APIs
SR-API-06	The system has to allow to access/consume data through RESTful API	Data Management APIs
SR-POLICY-01	Data and service access policy	Data Management APIs

SR-LICENSE-01	Data licenses definition	Licence
SR-LICENSE-02	Customisable Licenses	Licence
SR-LICENSE-03	Pre-built Licenses	Licence
SR-SLA-01	SLA management	SLA
SR-SLA-02	SLA common metadata	SLA
SR-MODELS-01	Asset description taxonomies	Models
SR-MKTPLACE-01	Marketplace access	Marketplace
SR-MKTPLACE-02	Asset publication procedure	Marketplace
SR-MKTPLACE-03	Flexible revenue and pricing models	Marketplace
SR-MKTPLACE-04	Asset catalogue	Marketplace
SR-MKTPLACE-05	SynchroniCity compliance policy validation	Marketplace
SR-MKTPLACE-06	Asset request procedure	Marketplace
SR-MKTPLACE-08	Marketplace peering	Marketplace
SR-PRIVACY-01	Privacy policies guidelines	Data protection and Privacy
SR-PRIVACY-04	Personal Data usage	Data protection and Privacy
SR-SECURITY-03	Access policy	Platform

Further work on Task 2.1 has revisited functional requirements, complemented them with a list of initial *technical requirements* shown in Table 7, and addressed them to the SynchroniCity architecture and components. A fuller description can be found in the Annex.

Table 7. Technical requirements (initial set)

D1.3 Identifier	Title	Category
SR-MODULARITY-01	Container technology	Decoupled and distributed components
SR-INT-OPEN-01	Use of publically accepted and open standards	Interoperability and Openness
SR-SCALABILITY-01	Horizontal and vertical scaling	Scalability
SR-LEGACY-01	Flexible support of new and legacy components	Legacy Compatibility and heterogeneous landscape
SR-ROBUSTNESS-01	Self-healing and robust system	Resilience to failure and Robustness

SR-PERF-01	Real-time user experience	Performance
SR-PERF-02	Operational	Performance
SR-COMM-01	IoT communication patterns	Communication
SR-COMM-02	IoT integration	Communication
SR-API-01	Standard and Open API	Data Management APIs
SR-STORAGE-01	Physical data storage location	Data Storage Management
SR-STORAGE-02	Categorization	Data Storage Management
SR-MODELS-02	Standard and open data models	Models
SR-MKTPLACE-07	Marketplace transparency	Marketplace
SR-PRIVACY-02	Data protection	Data protection and Privacy
SR-PRIVACY-03	Anonymization	Data protection and Privacy
SR-SECURITY-01	End-to-end secure communication	IoT infrastructure
SR-SECURITY-02	IoT adaptation policies	IoT infrastructure
SR-SECURITY-04	Flexible security capabilities	Platform
SR-MKTPLACE-05	SynchroniCity compliance policy validation	Marketplace
SR-MKTPLACE-06	Asset request procedure	Marketplace
SR-MKTPLACE-08	Marketplace peering	Marketplace
SR-PRIVACY-01	Privacy policies guidelines	Data protection and Privacy
SR-PRIVACY-04	Personal Data usage	Data protection and Privacy

2.2.1 Activities

The validation activities related to functional and technical requirements will be specified within Task 4.2, in order to adapt them to the progress on architecture definition and framework deployments in each RZ. They will be focused on:

- Evaluation of the whole set of functional requirements provided by WP1 and reviewed by WP2 (architecture) and WP3 (services), in terms of SynchroniCity framework final functionalities.
- Evaluation of the whole set of technical requirements initially identified in Task 1.2 and revisited in Task 2.1. These technical requirements will be evolved and detailed within WP2 and WP3, in terms of architecture, components and services and all this work must be considered when facing each evaluation process.

As already mentioned, the functional and technical requirements apply to the whole SynchroniCity framework, so their evaluation process would be the same in each RZ, as they will use the same framework to support the same DSM. Attending to this, each RZ will check the complete set of requirements using its SynchroniCity Architecture, assisted by WP2 (for components and architecture support) and WP3 (for service framework support) partners, and report its degree of fulfilment to technical WPs (WP2 and WP3) and open call management (WP5), as well as to the SynchroniCity monitoring framework (WP1). This process will be carried out in two stages:

- During first one (M12-M17), each RZ will analyse the requirements set using their already deployed IoT infrastructures and architectures, identifying which requirements are already achieved and those that need special effort to be implemented. This will be useful for RZs themselves, to plan their SynchroniCity compliant framework deployment, and for SynchroniCity Open Calls, to have a first impression of what, and how, would be offered to external partners. This will be addressed as part of the activities undertaken in WP2, assisted by partners involved in Task 4.2.
- Second stage (M25) will evaluate the requirements once each RZ has deployed its SynchroniCity framework, ensuring the proper achievement of all pointed requirements. This will provide an overall validation of SynchroniCity architecture, as well as its corresponding service framework and building blocks, in turn useful for external partners to know how to exploit SynchroniCity features. This will be led by WP2 technical partners, assisted by partners involved in Task 4.2.

2.2.2 Objectives

This validation process will provide an overall evaluation of the whole SynchroniCity framework, including its architecture reference model, components performance, integration and services support, by ensuring the proper fulfilment of the complete requirements set, from a technical and functional perspective, emanated from the work carried out mainly within WP1, WP2 and WP3.

With this, SynchroniCity will achieve two main objectives:

- For external partners participating on the Open Call, and furthermore for SynchroniCity sustainability, it offers an easy-to-follow description of SynchroniCity capabilities and features, that helps on identifying integration strategies and development frameworks.
- For determining SynchroniCity project success, it will provide overall KPI monitoring mechanisms.

2.2.3 Expected outcomes

Related to the described approach and activities to be carried out, this validation process will produce two main sets of outcomes, aligned with the objectives and derived from the two mentioned stages:

- From the initial requirements checking (stage 1), a set of actions, improvements and steps to guarantee the proper fulfilment of all functional and technical requirements and the deployment of the SynchroniCity compliant framework, particularized to each RZ implementation.
- From the final requirements evaluation (stage 2), a verified set of SynchroniCity framework features and KPIs values, derived from the requirements, to assist external developers and consumers on the different ways they can interoperate with this framework.

On the other hand, but also oriented to the external actors and main SynchroniCity objectives, this validation will guarantee the security and privacy functionalities, integration capabilities and supported standards required by the envisioned SynchroniCity framework and eventual DSM, reinforcing further technical and functional evaluations.

2.3 Architecture

WP2⁶ provides the high-level specifications of the SynchroniCity Reference Architecture for IoT Enabled Smart Cities, based on the analysis of the standard technologies and current deployments on the RZs, and focused on finding commonalities among them. This architecture will provide the required functionalities and interfaces to support the SynchroniCity framework and eventual DSM, including, among others, IoT and legacy system management, data access and user management, security and privacy or marketplace mechanisms.

2.3.1 Activities

The validation strategy for the SynchroniCity architecture is based on the overall requirements identified in its first round within WP2 (Task 2.1) and so, closely tied with its components validation, but considering the platform as a whole, looking at the complete set of functionalities, standards and capabilities offered to RZs and third parties. This will trigger Task 4.2 activities that will deeply analyse the initial set of requirements, refine and then complement them to align this validation process with the SynchroniCity architecture evolution, ensuring that the final version covers all requirements in terms of interoperability, reliability, data management, and security needed to support the SynchroniCity framework and the pilots.

The validation activities will be linked to the architecture progress, aligned with Task 2.2 (interoperability and data management), Task 2.4 (data gathering, access to functionalities, security) and Task 2.5 (deployment, integration and operation), and will involve *all technical and developer partners plus all the RZs*. This process will validate the SynchroniCity architecture according the requirements compiled and analysed in Task 2.1:

- **Architectural system requirements**, referred to the pure main architectural characteristics
 - *Decoupled and distributed components*; deployed through modular approach, thus every component can be replaced easily and with a very limited impact on other components and infrastructure.
 - *Interoperability and Openness*; supporting as many publically accepted standards and protocols as possible for communication and exchanging data.
 - *Scalability*; with an easy expansion process when more users of “things” and/or streams of data are foreseen, including new nodes (info sources) and more resources (e.g., Central Processing Unit (CPU) performance, disk space or memory).
 - *Legacy Compatibility and heterogeneous landscape*; the architecture must be able to support both new and legacy components, while handling different versions of them. Cities need to maximize the use of legacy wired/wireless infrastructures; thus, the system has to support IoT based services by efficiently (re-)using already available assets.
 - *Resilience to failure and Robustness*; it should provide a self-healing system, including redundant links that cover breakdowns.
 - *Performance*; real-time user experience, new available assets discovering, SLAs definition and support.
 - *Feedback and Monitoring*; to facilitate the asset selection by the end users, the global platform polishing and improvement, and to build a reputation for the providers which can be exploited among different city marketplaces.
 - *Communication*; the architecture will handle different protocols (e.g., LoRa, 802.15.4, NB-IoT, WiFi, LTE, GPRS) and be flexible to incorporate future changes,

⁶ D2.1.1 Reference Architecture for IoT Enabled Smart Cities, SynchroniCity, 2017

supporting different communication patterns such as telemetry, query/retrieve petitions, management commands, notifications.

- **Data management**

- *Data Management APIs*; standard and open APIs to enable the access and consumption of data by applications and services. This facilitates the reuse of solutions thus avoiding vendor lock-in.
- *Data Storage Management*; this addresses the storage of data from both platform and usage perspectives: data could be stored into a locally owned system, a cloud or a hybrid system, depending on the data characteristics and services/applications requirements. Therefore, the architecture should take into account different data format, providing storage support for both unstructured (e.g., raw data) and structured data. In order to guarantee that data access is performed in accordance with their license, policies of distribution and/or charging, the system should support different data categories based on restriction of their usage such as public or open data, private data and commercial data.
- *Data Models*; support open and standard data models and metadata by providing pre-built taxonomies to describe assets (e.g., data, services, applications, devices) to simplify the definition of the assets description and to allow reuse of existing data models.
- *Marketplace*; SynchroniCity architecture will support a marketplace whose digital assets can be exchanged or traded among users, with different license policies defined by providers. This includes strict management in terms of validation procedures to be followed, in order to publish or request assets in the marketplace, access policies, business models and federation capabilities among other cities' marketplaces, thus enabling a DSM.
- *License*; in order to support a dynamic ecosystem in which providers can establish various business models, the architecture will provide data license templates that can be easily customized to an intended business model. To facilitate the publication process, providers should be able to use standard licenses (e.g., General Public Licenses (GPL), Apache, Creative Commons), thus SynchroniCity should allow the reuse of existing models and predefined usage licenses.
- *SLA*; allow definition and management of extensible SLA for data access as well as provide common metadata to define SLA so that the management and the comprehension of the SLA descriptions can be simplified.

- **Security and Privacy**

- *Platform security*; the platform should provide flexible security capabilities in order to accommodate the different needs of specific target scenarios in terms of confidentiality, integrity, authentication, authorisation, immutability, trust and non-repudiation.
- *Data protection and privacy*; the system will allow to define and manage policies for data and service access control. It also will provide procedures and guidelines in order to ensure compliance with respect to data protection rules, which also include data anonymization and aggregation functionalities.
- *IoT infrastructure security*; the system should provide end-to-end security at the API level (southbound), handling security measures such as key management, authentication, integrity and confidentiality. The system should define adaptation

policies of these mechanisms in the boundary points while ensuring that security remains independent from low level IoT components.

Each RZ implemented IoT architecture will be analysed from the point of view of how these requirements are addressed on each of them:

- In a first round (starting on M12), the RZs' leading architectures will be validated, compiling the achievement of the basic set of architectural requirements needed to launch the SynchroniCity Open Call. WP2 will classify those requirements as basic or advanced, according existing implementations and project objectives. This should guarantee a minimum set of supported protocols, standards and APIs to provide a common open framework to develop SynchroniCity pilots and Open Calls applications which will be feasible for porting and replicating between leading RZs.
- A second round of this architecture validation (M25) will focus on the whole set of the architectural requirements (basic and advanced) and how these are addressed and covered by the final SynchroniCity reference architecture and the corresponding implementations in each RZ. This evaluation process will validate the enablers (architecture building blocks) and the relationships (communication interfaces, integration, feedback) required to achieve all SynchroniCity architectural objectives.

The validation execution process will be *carried out by each RZ technical partners assigned to each RZ, guided, assisted and supervised by WP2 responsible partners.*

2.3.2 Objectives

The architecture validation process will ensure a common IoT framework ready to be deployed in each SynchroniCity RZs that enables a new set of functionalities, from the point of view of compatibility and standardization, whilst integrates all legacy systems already deployed within them. In the same line of all SynchroniCity technical and functional validations, the main beneficiaries of the architecture validation will be:

- SynchroniCity RZs and external cities, that will get a common, standard and interoperable IoT architecture to support existing and incoming IoT services, validated for different communication protocols and environments at different levels (southbound and northbound).
- SynchroniCity project technical core and SynchroniCity overall evaluation process, identifying and providing technical metrics and KPIs focused mainly on Interoperability, as one of the main objectives of the project.

2.3.3 Expected outcomes

In close collaboration with WP2 and based on RZs IoT deployments and future plans, all the architectural requirements will be classified as basic features, needed to support interoperability and replicability, and advanced features, that will cover all the SynchroniCity objectives in terms of architecture. This whole validation process will check all these requirements before the WP5 Open Call is published, evaluating the available framework provided and supported by the RZs, and, later in the project, to evaluate the SynchroniCity reference architecture, the progress achieved by all RZs on its instantiation and the final set of features offered. In this sense, the outcomes of the validation process will be:

- Status of all RZs (focused on leader RZs), related to the basic features and requirements provided by their architecture implementations. This validated list will be a reference for the other RZs and the starting point to converge to the SynchroniCity architecture reference model.
- Validation of the whole SynchroniCity reference model, with respect to all the identified architectural requirements, and guaranteeing the portability, replicability and interoperability of all applications developed on top.

- Validation of each final implementation of this architecture reference model on RZs, showing the achievements on the list of architectural requirements.

All these outcomes will assess Task 2.1 progress and feed D4.2.1 and D4.2.2. Aligned to this, it will also identify and describe the technical KPIs that address and guarantees a portable, standard and resilient architecture to support the pilots.

2.4 Components and enablers

The components and enablers compose the set of hardware and software pieces that finally furnish the architecture with specific technical capabilities that later result in supporting concrete functionalities. The same functionality can be articulated using different technical components, so, the way this is achieved will depend on each RZ implementation. This validation process will focus on how the RZs' instantiated component sets are able to provide the same functionalities, according the standards addressed by the architecture.

2.4.1 Activities

The introduced SynchroniCity reference architecture identifies a set of logical modules to initially support SynchroniCity pilots:

- **Context Data Management**, related to context information captured by IoT devices and other public and private data sources.
- **IoT Management module**, responsible to interact with the heterogeneous sets of deployed devices.
- **Data Storage Management**, oriented to data storage and data security and quality, in the specific context of IoT systems and smart city platform interacting with heterogeneous sources.
- **Marketplace and Asset Management** module to support business interactions between suppliers of assets or resources and consumers.
- **Security, Privacy and Governance**, that covers all the security aspects related to three main pillars: data, IoT infrastructure and services. Around these pillars, security functionalities provide crucial security properties such as confidentiality, authentication, authorization, integrity, non-repudiation, access control.
- **Monitoring and Platform management services**, that includes functionalities to manage platform configuration and to monitor activities of the platform services.

Each logical module will, in turn, group a combination of technical components that articulates the corresponding module functionalities.

This identification process, done within WP1 and WP2, has considered a set of initial premises:

- Architecture guidelines and use case analysis, that are reflected in D1.3, which provides the SynchroniCity platform scenarios and a first set of functional and technical requirements.
- RZ current IoT architectures and deployments analysis.
- Reuse of existent and relevant standards and initiatives in the field of IoT and Smart City platforms.
- OASC principles, in terms of common APIs, information models and data publication platforms.

Components validation processes are to be carried out within Task 4.2, assessing Task 2.5, which will ensure the proper achievement of the reference architecture core functionalities, provided by its core components, but considering the current deployments, implementations and planning evolutions on each RZ. Therefore, the set of physical components that compose each logical module may vary from one implementation to another. From this point of view, the related checking activities should focus on the interoperability points between logical modules, identified in WP2,

and their corresponding functionalities. This way, the same incomes and outcomes from each logical module should be guaranteed, leaving to the cities its real implementation.

To close this components and enablers validation, WP2 will also provide a technical reference implementation for each logical module, coming from existing open IoT architecture and trying to align as much as possible current RZs infrastructures. This implementation will be offered as a first option to those cities that have not implemented any of the required logical modules and should be validated, according the same set of requirements applied to the RZs' deployments.

This way, activities here considered will be focused on checking the proper performance of each architecture component/enabler. These will be evaluated and checked according their specific set of technical and functional requirements defined within WP2, ensuring integration and interoperability. Two different testbeds will be used for this purpose: and stand-alone operative mode, to evaluate specific functionalities and/or characteristics particularly addressed to a single concrete component; and an integrated mode, connected to other related platform components, to evaluate the communication features, standard supports of each logical module.

The components/enablers validation will offer the baseline scenario to check all technical, and later functional, requirements proposed first in WP1 and expanded in WP2. In turn, the overall architecture validation will also rely on the logical modules and their integration/interoperation capabilities, so, the actors involved and evaluation stages will be aligned with the proposed schema for functional and technical validation. Therefore, in order to guarantee a SynchroniCity platform, ready to support the WP5 open call and so project expansion, achieving all technical and functional requirements, each RZ will participate on this process, checking all requirements addressed to each architecture logical module according their existing instances. All RZs will be properly assisted by WP2 and WP3 partners, to ensure the required components features and interoperability capabilities. This process will consist on two basic stages:

- During the first one (M12), current status of each RZ deployments will be analysed within WP2 (Task 2.5), in terms of deployed technical components and according architecture logical modules. This will provide a list of already covered functionalities and the status of the different WP2 interoperability points. RZs will also know which are the components they need to improve/implement, while cooperation between RZs is fostered.
- Second stage (M24) will evaluate the RZs' logical modules (and components) running, according the corresponding components requirements and in terms of interoperability, once each RZ has deployed its SynchroniCity framework. This will provide the final list of components running in each RZ, set of available APIs and functionalities ready to be used and supported in the open calls. Besides, it will also pave the basis for the overall validation of SynchroniCity architecture as well as that of the general functional/technical requirements..

2.4.2 Objectives

Aligned with the described activities, the components and enablers validation process will focus on the SynchroniCity reference architecture logical modules and its implementation on each RZ. It will check and evaluate the data models, incomes, outcomes, protocols and data formats managed by each component in order to ensure the same functionalities and interoperability capabilities on each SynchroniCity framework instance. Therefore, SynchroniCity overall architecture and SynchroniCity functional and technical requirements can be later validated.

Following the SynchroniCity reference architecture depicted in WP2⁷ the validation activities will assess Task 2.5 on the evaluation of deployed components in each RZ. The objectives to obtain, according the proposed stages will be:

- In M12, aligned with Tasks 2.1 and 2.5, check and evaluate current components deployed in RZs, according logical modules requirements. The validation of these components,

⁷ D2.1.1 Reference Architecture for IoT Enabled Smart Cities, SynchroniCity, 2017

comparing the RZs' implementations, will provide a real photo of the SynchroniCity architecture starting point, as well as the set of components, functionalities and integration schemas that should be addressed to achieve the whole set of functional and technical requirements. In turn, this will support the first validation of the SynchroniCity architecture.

- Validate (M24) the proposed components for the final SynchroniCity reference architecture, to ensure the proper achievement of technical and functional requirements.
- Assist Task 2.5 on evaluating and monitoring the RZs' implementation of the SynchroniCity logical modules.

2.4.3 Expected outcomes

The outcomes of the components and enablers validation will be resumed as follows:

- A set of current implementations of each SynchroniCity architecture logical module, deployed in each RZ, detailing the different components used and the set of functionalities validated. This will feed D4.2.1. The evolution of these logical modules, to align with SynchroniCity architecture will be reflected on D4.2.2.
- A description of all components conforming each logical module on SynchroniCity reference architecture, coming from Task 2.1, detailing the validated functional and technical requirements addressed. This will be shown in D4.2.2.

2.5 Services and applications

SynchroniCity project will implement and deploy a set of innovative IoT-based applications and services, aimed to foster and leverage the SynchroniCity framework for IoT-enabled Smart Cities. These services and applications will be provided by and developed on top of SynchroniCity architecture, managed within WP3 with the purpose of demonstrating the replicability, portability and compatibility of the SynchroniCity compliant solutions. Services and applications to probe SynchroniCity capabilities have been grouped in three themes, attending to Cities and RZs priorities:

- **Human-centric traffic management** - Leveraging data coming from different IoT systems to manage traffic in such a way that there is a more optimal balance between the needs of all involved stakeholders, including cyclists.
- **Multimodal Transportation** - Stimulate combinations of often fragmented urban information to tackle transportation management of both people and goods in large territories (and between them) in a more efficient and less vertically-oriented way.
- **Community Policy Suite** - Accelerate the adoption of new services within the pilot city RZs by enabling IoT-based services to adapt to changing circumstances by using a dynamic data-driven platform to inform future IoT investment, and respond quickly to citizen needs

Each of these themes will result in the development of a specific set of core services, information sources and APIs supported by SynchroniCity architecture. This technical validation will focus on the validation of the associated requirements for each RZ, in order to guarantee the proper implementation of the applications and local pilots related to the use cases defined within each theme.

2.5.1 Activities

The activities to be carried out within this technical validation process will assist the progress of different Tasks within WP3. Only the main themes and initial use cases have been identified at this time. RZs have been aligned with these themes, defining different use cases and identifying the technical and functional requirements linked to each of them, as shown in Table 8.

Table 8. Use-cases identified

Theme	Use Cases / Applications	RZs involved
Human-centric traffic management	Data-driven bicycle mobility	Eindhoven, Antwerpen, Milan, Carouge
Multimodal Transportation	Multimodal Navigator, combining Parking and Ticketing services plus environmental and traffic information.	Porto, Santander, Milan, Helsinki
Community Policy Suite	Agile governance	Porto, Manchester

Detailed information about these use cases, including descriptions, canvas models, and technical requirements will be reported by D3.1⁸.

The use case analysis done by Task 3.1 identified a set of baseline IoT services for each use case and theme, while identifying the required information to implement the defined city pilots. These IoT services, IoT sources and IoT deployments compose the services and applications technical and functional requirements, also linking with SynchroniCity architecture and components requirements, in terms of data models, supported standards and open APIs. In this sense, the first validation activity is to check the implementation of the baseline IoT required services set in each RZ, to be reflected in D4.2 (phase 1 of technical validation), in M17:

- Technical RZ representatives from Eindhoven, Antwerpen, Milan and Carouge to check Data-driven bicycle mobility IoT baseline services.
- Technical RZ representatives from Porto, Santander, Milan and Helsinki to check Multimodal Navigator IoT baseline services and information availability.
- Technical RZ representatives from Porto and Manchester to check Community Policy Suite baseline services.

The final implementation of identified city pilots and applications will require a customisation of the required baseline IoT services, including the development of concrete services to provide aggregated information, to adapt and expand the core pilot according to each involved RZ capabilities. A second validation process will be triggered, synchronised with D4.3 and D3.6 (M25), to evaluate these final baseline IoT services and customised services:

- Technical RZ representatives from Eindhoven, Antwerpen, Milan and Carouge to check Data-driven bicycle mobility IoT baseline services implementation and customised services deployment in each corresponding RZ.
- Technical RZ representatives from Porto, Santander, Milan and Helsinki to check Multimodal Navigator IoT baseline services implementation and customised services deployment in each corresponding RZ.
- Technical RZ representatives from Porto and Manchester to check Community Policy Suite baseline services implementation and customised services deployment in each corresponding RZ.

All these services and tools validations will be done by checking a set of defined inputs and outcomes which will be defined in Task 3.2 and Task 3.3, according interoperability parameters defined in WP2.

⁸ D3.1 Documentation of service designs, SynchroniCity, 2018 (forthcoming)

2.5.2 Objectives

One of the SynchroniCity project objectives is to define, implement and replicate a set of use cases, driven by RZ interests in smart city applications and citizens involvement, developed on top of a common SynchroniCity reference IoT architecture. These use cases will so require a common set of IoT baseline services to support the final applications that articulate them. Besides this, customised services or customisation tools to adapt and complement the final application to each city particularities will be also required. All this set of tools will be part of the SynchroniCity framework. The objectives of this validation process are:

- Validate the implementation of all identified baseline IoT services required to implement the defined city pilots in all the RZs involved on each theme. This will ensure each RZ is ready to deploy the selected pilot.
- Validate the implementation of each required customised service or customisation tool to complement the baseline IoT services and support the final deployment of the selected pilots in each city.

These two validation sets will set the layout for integration and replication validation process.

2.5.3 Expected outcomes

According to what has been described, the main outcome will be a validated service framework and customisation tools set to deploy use cases applications. Each involved RZ will have a validated set of baseline services, customised services and customisation tools, deployed and compliant with SynchroniCity architecture and, depending the use cases involved, ready to support use case applications deployment, replication and portability. This will provide a list of defined and validated IoT baseline services required to be available in any city interested in deploying one of the SynchroniCity applications.

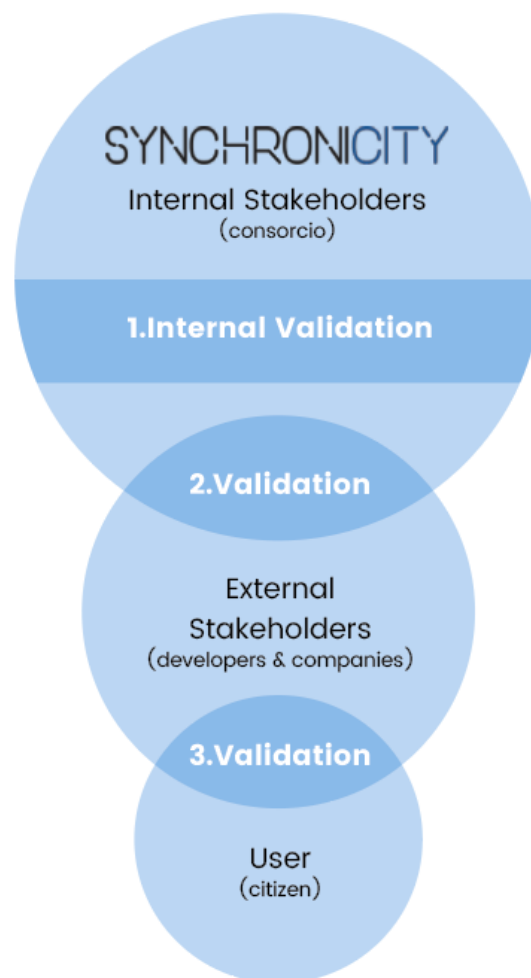
3 User and stakeholder validation

3.1 Approach

In this section, the focus is on the User and Stakeholder validation of the services, platform and tools developed by the Project. For this purpose, three main types of users were identified according to their characteristics and connection to the project, shown in Figure 5:

1. Stakeholders: The stakeholders should be engaged in all the design and development phase to identify needs and requirements and to enable an iterative validation process. Stakeholders can be both Internal (consorcio) or External (those include Academia, Industry, Policy Makers, Entrepreneurs, Companies, Citizens...).
2. End Users: The end users vary according to the type of validation being undertaken, e.g. citizens, in service validation, developers, in the Platform Validation or Stakeholders in the tools validation.
3. Developers and SMEs: this group is essential for technical and user validation, as they are able to analyse both the tools and also the platform, where they are frequently the End Users.

Figure 5. Types of users and stakeholders identified for the SynchroniCity project



The direct and active participation of all stakeholders in the design development process is acknowledged by many as being a powerful tool to drive long-term engagement.

In order to be able to promote a proper user validation process it is important to adapt engagement methodologies to match the state of the project. This will take into consideration:

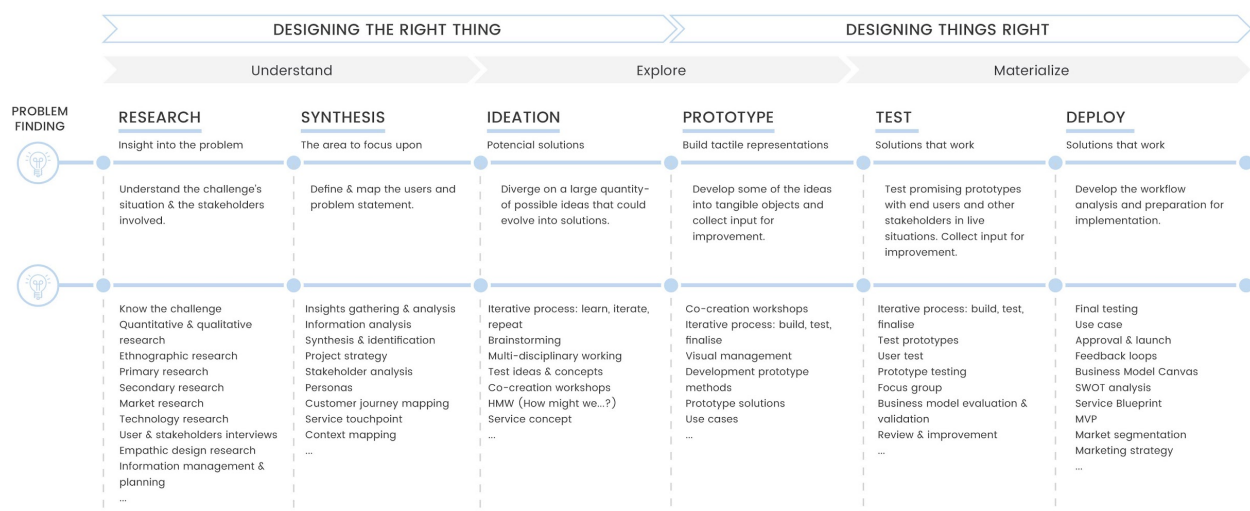
1. The stage and maturity level of the solution
2. Number of potential users
3. Criticality of interfaces
4. Degree of innovation

To assess the status of the solution it is essential to understand the level of maturity of the design, which we can divide into the following phases:

- **Research:**
 - o Goal: Understand the challenge's situation and the stakeholders involved.
 - o Solution maturity: concept or idea; primary research; market research.
- **Synthesis:**
 - o Goal: Define and map the users and problem statement.
 - o Solution maturity: understands end user and stakeholder; primary and secondary research; data analysis; market research.
- **Ideation:**
 - o Goal: Diverge on a large quantity of possible ideas that could evolve into solutions.
 - o Solution maturity: service concept; opportunity; strategy;
- **Prototype:**
 - o Goal: Develop some of the ideas into tangible objects and collect input for improvement.
 - o Solution maturity: tangible prototype; value proposition canvas.
- **Test**
 - o Goal: Test promising prototypes with end users and other stakeholders in live situations. Collect input for improvement.
 - o Solution maturity: prototype or MVP; value proposition canvas.
- **Deploy:**
 - o Goal: Develop the workflow analysis and preparation for implementation.
 - o Solution maturity: MVP or product; business model; pilot.

Figure 6 maps what needs to be validated at each level of maturity.

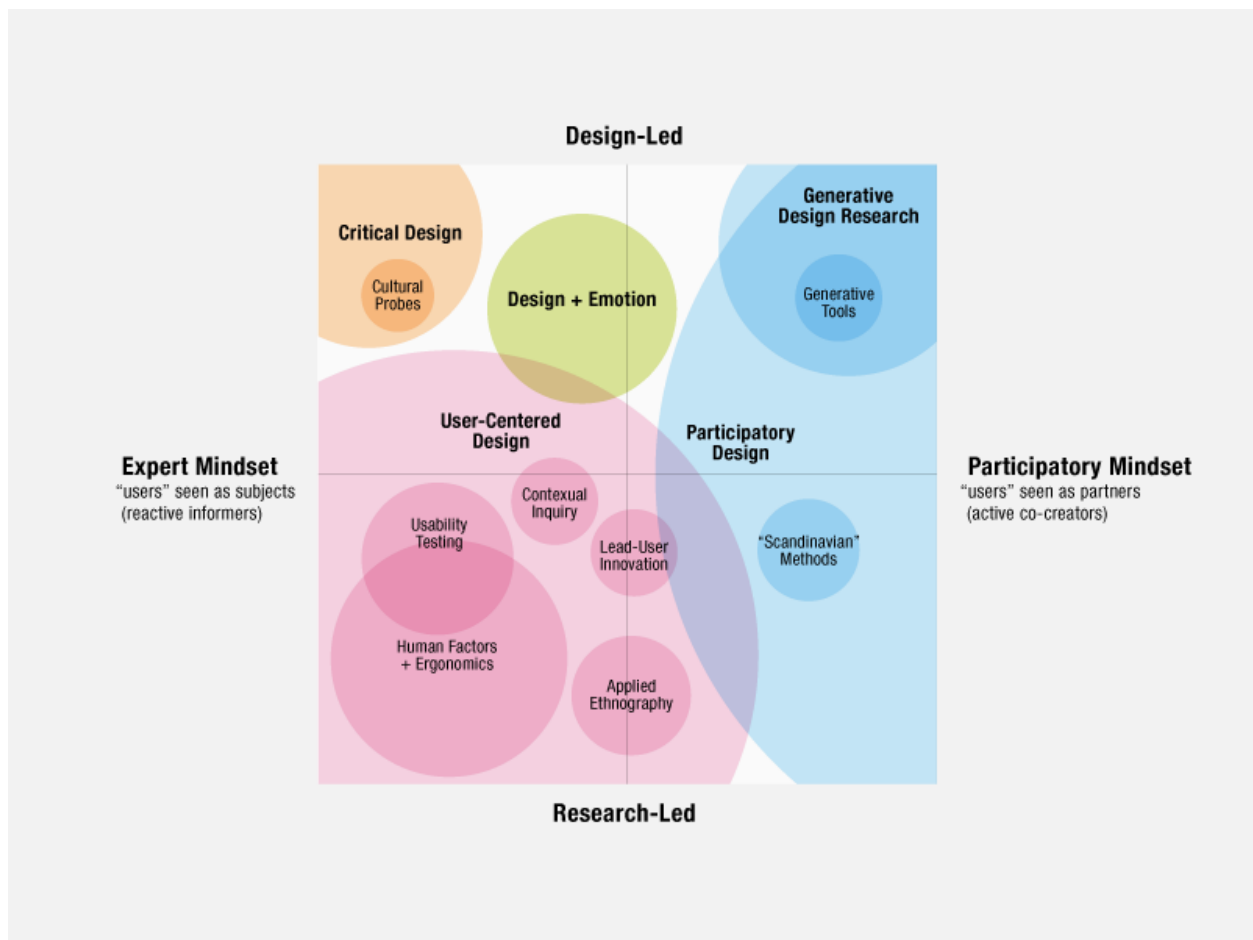
Figure 6. Process for User and stakeholder validation



The implementation of an empathic design approach, also known as user-centred design, during the research stage and throughout the innovation process is intended to support design teams in building creative understanding of users and their everyday lives (needs, motivations and frustrations).

Creative understanding is the combination of a rich, cognitive and affective understanding, and the ability to translate this understanding into user-centred products and services⁹. Sanders' topography of user research in design¹⁰ is a useful way to understand how the empathic design approach fits within the design research process. This involves using a design research map, shown in Figure 7, which can be used as a framework for organizing design research tools and methods between a focus on design-led or research-led, and with an expert or participatory mindset.

Figure 7. Topography of design research, adapted from "On Modeling"



We believe that it is important to use an iterative process for design and for validation. Iterative processes can be used at any phase of the design process, including when the solution or product has already been launched in the market and it needs improvements. There are several benefits ensured by iterative process:

- It allows for rapid resolution of misunderstandings within the project team and established clarity early in the development lifecycle;
- It gives the development team some certainty that their efforts are being focused on adding value for users;

⁹ Wright, P. C., & McCarthy, J. (2005). The value of the novel in designing for experience. *Future interaction design*, 9-30.

¹⁰ Sanders, L. (2008). On Modeling: An evolving map of design practice and design research. *interactions*, 15(6), 13-17.

- It brings out user feedback to ensure that system requirements meet user needs;
- It can help with users' relationships to show the evolution of a design rather than "dumping" a finished product on them;
- It provides regular testing which can provide a strong desired performance framework for acceptance testing;
- It allows for easy incorporation of "lessons learned" in the final product;
- It gives stakeholders better visibility of progress at each iteration.

3.1.1 Build innovation around experience

Innovation is primarily about people. Companies and organization need to have holistic thinking to be able to answer to increasing customer, citizen, and market needs and expectations.

Focusing on the nature of the experiences that an organisation creates for citizens provides the starting point for innovation. This requires putting emphasis on its users by thinking about the surrounding ecosystem and not just considering the product specifications and technologies. The focus shifts from the things people use, to what they do— their behaviours, activities, needs and motivations. By understanding and studying people's experiences, the focus isn't only on the obvious experience of "using the product", but on the series of activities that surround the context in which it is used.

A sufficient User and Stakeholder validation of the services, the platform, and the tools developed through the Project requires understanding the user motivations, across the multiple user groups, as well as the needs and beginning-to-end experience that those user groups will have.

3.1.2 Cultivating an innovation culture

Cultivating an innovation mind-set among all the stakeholders is essential to obtain an innovative, effective and efficient final service or product. Innovation practice is a collaborative process and people, including end users, internal and external stakeholders, with different backgrounds need to come together to make the process thorough, inclusive, and valuable to those involved. Planning innovation relies on the understanding of effective and compatible design methods allowing the stakeholders to practice design innovation collaboratively, reliably and repeatedly. An understanding of this process enables the development of a coherent and correct validation.

The following examples¹¹ correspond to desirable features that are prominent elements characteristic of the innovative project endeavour:

- Exploratory: the process mind-set must be led by exploration of knowledge, skills and abilities of each team member or stakeholder.
- Rational: the design methodologies should involve logical reasoning and experiments.
- Investigative: ability of questioning and evaluate the design methodologies to better fit to each innovative process.
- Creative: know-how, brainstorming, lateral thinking and analogies to solve problems and catch opportunities through an indirect and creative approach.
- Opportunistic: have a bottom-up approach throughout the process.
- Incremental: apply a critical thinking during the innovative process to be able to analyse, synthesize and evaluate the information gathered.
- Decision-making: create valuable judgements.
- Iterative: the design process is iterative. The service or product should be analysed and experimented repeatedly to arrive at a decision or a desired result.
- Transdisciplinary team: to be able to contribute with different knowledge and expertise.
- Interactive: cultivate a hands-on approach through the design team.

¹¹ Evbuomwan, N. F. O., Sivaloganathan, S., & Jebb, A. (1996). A survey of design philosophies, models, methods and systems. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 210(4), 301-320.

Several innovation methodologies which can be applied to support the development phase of the solutions:

- Service Design: the end goal of the innovation process is to create a service, product, or experience that people want (desirability), has real potential to become useful (viability), and can easily or conveniently be built in terms of technology (feasibility).
- Design thinking: the design phase is essential for identification of issues and solutions matching needs to market opportunities and customer value. This process was developed by IDEO and it's involves massive collaboration with all the stakeholders and frequent iterations of a solution. It has five very clear phases: Empathize, Define, Ideate, Prototype and Test. The end goal of the process is to create a desirability product, service, or experience that users want, has real potential to become useful (viability), and can easily or conveniently be built in terms of technology (feasibility).
- User Experience and Usability: to stimulate or improve an intuitive and easy usage of a product these methodologies encourage the removal of barriers, as well as they measure the emotional connection of the user.
- Participatory Design: Integrated and knowledge-based decision making during the innovation process highly depends on the involvement of the right stakeholders, which should be involved through co-design in different phases.

3.2 Stakeholder validation

Stakeholders are a primordial element of the development and validation phase. In the SynchroniCity project there are two core groups of stakeholders to be considered: internal (consortium) and external (local and international partners which participate in the ideation and implementation of the pilots). It is crucial to promote a strong engagement of Stakeholders in the design phase to:

- assess stakeholders needs and expectations, ensuring the end result is a reflection of real needs and priorities;
- an integrated and common vision for the solution;
- develop accountability and trust;
- motivating stakeholders for a long-term commitment ultimately leading to sustainability.

The validation processes are based on the needs and expectations of the stakeholders and users. This validation should occur with the internal stakeholders (primarily WP3 participants) in an iterative way during all the phases of development, and be conducted with the external stakeholders during the implementation phase.

3.2.1 Activities and outputs

The following validation activities will be held by partners involved in Task 4.3 and in WP3. As referred in the Chapter "Services and Applications" only main themes and services have been identified. A more concrete definition of the specific solutions will enable a more accurate choice of activities for each case, nevertheless we identify here the main activities suggested to validate:

- **Adaptability:** Referring to the service provider response to customer needs, requests and behaviour. This validation is required to assess the flexibility and adaptability of the Platform and services to different contexts and needs of the stakeholders, in order to ensure the that the solutions are attractive to new users and contexts, ensuring the future replication of the services. This will be done by checking, through an interview that compares service provider actions with the technique descriptions, if the service providers (WP3 theme leads) used the following techniques: Co-creation techniques, Customer research.
- **Usability:** A concept in user interface design that refers to how effectively and efficiently a user can interact with a user interface. Usability validation is required to report to the

service provider that they have taken the correct actions to ensure that the end solution/system is easy to learn, efficient to use; this is essential when considering the external stakeholders usage (which sometimes might be partially end users). This will be done through users' tests of the solutions administered in each RZ by the participants of T4.3: User satisfaction tests, User validation tests, Focus groups, concept tests.

- **Stakeholders experience:** User experience is the emotional response the user has to a service and product. This validation is required because a focus on a deep understanding of stakeholders wishes, interests and needs would improve the commitment with the service and product. In order to be a meaningful and valuable stakeholders experience, the information must be useful, usable, desirable, findable, accessible and credible. This will be done by using the following techniques administered in each RZ by the participants of T4.3: Focus group, stakeholder tests, online test.
- **Value Co-creation:** Value co-creation creates value with, and for, multiple stakeholders through co-creation activities and ongoing interactions that lead to an innovative solution. By involving all of the relevant stakeholders during the research journey, the project is supplied with genuine insights of the end users' needs and values. This validation is required because the implementation of value co-creation throughout the project ensures meaningful interactions and enriched end user experiences. Openness and understanding is needed to work across different sectors and cultures with flexibility, fairness and transparency being essential to the value co-creation process. This will be done through the following activities administered in each RZ by the participants of T4.3: Iteration design, Co-creation activities, Insights validation, Research validation, Secondary research.

3.3 User validation

Synchronicity project will develop several services and IoT pilots to be used by citizens, Municipalities and developers, amongst others, as end-users. To assess user interests and needs, the solutions must be developed with the end-users' involvement as well as to have their validation in different phases of the project.

In the pilot solutions developed in WP3 by the RZ described in the chapter "Services and Applications" the final users are mainly citizens, nevertheless, especially in the case of the Policy Community Suite the administration, namely the Municipality plays this role. Therefore, in this case, in addition to the citizens and visitors' validation it is essential to involve the different municipal departments and municipal companies managing the city. In the case of the technical development, in particular in what concerns the WP5 Open Call, developers are the final users of the Architecture developed, prior to developing, themselves other services.

3.3.1 Activities and outputs

The main activities related to user's validation will be developed by WP3, 4 and 5 (in the case of the Open Call), partners. These aim at validating the solutions from an ideation phase to the deployment phase while involving end-users in co-design and co-creation processes as well as testing activities depending on the goals, themes and maturity of each solution. Table 9 points out a set of methods to be applied, providing a description and the level of maturity of the related solution/implementation.

Table 9. User and stakeholder validation methods

Methods	Description	Maturity level of solution
Focus group	Present the concepts to a small focus group and watch how they react.	Concept or prototype

Methods	Description	Maturity level of solution
Concept tests	Moderated tests ask participants to think aloud as they interact with your prototype or artefact.	Concept or prototype
Hallway testing	Get feedback from people close by who. Colleagues in other departments can provide quick, initial reactions on your concepts, for instance.	Prototype
Online tests	Use of online services that provide feedback on concepts and prototypes, for example userbrain.net.	Prototype or MVP
Diary study	A diary study is a research and validation method used to collect qualitative data about user behaviours, activities, and experiences over time.	Concept, prototype or MVP
Explanatory video	Create a video explaining your service and circulate it on the Internet. Measure interest via traffic and response rates.	Concept
Landing page	Announcing the fictitious launch of your proposed service. Able to measure traffic to the website over a given period of time, the number of signups, and responses to our survey.	Prototype or MVP
Prototype testing	Simulate a functioning version of the concept and solution. Test this with potential users and measure concrete aspects such as task completion and satisfaction.	Prototype or MVP
Concierge service	Starts with a simulated version of the service. Invite a very limited set of potential users to sign up, and then provide the service manually.	Prototype or MVP
Limited product release	Create a version of your service with only one or two functioning features. Measure the success and appeal of those features.	MVP
Remote usability tests	Remote usability testing allows you to get customer insights when travel budgets are small, timeframes are tight, or test participants are hard to find.	Prototype or MVP
Usability testing of icons	To ensure that people understand the meaning and purpose of icons, conduct multiple types of tests at various stages of the product-development cycle.	Prototype
A/B testing	Two different versions of a design on the world and see which performs the best.	MVP
Out-of-box testing	Out-of-the-box testing is a testing method in which users are observed unpacking a product	MVP

Methods	Description	Maturity level of solution
	from its box. Out-of-the-box testing is useful in ascertaining how intuitive the set-up procedure for the hardware or software is for the user.	
Eye tracking	Eye tracking research to shows where participants look and what page elements, navigation cues, or content their eyes fixate upon. This allows product teams to find out definitively how noticeable and discoverable their designs and navigation systems really are.	MVP
Visual preference testing	A method that allows potential users to review and provide feedback on a solution's visual direction.	MVP
5-second test	A 5-second test is a usability test in which a participant is shown the user interface of a software application or website for five seconds. After the 5-second test, the participant is then asked what he can remember from the layout he has seen. This is a particularly useful method to see whether key visuals or call-to-action buttons have the right impact on the user.	MVP

3.4 Engagement validation

In addition to Users' and Stakeholders' validation, and in order to build a sustainable solution, one of the most relevant elements to consider is user and stakeholder engagement.

3.4.1 Activities and outputs

To ensure user's engagement several validation techniques can be deployed:

- **Empathy:** Empathy is defined as a skill to understand and sense other people's feelings and thoughts without having had the same experience. In the context of urban service design empathic understanding means a designer will relate to the user by gaining an emotional connection and understanding of certain experiences. This validation is required because using an empathic approach allows a service designer to relate and get closer to the user, their lives and experiences, not just knowing about the user. This approach will increase the engagement of the user with the product; reporting back from the validation will allow follow-up services to take into account failings. This will be done by checking, through an interview that compares service provider actions with the technique descriptions, if the service providers used the following techniques: Research techniques, Secondary research, Ethnography techniques, Deep interviews, Diary research technique.
- **Interaction quality:** Trust and co-operation: Trust and cooperation are two key values required during engagement with citizens and stakeholders. The involved actors also need to build a trust relationship with the solution. This validation is required to ensure permanence and usage of the tools and solutions from the users side; the output of this validation will be fed back to the service providers to alert them in order to make changes.

This validation will be done by checking, through an interview that compares service provider actions with the technique descriptions, if the service providers used the following techniques: User Validation, Stakeholders validation.

- **Co-creation:** Co-creation is one of the cornerstones for innovation. Individual knowledge and creativity are not enough to find user centred solutions to complex problems that most cities face. Co-creation involves relevant stakeholders and it also provokes their creativity by using creative design thinking tools and methods. In this way, co-creation process generates an excellent result for service innovation. This validation is required because it is thought that having a participatory design point of view reduces risk of failure for the end-product and it can ensure the project is internally fulfilling the stakeholder engagement requirement as well as matching the user needs by involving users throughout the co-creation process. This validation will be done by checking, through an interview that compares service provider actions with the technique descriptions, if the service providers used the following techniques: Iteration design, Co-creation activities.
- **Adoptability:** Adoptability refers to the service's eligibility for quick and sustainable adoption from the Users. This validation is required because high quality design will be a pre-condition to the aim of getting widespread citizen and city employee adoption of the new services. This validation will be done by checking, through an interview that compares service provider actions with the technique descriptions, if the service providers used the following techniques: Adoption validation with minimum viable product (MVP).

4 Replication validation

4.1 Approach

This section will focus on defining the replication directives for the validation methodology that will be applied in the SynchroniCity framework.

Replicability is one of the key concepts to assess the SynchroniCity framework and the eventual DSM. Therefore, one of the project objectives, PO3, is to provide a homogeneous environment across the RZs, with replicable IoT-enabled citizen-centric services.

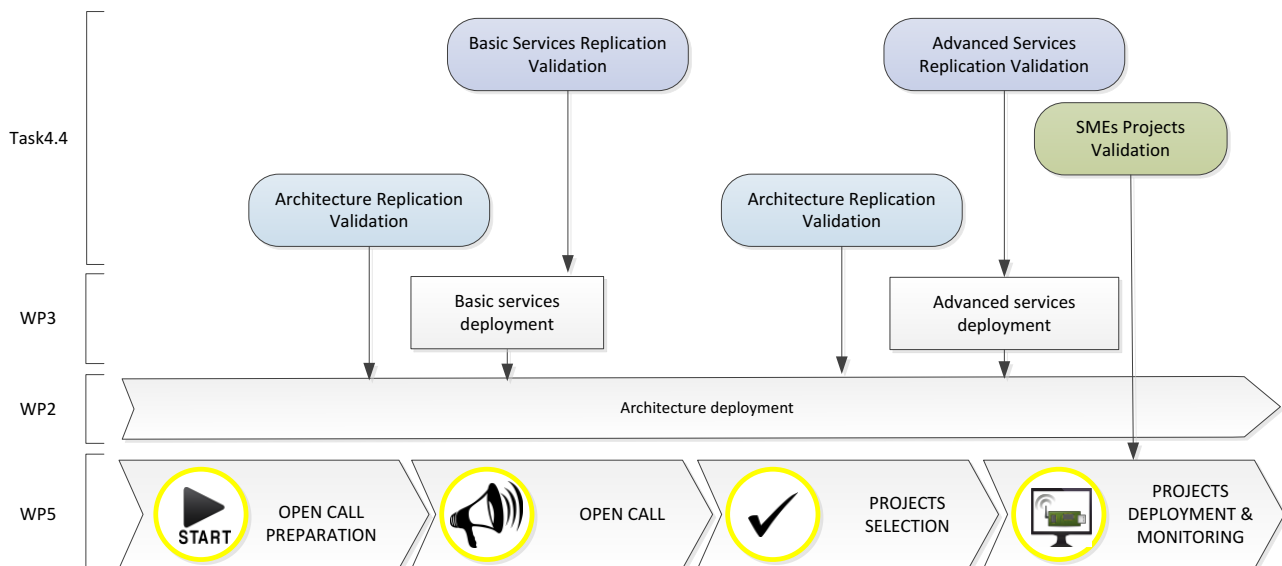
For that purpose, when addressing replication validation, two different approaches will be adopted:

- Architecture replication, which will assess the capability of SynchroniCity architecture replication from one city to another, including new sites or cities.
- Services and applications replication, referred to the ability of the SynchroniCity framework to replicate services and applications across the different RZs. It will focus on the services defined in WP3 and on SME projects coming from the WP5 Open Call.

In addition, subtask 4.4.1 is responsible for assessing both the replicability and the fulfilment of SynchroniCity guidelines, which are established in WP1, by the SME's projects supported by the Open Call. A subsection for SME's project validation describes this.

Replicability validation, addressed by Task 4.4, starts at M13 and lasts almost up to the end of the project. **When** the replication validation process is going to be applied is closely related with the Open Call steps developed in WP5 and the services deployment calendar established in WP3. Figure 8 represents the main steps in the replicability validation process.

Figure 8. Replicability validation process



The validation process will be carried out within all applicable RZs (**where**), as in the architecture validation, meaning those RZs that have concrete services or projects deployed. These tasks will be carried out by several different partners, including: architecture validation will be led by Task 4.4 partners involved in WP2, supported by those who are responsible for deploying the architecture in each RZ, services will be validated by consortium partners involved in WP3 (**who**). In the case of

SMEs projects, depending on the scope of the project the validation can be carried out by WP2 or WP3 involved partners.

4.2 Architecture replication validation

4.2.1 Objectives

The goal of the architecture replication validation is to check the capability of the RZs to mimic the SynchroniCity framework and integrate it within the legacy components (**what**).

Task 4.4 will define the approach to be followed when tackling architecture replication validation, focused, among others, on the adoption of common data models, AAA, northbound, southbound APIs and data monetization framework.

The main criteria that will be followed for assessing the architecture replicability are resumed in Table 10.

Table 10. Replicability of SynchroniCity's architecture validation criteria

Criteria	Methodology
Degree of implementation	Check the degree of implementation of SynchroniCity Architecture in the RZs: - Adoption of common data models - AAA - Northbound and southbound APIs - Data monetization framework
RZ's feedback	Collect experiences from the RZs to qualitative (and eventually quantitative) assess the design carried out
Specifications	The solution must provide the guidelines to replicate SynchroniCity Architecture

The degree of implementation of SynchroniCity platform at each one of the RZs has to be validated, with special focus on the integration with the legacy components. The correct implementation of interoperability points (northbound, southbound, APIs, data models) is essential for supporting common services, applications and for the incorporation of new IoT devices. This process will be based on the guidelines for the replicability of the architecture established in WP1¹² and architectural specifications adopted in WP2¹³.

The feedback from the RZs will be crucial to find potential interoperability issues, which can be used by WP2 to improve the replicability capacity of the reference architecture.

Complete and clear specifications are critical for reaching the objective of a DSM. It's required that proper guidelines or "how to" are provided oriented to two different stakeholders: the information about the interoperability points of the architecture is required for those stakeholders interested on providing services or additional infrastructures. A complete specification will also need to be provided, with a focus on those cities that would like to replicate SynchroniCity framework. These

¹² D1.3 Guidelines for SynchroniCity architecture, SynchroniCity, 2017

¹³ D2.1.1 Reference Architecture for IoT Enabled Smart Cities, SynchroniCity, 2017

specification documents have special relevance for WP5 for the correct development of the Open Call. For this reason, they must be evaluated before the Open Call projects deployment phase.

The processes and mechanisms to assess the exposed criteria will be detailed in Task 4.4.

4.2.2 Activities

Task 4.4 will validate, at each RZ, the adoption of the standards and technologies required to support the SynchroniCity framework, identified and detailed in WP2 during the design of the architecture.

To assess the integration of legacy components and the interoperability points of SynchroniCity platform, the architecture replication validation process will be carried out within all the RZs (**where**), with the support of the RZs technical partners (**who**).

The validation process will be carried out in an iterative way at different stages of the project, as shown in Figure 8, related with the services deployment (**when**), mainly:

- Before basic services deployment (WP3).
- Before advanced services (WP3) and SME's projects (WP5) deployment period.

4.2.3 Expected outcomes

The initial outputs of the activities will be a set of metrics and KPIs that will feed WP2 for improving SynchroniCity framework but also WP6, for evaluating the impact and sustainability of the project. The validation activity will guarantee the impact of the project, considering the replication capacity of its architecture, as well as the replicability of the services.

This validation will guarantee the replication and integration capabilities of the SynchroniCity framework required by the envisioned DSM. The assessment on the SynchroniCity architecture replicability will be provided in deliverable D4.4 in M32.

4.3 Services and application replication

4.3.1 Objectives

In the case of services and applications, Task 4.4 will evaluate the degree of applicability of each service or application developed in WP3 to different RZs.

The main evaluation criteria to be tackled are exposed in Table 11 (**what**). Task 4.4 will further develop the application of these criteria.

Table 11. Replicability of services and applications validation criteria

Criteria	Methodology
Degree of application	Degree of applicability of the service in the RZs
Feedback from services and application implementation	Collect experiences from the services and applications implementations (WP3) to qualitatively (and eventually quantitatively) assess the design carried out
Specifications	The solution must provide the guidelines to develop services and application on SynchroniCity Architecture

The applicability of a service to different RZs has to be measured to check the replicability of the service. It is a fact that not all cities around the globe, not even not all RZs involved in the consortium, rely on the same collection of experience, infrastructure, abilities or resources, therefore a thorough analysis exercise must be conducted to agree upon a fair judgment with respect to the chance to replicate a certain service in diverse places. In addition, the experiences recollected from the implementation process will be a valuable feedback to improve the architecture replicability (WP2) and the second wave of services (WP3/WP5).

Finally, it's important for the evolution and sustainability of the project to have a *"how to"* specification with the guidelines and standards to follow in the development of new services/applications on top of the SynchroniCity framework.

4.3.2 Activities

This task will define the approach to be followed when tackling Services and Applications Replication validation.

The validation process will include all RZs (**where**) grouped by the application areas defined in WP3:

- Human centric traffic management: Eindhoven, Antwerpen, Milan, Carouge
- Multimodal transportation: Porto, Santander, Milan, Helsinki
- Community policy: Porto, Manchester

Services integration and replication validation will be carried out in Task 4.4 by WP3 partners involved in it, along with the RZs implicated in the different application areas (**who**).

Validation will be carried out in an iterative way, taking into account the stages of WP3 (**when**). Considering that the services and applications for the RZs will be provided in a two-stage process in WP3, the timeline for validating their replicability will be the following:

- After the first version of the service's prototypes are developed (D3.1 is expected for M14), the validation of the adoption of such services will take place, to serve as a reference for the deployment of the second version of the service prototypes, planned for M25. The outcomes will be provided to WP3 to support the development of the advanced version of the cities services.
- In M25, D3.6 is expected, providing an advanced version of the services to be provided by the RZs. At this stage, the replicability of the services will be tested again, checking the improvements and providing the corresponding report.

4.3.3 Expected outcomes

The evaluation report will generate a set of metrics and KPIs that will feed WP3, providing feedback of the basic services replicability to support the development of the advanced version of the cities services.

The outcomes will provide information about the interoperability with the APIs and data models that will be helpful for WP2 to improve the architecture and, in addition, for WP5, advising the Open Call and SMEs projects.

Finally, WP6 will also take advantage of this evaluation reports, including Task 6.4 for evaluating the impact of the project. The validation activity will guarantee the impact of the project, considering the replicability of the services.

The assessment on the services and applications replicability will be provided in deliverable D4.4 in M32.

4.4 SME project integration

4.4.1 Objectives

Subtask 4.4.1 will be responsible for assessing the alignment of the different components, enablers and services carried out in the SMEs projects to the main SynchroniCity guidelines established in WP1¹⁴ and architectural specifications adopted in WP2¹⁵.

Table 12 states the main criteria that will be evaluated for assessing the SMEs projects (**what**).

Table 12. Replicability of SME project integration validation criteria

Criteria	Methodology
Alignment with SynchroniCity guidelines	Assess the fulfilment of the main guidelines and architecture specification of SynchroniCity: - Adoption of common APIs - Interoperability with legacy components
Degree of application	Degree of applicability of the project in the RZs
SME's Feedback	Collect experiences from the SME's projects integration to qualitatively (and eventually quantitatively) assess the overall architecture design

One of the key activities is to assess the fulfilment of SynchroniCity guidelines and specifications, for the adoption of common APIs, data models and interoperability with legacy components. The degree of applicability/ replicability of every particular project to different RZs will also be checked and evaluated, being this a crucial point to validate the project's concept and assure the platform sustainability once the project comes to an end.

Finally, to collect the experiences from the integration of the projects in the SynchroniCity framework during the different stages of evolution, such as the Open Call, will be an interesting input to evaluate the success of the project.

4.4.2 Activities

This section describes the approach to be followed when tackling SMEs projects integration validation in subtask 4.4.1

The development of this Task will be highly related with WP5 as it will follow the evolution of the SMEs projects selected in the Open Call, based on the report mechanisms that will be established in the Open Call text by WP5 (**when**).

The validation process will be carried out by Task 4.4 partners (**who**), and supported by the RZs **where** the project is deployed. The approach to be followed will be based on the procedures established in Task 4.2 for the technical validation of the services and of the architecture (**how**). See 2.3 for the details of those activities.

¹⁴ D1.3 Guidelines for SynchroniCity architecture, SynchroniCity, 2017

¹⁵ D2.1.1 Reference Architecture for IoT Enabled Smart Cities, SynchroniCity, 2017

4.4.3 Expected outcomes

The report performed with the results of the assessment of the SMEs projects will be a valuable input for the sustainability and the evaluation of the impact of the project (Task 6.1 and Task 6.4 respectively).

The technical validation of the SMEs projects will be provided in deliverable D4.5 in M32.

5 Market validation

5.1 Approach

This chapter will focus on the description of the metrics identified for validating the Synchronicity market, which will include four main areas directly linked to the approach:

1. architecture adoption
2. service framework adoption
3. applicability and potential of the Synchronicity business model
4. sustainability and replicability

When validating the potential market for Synchronicity, it has to be considered that the different areas mentioned above are strongly interdependent and require the collaboration of different work packages within the project. This activity is linked to the definition of the “Advanced data marketplace mechanism” in WP2 and specifically in Task 2.3, expected to be deployed by M20. Indeed, Task 2.3 will provide an analysis of the innovative marketplace mechanisms for developing a common solution and reducing the current barriers in sharing open data. The adoption of a marketplace framework will constitute the most important objective and result to be achieved at the end of the Synchronicity project, as it is the main goal expected by the EC.

At technical level, the adoption of the architecture by the RZs will be ensured by WP2 in Task 2.5. The cities will collaborate to integrate and adapt their existing infrastructures, platforms and systems to the principles and APIs of the Synchronicity architecture. Its adoption will be monitored by WP1 in Task 1.3 throughout the whole duration of the project, recording progress on the activities and the needs of the cities.

The deployment and operation of the service framework will be carried out within WP3 in Task 3.4. The service pilots will be defined in accordance with the cities and the WP3 Task Leads, as services developed by the RZs, as well as the solutions developed by the SMEs that apply to the Synchronicity open call. For each RZ a specific documentation on the deployment and operational characteristics will be provided, which will serve as baseline for the validation of the service framework adoption.

A detailed analysis of the relevant market for Synchronicity will be exploited in WP6, in Task 6.1 in M12, along with the definition of the Synchronicity business model. It is clear that an analysis of the IoT market is the necessary baseline for identifying which are the current challenges in terms of business models and market size, the effective needs of the end-users and how to boost the innovation opportunities for the SMEs that will contribute to services’ development, through the SynchroniCity open call and in strict collaboration with the RZs. The analysis of the market shall consider the three themes exploited by the project for the use cases:

- Human-centric traffic management
- multimodal transportation
- community policy suite

Sustainability is strictly connected with the replicability of the Synchronicity services on the market. For this reason, in Task 6.1, an approach to attract additional external investments for the cities involved in the project will be investigated.

Starting from these considerations, we have here defined a process and the specific indicators for validating the real effectiveness and sustainability of the DSM that SynchroniCity is aiming to develop. The market validation should consider not only the technical aspects, but also the social and economic enablers on which the project will build upon to increase the confidence of businesses and individuals in sharing and consuming IoT based data sources, thus reducing the barriers for integrating tools and provide a single marketplace for different smart cities in Europe and beyond.

5.2 Architecture adoption

5.2.1 Activities

The adoption of the Synchronicity architecture will be evaluated by verifying that the actual implementation supports all the cities and the uses cases defined in WP3. To achieve this objective, it is very important to first identify the stakeholders within the cities. A first attempt of providing this list has been exploited by WP1 in Task 1.3 by collecting information via the first version of the monitoring framework template that has been filled in by all the RZs from M4 to M8. The stakeholders are associated to the main themes selected by each city, and are reported in Table 13.

Table 13. Description of the stakeholders of the cities

City	Themes	Stakeholders
Antwerp	Human-centric Traffic Management and Multimodal Transportation	Smart mobility-services' providers, public transport companies, mobility providers, government academic institutions, accelerators, students' networks and other city departments involved in developing co-creation activities
Carouge	Human-centric Traffic Management and Multimodal Transportation	City officials in Carouge, transportation police
Eindhoven	Human-centric Traffic Management and Multimodal Transportation	Traffic and environment department city of Eindhoven, service provider, owner of the sensors' network, regulators
Helsinki	Human-centric Traffic Management and Multimodal Transportation	transit operators
Manchester	Community Policy Suite	IoT companies, universities, accelerators and networks
Milan	Human-centric Traffic Management and Multimodal Transportation	Mobility department of the city of Milan, Municipal Police, Mobility Agency, Energy Provider, public and private transport operators.
Porto	Multimodal Transportation and Community Policy Suite	Transit operator, Land use regulation offices, municipality, universities, transport operator, municipality commissions, metropolitan area offices.

		IoT tech companies, universities, accelerator/networks.
Santander	Human-centric Traffic Management and Multimodal Transportation and Community Policy-making	Service and consumer providers, deployment owners and service providers, end users, outsourced service providers, utilities IoT tech companies, academic institutions, accelerators and networks

A criterion for evaluating the architecture adoption is the *innovativeness level* of the solution itself, which will ensure that the same technical level is provided to each city. There are different methodologies that will be used to assess the architecture adoption against this criterion, such as perceptual and positioning mapping and benchmarking.

- Perceptual mapping will help to visually display the perceptions of customers or potential ones.
- Position mapping will analyse the competitive position against other solutions.
- Benchmarking will serve to understand not only the level of innovativeness, but also the inventiveness of the solution.

Considering that the customised IoT service prototypes for the RZs will be provided twice during the duration of the Synchronicity project in WP3, and more in detail in Task 3.3, the timeline for validating the Synchronicity market is the following:

- In M14 in D3.3.1, the first version of the service' prototypes will be developed, as well as the validation of the adoption of such services from M14 to M18 (stage 1), to serve as a reference for the deployment of the second version of the service prototypes, planned for M25.

5.2.2 Objectives

The market validation process, compared to the other validation systems presented in this document, will specifically focus on the sustainability and replicability of the Digital Single Market developed by Synchronicity. In detail, we will evaluate that the services developed within both WP3, through the use cases, and in WP5 via the Open Call with the SMEs are consistent and valuable for the market.

5.2.3 Expected outcomes

The *validation of the architecture implementation* and adoption will be exploited through test and reports with the stakeholders of the RZs, in order to verify if the implementation supports all the use cases and to ensure that the solutions deployed provide innovation to the Digital Single Marketplace. Innovativeness of the solution is the main factor to be assessed in terms of impact of the Synchronicity architecture adoption

5.3 Service framework adoption

5.3.1 Activities

The adoption of the service framework will be evaluated through four different criteria: feasibility of the business plan, broader market validation, time model, market research and analysis.

The methodologies relevant to perform business plan feasibility evaluation are the business model canvas, the financial business plan, the investments and sales strategy plan.

These methodologies altogether determine if the business idea is viable, including the income statement, the cash flow projection and the balance sheet of the business over 3 to 5 years.

The methodologies available to perform *broader market validation* are value network analysis and the stakeholder mapping.

The *time model* criterion is evaluated against test reports with the stakeholders.

For the *market research and analysis* criterion, statistical methodologies and questionnaires can be very useful to gather qualitative and quantitative data on the market niche or market segmentation in the different cities.

- In M14 in D3.3.1, the first version of the service' prototypes will be developed, as well as the validation of the adoption of the service frameworks from M14 to M18 (stage 1), to serve as a reference for the deployment of the second version of the service prototypes, planned for M25.
- In M25 in D3.3.2 a second version of the prototypes will be provided and validated from M25 to M29 (stage 2), giving the time to the RZs to deploy them by M32.

5.3.2 Objectives

The first criteria (*feasibility of the business plan*) will be used to ensure that the services are financially viable and that a business plan has been drafted for each city, to allow the solutions to continue to live following the ending of the project. Furthermore, this criterion enables those involved in T4.3 (**who**) to validate the profitability, strengths, risk and business opportunities of each service.

The *broader market validation* criterion verifies the level of usefulness and applicability of the commercial solutions developed. This also aims to assess the different commercial partners and their role within the RZs.

The *time model* criterion is relevant for verifying that the services life-cycle and times of development, prototyping and implementation is effective and efficacy, as well as not overlapping with other systems already in place in the RZs

The *market research and analysis* criterion is relevant to understand the acceptability and motivation of the potential customers of the services in all the RZs.

This validation process will provide a complete picture on the Synchronicity architecture and service framework adoption, along with an analysis of the potential impact of the services developed on the market.

5.3.3 Expected outcomes

The business model canvas helps to describe the rationale of how an organisation creates, delivers and captures value. More broadly, the different methods will generate a set of metrics and KPIs.

5.4 Applicability and potential of the SynchroniCity business model

5.4.1 Activities

The applicability and potential of the Synchronicity business model will be analysed first by considering the feasibility and applicability of the *business models* to verify that they are applicable for all the RZs and effective in terms of sustainability plans. This will happen through expert reviews, questionnaires with the RZs collected via the monitoring framework template, in WP1, and a SWOT Analysis conducted by those participating in Task 4.3 based on the Monitoring Framework data (**who**).

The second criterion will be the go-to-market strategy to define and select a target market to pursue, understand the market and the target audience, as well as provide a market segmentation. The methodologies relevant to perform such analysis are keyword analysis, Google Market Trends, Social chatter and Target profile (Persona).

To allow for assessment of the *marketing strategy* criterion each initial service should develop a marketing strategy plan, along with a digital marketing and communication strategy, which can then be validated by participants in T4.3.

The final criterion is the *revenue model*, the validation of which will be performed by participants in T4.3 through expert reviews and via a specific questionnaire that will be distributed to the cities through the monitoring framework template in WP1.

5.4.2 Objectives

Considering the feasibility and applicability of the *business models* to verify that they are applicable for all the RZs and effective in terms of sustainability plans.

The criterion of the *marketing strategy* is aimed to identify, anticipate and satisfy customer requirements and develop profitability, as well as basic, short-term and long-term activities in the marketing field.

The *revenue model* aims to verify the feasibility of the revenue model in terms of effectiveness for all the services deployed in the RZs.

This validation process will provide an analysis of the potential impact of the services developed on the market.

5.4.3 Expected outcomes

The work performed will generate a set of metrics and KPIs that will feed both WP4/WP6, and more in detail Task 6.4 for evaluating the impact of the project. The validation activity will guarantee the impact of the project, at business level.

5.5 Market sustainability and replicability for the Digital Single Market

5.5.1 Activities

This final area of the market validation metrics is probably the most complex to be analysed and will be done by exploiting 5 criteria: economic impact, service acceptance, uptake, competitors and human resources. The *economic impact* criteria is part of an holistic approach to validation which is ultimately meant to provide stronger business cases for investment in IoT infrastructure. The *service acceptance* criteria will be used to evaluate the different service acceptances in the cities and the implementation of the monitoring strategy. This process will be exploited via the monitoring framework template and the tools from WP1 and WP3 aimed at developing co-creation processes.

The same methodology will be used to analyse the *uptake* level of the services in each city, both at user and citizens' level. The capability to keep pace with *competitors* is another relevant criterion and to this scope there will be used the methodologies and tools from WP3 and WP6, Likert scale (self-evaluation), the positioning map, competitor analysis and benchmarking. The ultimate criteria is the *human resources* management to understand the business strategy and operation via a human resources plan.

5.5.2 Objectives

This validation process will provide a complete picture on the Synchronicity architecture and service framework adoption, along with an analysis of the potential impact of the services developed on the market. The main objectives of performing such a complex activity are:

- for the *Synchronicity consortium* to verify that both the approaches followed in terms of advanced data marketplace mechanisms exploited in WP2, and the services defined and deployed in WP3, are both consistent and valuable for the market
- for *internal and external partners* of the project, to ensure the replicability of the solutions developed on the Digital Single Market exploited by Synchronicity

5.5.3 Expected outcomes

The work performed will generate a set of metrics and KPIs that will feed both WP4/WP6, and more in detail Task 6.4 for evaluating the impact of the project. The validation activity will guarantee the impact of the project, both at business and sustainability levels, as well as the replicability of the services deployed in WP3.

6 Conclusion

Over the preceding sections, the approach to validation across a holistic range of areas has been described. The intended validation was categorised to create a holistic approach to project validation and these descriptions of the methodologies will ensure that the validation methods that are to be fully specified in each validation deliverable are consistent and founded upon these principles. This will then allow for validation to be conducted in a consistent manner across the RZs, where applicable.

In Section 2 Technical and Function the validation is shaped by the output of other SynchroniCity work packages. These define the requirements consistently across all RZs, while key times and personnel for validation activity are identified across the duration of the project, including:

- Basic functionalities in M12-17
- Compatibility with final SynchroniCity architecture in M25
- Compliance of RZs with requirements in M12-17
- Overall final compliance with requirements in M25
- The achievement of basic architectural requirements from M12
- The achievement of all architectural requirements from M25
- The status of the RZ components from M12
- The components in terms of requirements and interoperability in M24
- The compliance of the basic services with the technical and functional requirements in M17
- The compliance of the final services in M25.

Most of the above validations are suggested to be delivered in D4.2, while other results will be reported in aligned documentation in other WPs.

In Section 3 User and Stakeholder the validation is shaped by an understanding of the “innovation process” and the activities that allow for the successful delivery of innovation. The validation activities are primarily scheduled to occur concurrently with WP3 and WP5, and delivered by both partners in Task 4.3 and the partners in those WPs.

In Section 4 Replication the validation stems from PO3, requiring assessment of architecture replication, service and application replication as well as the SME projects fulfilment of the SynchroniCity guidelines. In terms of when activities will occur, this Task aligns with both WP2 and WP5 and will be carried out by partners involved in T4.4 but supported by WP2.

In Section 5 Market validation the rationale for the activities derives from the aim to have project services and SME projects to continue beyond the project in a sustainable way. Validation activities, carried out entirely within WP4, include:

- Service adoption, validated from M14 to M18
- Service framework adoption, validated from M14 to M18
- Service prototypes, validated from M25 to M29
- Applicability and potential, validated through a number of activities occurring throughout the project
- Economic impact, service acceptance, uptake, competitors and human resources, validated through a number of activities occurring throughout the project

Across these topics, a holistic validation should be delivered, the outcome of which should be an indication of if different aspects of the SynchroniCity project fit requirements and have the potential to long-term adoption.

APPENDIX

Project challenges

- 1) Scaling city platforms **without vendor lock-in**
- 2) Increasing the portability of IoT services **without city lock-in**
- 3) Developing services that really meet **citizens' needs**
- 4) Encouraging **IoT infrastructure investments** in cities
- 5) Quantifying the **socio-economic value of IoT** interventions in cities
- 6) Encouraging new **high-value data sources** beyond open data
- 7) Enable **agile policy-making** for cities
- 8) Enabling **new business practice** and stakeholder **incentivisation**

Project objectives

PO1: Establish technical foundations of DSM 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	PO2: Provide advanced marketplace enablers that increase the confidence of businesses and individuals in sharing and consuming IoT based data and other data sources. Enable the emergence of a richer marketplace and integration tools that lower barriers for participation	PO3: Establish RZ 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 RZs
PO4: Pilot IoT-enabled services that directly address citizen needs and enable breakthroughs in several high-impact areas, starting with adaptive traffic management, multimodal mobility, community-based policy making. Establish proof-points of the proposed marketplace mechanisms for others to follow	PO5: 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	PO6: 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 market place
PO7: 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 tools that allow tracking and monitoring of the effectiveness during pilot periods and beyond.	PO8: To provide insights into new business model opportunities enabled by the market place through the generation of secondary revenue streams from IoT infrastructure investments and enabled multi-sided platform eco-system constellations	PO9: 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

Project KPIs

	KPI	Description	Indicator unit	Expectations
Social innovation	Citizen Centred	Number of users of the services (in all the pilots)	#	350000
	Awareness impact	Percentage of people in the target group that have been reached and/or are activated by the project	% of people	75%
	Perceived value from the citizens	Perceived value for the end users and citizens involved	Surveys based in Likert scale (% of surveys with average to good results)	>= 70%
	Quality of life	Perceived increment of the quality of life of the citizens involved	Surveys based in Likert scale (% of surveys with average to good results)	>= 70%
Access to services	Service implementation	Number of services implemented during the project lifecycle.	#	20
Governance	Involvement of the city administration	The extent to which the local authority is involved in the development of the project, other than financial, and how many departments are contributing (number of	#	4

	KPI	Description	Indicator unit	Expectations
		departments involved in each city)		
	Perceived value from the decision makers	Perceived value for the local government and decision makers involved	Surveys based in Likert scale (% of surveys with average to good results)	>= 75%
Innovation	IoT connected devices	Number of IoT connected devices implemented during the project lifecycle in all the pilots	#	10000
		Total number of IoT connected devices by the end of the project, including previously installed	#	100000
	Open data sets	Number open data sets in use, in all the pilots	#	70
	Quality of open data	The extent to which the quality of the open data produced by the project was increased	Surveys based in Likert scale (% of surveys with average to good results)	>= 65%
	Apps developed	Number of developed apps, in all the pilots	#	30

	KPI	Description	Indicator unit	Expectations
	Improved interoperability	The extent to which the project has increased interoperability between infrastructures, in all the pilots	Surveys based in Likert scale (% of surveys with average to good results)	10
Local eco-system involvement	Participatory governance	Share of population participating in the service definition	% of people	>= 0,3%
	SME involved	Number of SME involved in all the process in all the pilots	#	100
	Partners engagement	Number of local ecosystem partners involved in the project during its lifecycle, in all the pilots (SMEs, creative hubs, citizen organisations, etc.)	#	200
	Local Job creation	Jobs created by the project	#	60
Safety	Data Privacy	The level of data protection by the city - users perception on security levels. Alternatively - PIA approach – privacy by design.	Surveys based in Likert scale (% of surveys with average to good results)	>= 90%
Replication and Scalability	Replication potential	Number of replicated services during the project lifecycle.	#	4

	KPI	Description	Indicator unit	Expectations
	New follower city members/interested	Number of new follower cities or interested decision makers	#	8
	Beyond the zone	Number of cities which have deployed services beyond the initial RZ	#	5
	Beyond the sector	Number of new sectors enriched with services beyond those covered by the base applications	#	3

Architectural requirements

The requirements presented in the next paragraphs are described using the following set of attributes:

Title	<i>The title of the requirement.</i>
Category	<i>A high level classification of the requirement.</i>
ID	<i>The unique identification code for the requirement.</i>
Requirement Type	<i>Typology of the requirement:</i> <i>Functional: it is a requirement that expresses a functionality of the platform that will be directly used by a user (human or external system).</i> <i>Non-Functional: this type of requirement is related with platform features that are not specific behaviours or functions, such as performance, security and interoperability.</i>
Requirement Description	<i>The description of the requirement.</i>
Rationale	<i>Motivations that justify the need for the requirement in the context of the project.</i>
Priority	<i>The priority level for the implementation of the requirement:</i> <i>High: the requirement has high priority and has to be implemented in the first version of the platform.</i> <i>Medium: the requirement has medium priority and should be implemented in</i>

	<i>the final version of the platform.</i> <i>Low: the requirement has low priority and its implementation is optional.</i>
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Table 14: Generic template for requirements description

A1.1 System Requirements

Title	Container technology				
ID	SR-MODULARITY-01	Category	Decoupled & distributed components	Priority	High
Requirement Description	The system should be based on a modular architecture design.				
Rationale	Services and components should support deployment through container technology, which will increasing the chances of services being adopted by cities. This also reduces the risks associated with deployment, and can greatly improve the development lifecycle.				
Requirement type	Non-Functional				

Title	Use of publically accepted and open standards				
ID	SR-INT-OPEN-01	Category	Interoperability & Openness	Priority	High
Requirement Description	The system should be based on open and standard components.				
Rationale	The architectural components must be able to work together without jeopardizing the future. The system must use as many publically accepted standards as possible for communication and exchanging data; e.g., gateways and APIs might act as glue between those architectural components. Examples of open standards can be XML, json, SOAP or REST.				
Requirement type	Non-Functional				

Title	Horizontal and vertical scaling
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ID	SR-SCALABILITY-01	Category	Scalability	Priority	High
Requirement Description	The system should provide scalability to support large-scale IoT deployments.				
Rationale	The system should be flexible and responsive to evolving needs by considering both horizontal and vertical scalability.				
Requirement type	Non-Functional				

Title	Flexible support of new and legacy components				
ID	SR-LEGACY-01	Category	Legacy Compatibility & heterogeneous landscape	Priority	High
Requirement Description	The system has to facilitate the reuse of existing deployed devices.				
Rationale	Cities have to maximize the use of legacy wired/wireless infrastructures providing support to IoT based services and efficient (re)use of already available assets.				
Requirement type	Non-Functional				

Title	IoT Devices management				
ID	SR-LEGACY-02	Category	Legacy Compatibility & heterogeneous landscape	Priority	High
Requirement Description	The system has to allow to access/manage heterogeneous devices through a single common framework				
Rationale	Offer a uniform way to access to the different devices accessible in the marketplace is needed to overcome interoperability problems and facilitate the access reducing the need to deal with heterogeneous technologies				
Requirement type	Functional				

Title	Self-healing and robust system				
ID	SR-ROBUSTNESS-01	Category	Resilience to failure & Robustness	Priority	High
Requirement Description	The architecture must be resilient to failure				
Rationale	Taking into account that components might fail and communications be affected, it should provide a self-healing system, including redundant links that cover breakdowns. We should consider that most of the IoT technology has not yet reached a maturity level free from issues. Moreover, the interaction among many different types of components (e.g., sensors, network, wireless technology, data store, servers) from different actors could generate problems.				
Requirement type	Non-Functional				

Title	Real-time user experience				
ID	SR-PERF-01	Category	Performance	Priority	High
Requirement Description	The system should guarantee a real-time user experience.				
Rationale	Users should be able to responsively interact with the system, discover new available assets at run time. Assets provided by data producers should be available for fruition in compliance with their SLA.				
Requirement type	Non-Functional				

Title	Operational				
ID	SR-PERF-02	Category	Performance	Priority	High
Requirement Description	The system should be 24/7 operational and has a close to zero maintenance windows.				
Rationale	A continuous integration and delivery possible for each element in the architecture, automated testing to reduce regression and guarantee quality should support the system to be 24/7 operational and has a close to zero maintenance windows (software upgrades, firmware upgrades).				

Requirement type	Non-Functional
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Title	Usage monitoring				
ID	SR-MONITOR-01	Category	Monitoring	Priority	High
Requirement Description	The system has to provide advanced data usage monitoring functions.				
Rationale	This function is necessary in order to enable other marketplace services (usage statistics, revenue models, technical management).				
Requirement type	Functional				

Title	User Feedback collection				
ID	SR-FEEDBACK-01	Category	Feedback	Priority	High
Requirement Description	The system has to provide user feedback management for the different assets published on the marketplace				
Rationale	Feedback, rating and reputation mechanism are useful in order to facilitate the asset selection to the end users.				
Requirement type	Functional				

Title	IoT integration				
ID	SR-COMM-01	Category	Communication	Priority	High
Requirement Description	The system should be able to handle different IoT protocols				
Rationale	Communication in IoT can happen between the sensor/actuator and the gateway or between the gateway towards the platform or in some case (e.g., NB-IoT, LTE, etc.) directly from sensor/actuator to the platform. Communication with the sensor to the gateway (when wireless) is possible in numerous ways. At this moment a clear standard is not defined yet, thus, the platform should be able to handle different protocols (e.g., LoRa, 802.15.4, NB-IoT, WiFi, LTE, GPRS, etc.) and be flexible to incorporate future				

	changes.
Requirement type	Non-Functional

Title	IoT communication patterns				
ID	SR-COMM-02	Category	Communication	Priority	High
Requirement Description	The system has to facilitate the support of different communication patterns.				
Rationale	When new components are selected, they should comply with communication patterns such as: 1) <i>Telemetry</i> where communication flow is one-way from IoT device to gateway; 2) <i>Inquiries</i> , where requests from devices looking to gather required information or asking to initiate activities, for example devices having their own business logic need input from a central server; 2) <i>Commands</i> , where system provide execution commands to a device or a set of devices to perform specific activities; 4) <i>Notifications</i> where information flows from other systems to a device or a group of devices by sending a broadcast message such as a <i>time-sync message</i> .				
Requirement type	Non-Functional				

A1.2 Marketplace Requirements

Title	Marketplace Access				
ID	SR-MKTPLACE-01	Category	Marketplace	Priority	High
Requirement Description	The System has to provide a marketplace in which users are able to register and sign in with different roles. The system shall provide access management, allowing for easy granting and revocation of rights and privileges to the platform while restricting access to unauthorized users.				
Rationale	The System has to allow the participation of all the actors interested in the digital single market.				
Requirement type	Functional				

Title	Asset publication procedure
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ID	SR-MKTPLACE-02	Category	Marketplace	Priority	Medium
Requirement Description	The system has to provide a validation procedure to be followed in order to publish assets in the Marketplace.				
Rationale	The marketplace provider wants to ensure the quality of published resources (e.g., in terms of documentation, availability, completeness).				
Requirement type	Functional				

Title	Flexible revenue and pricing models				
ID	SR-MKTPLACE-03	Category	Marketplace	Priority	High
Requirement Description	The system has to provide different assets (e.g. data/service/application) and usage revenue models (e.g., pay per use).				
Rationale	The marketplace should support a dynamic ecosystem in which providers can establish various business models.				
Requirement type	Functional				

Title	Asset catalogue				
ID	SR-MKTPLACE-04	Category	Marketplace	Priority	High
Requirement Description	The System has to provide a marketplace in which it is possible to publish and search for different assets: services, data, providers and applications.				
Rationale	Different types of providers (of data, services, applications) have to be visible on a large audience in order to provide their assets in the digital single market.				
Requirement type	Functional				

Title	SynchroniCity compliance policy validation				
ID	SR-MKTPLACE-05	Category	Marketplace	Priority	Medium
Requirement Description	The System has to provide a set of SynchroniCity compliance policies for the developed solutions and has to be able to validate them inside the marketplace.				
Rationale	Cities need to know if a solution, developed for another city/domain, can be adopted/reused quickly and without much customization efforts.				

Requirement type	Functional
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Title	Asset request procedure				
ID	SR-MKTPLACE-06	Category	Marketplace	Priority	Medium
Requirement Description	The system has to provide a procedure for requesting assets to be available in the Marketplace.				
Rationale	Cities and citizens want to publish request for assets not already available in the Marketplace.				
Requirement type	Functional				

Title	Marketplace transparency				
ID	SR-MKTPLACE-07	Category	Marketplace	Priority	Medium
Requirement Description	The system has to operate in a transparent, fair and open way.				
Rationale	Cities should consider citizens' trust as a key success factor, providing transparency of city operation, by publishing availability of services and decision making. Cities should be explicit on the definition of purpose and restriction regarding IoT data collection.				
Requirement type	Non-Functional				

Title	Marketplace peering				
ID	SR-MKTPLACE-08	Category	Marketplace	Priority	Medium
Requirement Description	The system has to allow peering capabilities among different Marketplaces.				
Rationale	Cities want to federate their marketplaces, providing a (sub)set of functionalities in accordance with their governance policies.				
Requirement type	Functional				

A1.3 License and Policies Requirements

Title	Data licenses definition				
ID	SR-LICENSE-01	Category	License	Priority	High
Requirement Description	The system should allow data providers to define different usage licenses for data sources/datasets published on the marketplace.				
Rationale	The marketplace should support a dynamic ecosystem in which providers can establish various business models.				
Requirement type	Functional				

Title	Customisable Licenses				
ID	SR-LICENSE-02	Category	License	Priority	Medium
Requirement Description	In order to ease the definition of data usage licenses, the marketplace should provide templates that can be easily customized to an intended business model.				
Rationale	The system should simplify the process related to licence definition allowing the reuse of existing models.				
Requirement type	Functional				

Title	Pre-built Licenses				
ID	SR-LICENSE-03	Category	License	Priority	Medium
Requirement Description	The system should provide data providers with predefined usage licenses.				
Rationale	To facilitate the publication process, providers should be able to use standard licenses (e.g., GPL, Apache, Creative Commons)				
Requirement type	Functional				

A1.4 API Requirements

Title	Standard and Open API				
ID	SR-API-01	Category	API	Priority	High

Requirement Description	The system has to allow to access/consume data through standard and open API/protocols.
Rationale	The adoption of standard and open API facilitates the reuse of solutions avoiding vendor lock-in.
Requirement type	Functional

Title	Publish/subscribe data channels				
ID	SR-API-02	Category	API	Priority	High
Requirement Description	The system has to provide data publish/subscribe functionality.				
Rationale	This function is requested in order to simplify and improve the process to send and receive data in the system.				
Requirement type	Functional				

Title	Asset version management				
ID	SR-API-03	Category	API	Priority	High
Requirement Description	The system has to be able to track changes and version of API, datasets and assets in general.				
Rationale	The function is required in order to avoid problem in the access to the resources.				
Requirement type	Functional				

Title	Resources status notification				
ID	SR-API-04	Category	API	Priority	High
Requirement Description	The system has to be able to notify the user when resources/assets are updated.				
Rationale	The user should be notified about the asset status in order to avoid inconsistencies and problems.				
Requirement type	Functional				

Title	Lookup assets				
ID	SR-API-05	Category	API	Priority	High
Requirement Description	The system has to provide asset search functionality APIs. In particular it should be possible to look-up for assets using different methods (e.g., a free text search; search with system filters; Tags;)				
Rationale	This function is necessary to simplify the access to the API in the marketplace.				
Requirement type	Functional				

A1.5 SLA Requirements

Title	SLA management				
ID	SR-SLA-01	Category	SLA	Priority	High
Requirement Description	The system has to allow to define and manage extensible SLA for data access.				
Rationale	Adopting SLA allows to offer different level of services for the different stakeholder that are part of the digital single market.				
Requirement type	Functional				

Title	SLA common metadata				
ID	SR-SLA-02	Category	SLA	Priority	High
Requirement Description	The system has to provide a common metadata to define SLA.				
Rationale	Adopting common metadata models simplify the management and the comprehension of the SLA descriptions.				
Requirement type	Functional				

A1.6 Models Requirements

Title	Asset description taxonomies				
ID	SR-MODELS-01	Category	Models	Priority	High
Requirement Description	The system has to provide pre-built taxonomies to describe assets (data, services, application, devices).				
Rationale	This function is necessary to simplify the definition of the assets description and to allow reuse of existing data models.				
Requirement type	Functional				

Title	Standard and open data models				
ID	SR-MODELS-02	Category	Models	Priority	High
Requirement Description	The system has to support open and standard data models and metadata to describe the different assets of the marketplace				
Rationale	The adoption of standard and open data models facilitates the reuse of asset and solutions avoiding vendor lock-in.				
Requirement type	Functional				

A1.7 Security and Privacy Requirements

Title	Privacy policies guidelines				
ID	SR-PRIVACY-01	Category	Privacy	Priority	High
Requirement Description	The system has to provide procedures and guidelines in order to ensure compliance with respect to data protection rules.				
Rationale	Both the data provider and the data consumer must comply with the privacy and data protection policy.				
Requirement type	Functional				

Title	Data protection				
ID	SR-PRIVACY-02	Category	Privacy	Priority	Medium
Requirement Description	The Systems should be able in properly reacting to data violations (e.g. data are accessed by unauthorized entities or other data breach) with defined procedures.				
Rationale	It is necessary to provide systems for monitoring against any attacks and if a breach occurs an appropriate procedure must be in place to handle it.				
Requirement type	Functional				

Title	Anonymization				
ID	SR-PRIVACY-03	Category	Privacy	Priority	High
Requirement Description	The system has to provide data anonymization/aggregation functions in order to delete personal or restricted information coming from the data sources				
Rationale	It is necessary to have these type of functionalities in order to (re)use and publish data coming from different sources being compliant with privacy and data protection regulations.				
Requirement type	Functional				

Title	Personal Data usage				
ID	SR-PRIVACY-04	Category	Privacy	Priority	High
Requirement Description	The system has to provide functionalities to allow the end user to control his own personal data defining who and how can access to it.				
Rationale	End-user should have full control of his personal data.				
Requirement type	Functional				

Title	End-to-end secure communication				
ID	SR-SECURITY-01	Category	IoT infrastructure	Priority	High
Requirement Description	The system should provide security for data communication and interactions among users.				
Rationale	The system should use encryption and technology to secure data in transit.				
Requirement type	Non-Functional				

Title	IoT adaptation policies				
ID	SR-SECURITY-02	Category	IoT infrastructure	Priority	High
Requirement Description	The system should define adaptation policies of these mechanisms in the boundary points while assuring that security remains independent from low level IoT components.				
Rationale	In order to support both new and legacy IoT devices, the system should provide end-to-end security at the API level rather than supporting and coping with how different solutions (e.g., LoRa, 802.15.4, NB-IoT, WiFi, LTE, GPRS, etc.) handle security measures such as key management, authentication, integrity and confidentiality.				
Requirement type	Non-Functional				

Title	Access policy				
ID	SR-SECURITY-03	Category	Platform	Priority	High
Requirement Description	The system has to allow to define and manage policies for data/service access/usage.				
Rationale	This function allows a data provider to restrict the access of its data source(s) to third parties.				
Requirement type	Functional				

Title	Flexible security capabilities				
ID	SR-SECURITY-04	Category	Platform	Priority	High
Requirement Description	The system should define and provide flexible security capabilities in order to secure the platform which is going to support the services of the city.				
Rationale	Data and services can have different security requirements based on their scope. The platform which is going to support the services of the city should provide flexible security capabilities in order to accommodate the different needs of specific target scenarios, by providing support for confidentiality, integrity, authentication, authorisation, immutability, trust and non-repudiation when needed.				
Requirement type	Non-Functional				