H2020 Work Programme 2016-2017
H202-IoT-02-2016
Duration: 36 months

CROSS FERTILISATION THROUGH ALIGNMENT, SYNCHRONISATION AND EXCHANGES FOR IoT

H2020 – CREATE-IoT Project

Deliverable 01.04

Common methodology and KPIs for design, testing and validation

Revision : 1.0
Due date : 30-09-2017 (m09)
Actual submission date : 12-10-2017
Lead partner : IDC

Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Summary					
No and name	**D01.04 Common methodology and KPIs for design, testing and validation**				
Status	< Released>	Due	m09	Date	30-09-2017
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DoW	This deliverable summarizes part of the work carried out in task T01.02 (Common methodologies and KPIs), and includes first common methodologies and KPIs for design, testing and validation for success and impact measurement across various IoT use cases and application domains.				
Comments					

Document history

Rev.	Date	Author	Description
0.00	23-01-2017	SINTEF	Template/Initial version and overall structure.
0.01	04-09-2017	SINTEF, IDC	Contents and structure (draft).
0.02	08-09-2017	SINTEF	Proposed KPIs for design, testing and validation.
0.03	12-09-2017	SINTEF	Contributions of partners.
0.04	13-09-2017	SINTEF	New dimensions and restructuring.
0.05	16-09-2017	SINTEF, IDC	Alignment dimensions, fields and KPIs
0.06	19-09-2017	IDC, SINTEF, ATOS, ARTS	Input Sections 3, 4 and 5
0.07	29-09-2017	BLU, FE	Input section 4 (KPIs).
0.08	30-09-2017	IDC, ARTS, FE, BLU; SINTEF	Inputs and updates on several sections.
0.09	05-10-2017	SINTEF	Input section 5 and Dimension 1 and 2 updates.
0.10	06-10-2017	SINTEF, IDC	Integrated version.
0.11	09-10-2017	ATOS	Review.
0.12	11-10-2017	IDC	Review comments considered.
1.00	12-10-2017	SINTEF	Final version released.

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1. EXECUTIVE SUMMARY

Publishable summary

This document addresses the development of common methodologies and Key Performance Indicators (KPIs) for design, testing and validation and for success and impact measurement across various use cases and application domains. The document describes the evaluation methodologies and common KPIs for IoT applications and projects. The aim is to enable IoT Large Scale Pilots' (LSP) stakeholders to assess the IoT pilot's progress towards the stated IoT FA objectives and pilots collectively, their contribution to stated outcomes. The work will first focus to find a methodology for collecting and reporting on performance data early in IoT LSPs' implementation, including establishing baselines and benchmarks.

The present deliverable forms the basis for the work with the LSPs for developing the methodology and promoting the importance of KPIs for continuous monitoring, and ensuring the availability of timely, accessible and comparable data and the development of interim performance indicators to inform internal and external stakeholders on the progress of an IoT LSP towards achieving planned outcomes.

This deliverable is structured as follows:

- Section 2 provides a general introduction to the document including the purpose and the target of this deliverable, the contribution of the different CREATE-IoT's partners involved, and the relations with other activities in the project.
- Section 3 outlines the general theoretical framework underpinning our initial choice of common methodologies and IoT KPIs to support CREATE-IoT's objectives and, ultimately, serve the wider IoT European Large-Scale-Pilots Programme's goal. This framework will be used and constantly adapted to measure the success and impact of the five Large Scale Pilots taking part to the Programme through their use cases and along several focus areas and application domains.
- Section 4 delves into the of the theoretical framework by spelling out, defining and describing eight different broad dimensions under which to group the IoT KPIs to be used in the actual measurement of the IoT European Large-Scale Pilots Programme. For each Dimension, a series of KPIs is proposed and thoroughly described. Each KPI is further assigned with a specific metric and a specific method of measurement.
- Finally, section 5 deals with the main application domains and use cases currently represented in the IoT European Large-Scale Pilots Programme. It describes each domain's key features and distinctive traits and, for each domain, it suggests a preliminary list of KPIs to be further reviewed and approved by the LSPs actually involved in the IoT European Large-Scale Pilots Programme.

Non-publishable information

This document is public.

2. INTRODUCTION

CREATE-IoT offers the IoT Large Scale Pilots Programme the possibility to analyse the actual functioning in practice of the European's IoT ecosystem and to test the large-scale IoT demonstrations designed and implemented by the five Large Scale Pilots projects through their use cases and along five focus areas and application domains.

Deliverable D01.04 "Common Methodologies and KPIs for design, testing and validation" is part and parcel of CREATE IoT's fundamental role in coordinating and supporting the LSPs in the respective IoT Focus Areas by promoting an effective information exchange across the LSPs and better enable the IoT initiatives and the stakeholders involved in the IoT Large Scale Pilots Programme to respond to their own needs of good management practice, as well as the needs of end-users, the market and the society as a whole.

As a result, this deliverable proposes a comprehensive set of methodologies and a full list of preliminary KPIs to be used to measure the success and impact of the IoT European Large-Scale Pilots programme. It provides a quantifiable approach to measure, test, design and validate the demonstrations put forward by the LSPs, as well their overall impact. It translates the theoretical approach into a series of practical KPIs covering a wide range of dimensions, from the technology development and deployment and infrastructure in use within the different LSPs to the relationship with the IoT Ecosystem and the existing stakeholders' engagement strategies in place; form the impacts on businesses and the market place to the effects on the economy and the society as a whole.

2.1 Purpose and target group

The purpose of this deliverable is to propose a series of evaluation methodologies and common KPIs for IoT applications and projects to be applied within the IoT European Large-Scale Pilots Programme. These methodologies and KPIs will be further discussed with each of the LSPs and possibly adjusted to respond to their specific needs and as well as to the overall objective of the Programme before proceeding to their actual implementation through a series data collections measurements and evaluations. In so doing, this deliverable, and the resulting methodological approach and proposed KPIs, will serve the individual LSPs and the overall IoT European Large-Scale Pilots Programme in constantly monitoring their own performance and potential external impact on the wider IoT Ecosystem. In addition, this deliverable's results, and their subsequent updates, will also help the European Commission in gaining a comprehensive view on the effectiveness of the overall programme and introduce corrective actions and / or promote new impulse to address possible areas in need of attention while using well performing areas as best practice of other programmes and upcoming IoT related activities.

2.2 Contributions of partners

Contributions of the involved partners according to task T01.02 (Common methodologies and KPIs) are given below, and their involvement are reflected in the various sections of this report.

IDC is the task leader and will coordinate the activities, collect inputs from the relevant partners, validate the inputs within the consortium and outside the consortium through the involvement of relevant experts and lay down a shared framework for KPI's design, testing and validation. A specific effort of desk research, accompanied by a few selected ad-hoc interviews within and beyond the present consortium, will be undertaken by IDC senior analysts and consultants across at least three IDC expertise centres in Europe (Milan, London, Copenhagen), coupled by the involvement of the same numbers of IDC expertise centres outside Europe (Boston, US; Seoul, South Korea; Singapore, for the whole of the Asia-Pacific region). This transregional effort will

allow to identify the most relevant KPIs in relation to the IoT ecosystem in both mature and rapidly emerging markets so to integrate possible inputs currently not available at European level. The building of the proposed KPIs will be based on a rigorous identification of the IoT ecosystem's stakeholders, their needs and requirements and a subsequent classification of the potential impacts that the activities undertaken under the present project will produce on the IoT ecosystems under consideration.

SINTEF will contribute to KPIs to enable IoT LSPs' stakeholders to assess the IoT pilot's progress towards the stated IoT FA objectives and pilots collectively, their contribution to stated outcomes. The work will first focus to find a methodology for collecting and reporting on performance data early in IoT LSPs' implementation, including establishing baselines and benchmarks. SINTEF will work closely with the LSPs for developing the methodology and promoting the importance of KPIs for continuous monitoring, and ensuring the availability of timely, accessible and comparable data and the development of interim performance indicators to inform internal and external stakeholders on the progress of an IoT LSP towards achieving planned outcomes. Introduction of the concepts such Production/Manufacture Readiness Levels (PRL/MRL) and Market Readiness Levels (MRL) to evaluate the maturity of the technologies developed by the IoT LSPs.

ATOS will focus on the provision of a methodology for the large-scale deployment of IoT devices and the identification of relevant KPIs that facilitate its assessment.

ARTS will contribute in order to create synergies between WP01 and WP03 and exploit common efforts a panel of citizens and creative consumers. ARTS can work on defining a portion of KPIs together with technologists, entrepreneurs, multidisciplinary team of researchers and artists during the co-creation workshops.

TL contributes to the integration of the security and privacy by design methodology, integrating data protection impact assessment (from WP05) KPI in IoT.

BLU will develop an ecosystem map that identifies the stakeholders in each of the FA ecosystems and a common taxonomy that will help to align KPIs across the FAs. This map will also feed into WP03 that is focused on Creation, Innovation and Adoption and WP04 that looks at the European IoT Value Chain Integration Framework.

FE will contribute to definition of KPIs.

2.3 Relations to other activities in the project

The activities pertaining to the designing, testing and validation of common methodologies and KPIs are part of CREATE-IoT's Work Package 1 – Coordination and Support tot the IoT Focus Areas, whose aim is to coordinate and support the IoT Focus Areas through the development of a sound and coherent strategy for open exchanges and collaboration between the various activities of the Focus Areas and the different LSPs operating under the umbrella of the IoT European Large-Scale Pilots Programme.

In particular, common methodologies and KPIs are developed under Task 01.02, with a contribution of most of CREATE-IoT's partners (see 2.2 above). More importantly, this deliverable is closely interconnected with a series of other CREATE-IoT's activities and deliverables. More specifically:

It draws from the activities set forth in Task 01.01 IoT Focus Areas coordination and road mapping in as much as it leverages and applies the framework for collaboration and information exchange included in Deliverable 01.01 IoT FA strategy and coordination plan;

It further benefits from the results in Deliverable 01.02 IoT FA Road Map as it considers the next stages of IoT deployment outlined in in the road map as a potential future paradigm against which

to evaluate the evolution of the LSPs and the overall IoT European Large-Scale Pilots Programme in the coming years.

In turn, this document will feed into the following deliverables:

- The three IoT FA yearly coordination conferences (D01.03 – IoT FA Year 1 Coordination Conference; D01.07 IoT FA Year 2 Coordination Conference; D01.08 – IoT FA Year 3 Coordination Conference) representing some series common meeting platforms pulling together the IoT ecosystem and displaying best practices and lesson learned from of the IoT European Large-Scale Pilots Programme on a yearly basis.
- The IoT FA Road Map update (D01.05) where the evolution of the LSPs will be validated against the freshest results of the KPIs and further checked in view of the most recent update of the road map deployment.
- A Workshop on the evaluation of the IoT FA (D01.06) based on the common methodologies and KPIs to be held at the end of the second year of the project where the results of the first round of KPIs measurements (and the underpinning evaluation methodologies) will be carefully presented and openly discussed.

3. ESTABLISHING COMMON METHODOLOGIES - THE THEORETICAL FRAMEWORK

3.1 Common methodologies and IoT KPIs links

CREATE-IoT's principal objective is to stimulate collaboration between existing IoT initiatives, foster the take up of IoT in Europe and support the development and growth of the IoT Ecosystem based on open technologies and platform.

To achieve this objective, CREATE-IoT promotes strategic and operational synchronisation and alignment between the different activities under the IoT Focus Areas and, in particular, across the LSPs that are part of the IoT European Large-Scale Pilot Programme.

These activities translates into a series of concrete coordinating mechanisms ranging from a constant exchange of information on best practices and approaches on IoT's technical aspects (such as object connectivity, protocols, data formats, privacy, security, etc.), to the promotion of common practices for sharing conclusions and road mapping exercises for IoT developments at worldwide, European and national level and to efficient information dissemination across the IoT FA and LSPs for horizontal common interests' issues.

Among the coordinating activities carried out by CREATE-IoT as one of the two CSAs supporting the IoT European Large-Scale Pilots Programme, the development and implementation of common methodologies and KPIs to measure the LSPs performance and impact throughout the duration of the Programme plays a pivotal role. What is more, the design, test, validation and implementation of common methodologies and IoT KPIs, extends well beyond the remit of the IoT European Large-Scale Pilots Programme as a whole and the role of CREATE-IoT.

The KPIs, for example, will help verifying if each LSPs in their respective FAs deploys work in an integrated manner under operational or close to operational conditions to validate the ability to deal with traffic, processing and device compatibility (TRL 6).

Overall, the KPIs presented in this deliverable will be instrumental to guide each individual LSP towards its specific objectives and support each project towards the realization of large-scale demonstrations in their own IoT Focus Area and specific domain, i.e. smart living environments for aging well, smart farming and food security, wearables for smart ecosystems, smart cities and reference zones).

To this aim, the common methodologies and KPIs set forth in this deliverable are organized along three main types of indicators, each addressing a specific level of analysis:

- Generic indicators refer to areas of performance or evaluations that are common to all KPIs and all products, services and projects. These indicators will be applied to all LSPs and to the IoT European Large-Scale Pilots Programme as whole;
- Cross-domain indicators operate at a lower level by intercepting those processes and features pertaining to more than one domain and therefore potentially referring to more than one LSP but not to the Programme as a whole;
- Domain-specific indicators are designed for, and apply to, a single domain and are therefore used to measure the performance and impacts of one specific LSP.

At the same time, the common methodologies and KPIs presented in this deliverable and applied at project and programme level will be of help for the overall IoT ecosystem in Europe and beyond as they will allow the ecosystem stakeholders to verify the level of advancement, performance and impact of specific IoT demonstrations in well-defined domains.

Similarly, European and national policy makers will benefit from the KPIs measured in this deliverable as they will indicate the areas of performance in need of corrective actions, as well as those areas that could be used as best practices and examples in other IoT-oriented endeavours.

3.2 Key dimensions and main fields of measurement

In this document, a top-down approach is adopted to establish the main areas to be tested, validated and measured through a series of well-defined and quantifiable indicators.

- The first step consists in determining a number of broad areas on the basis of the impacts that the overall IoT European Large-Scale Pilots' Programme and each individual LSP can generate in the wider IoT ecosystem. These areas are called "dimensions" and are identified based on "where" the impacts are going to exert their effects: the technology, the market place, the economy and the society as a whole, for example.
- The second step is to assign a number of more specific and circumscribed sub-areas (called "fields") to each dimension to further narrow down, and better delimit, the impact spheres: the "technology development" dimension, for instance, is further broken down in six different fields each presiding over a specific element of the dimension in question – from IoT devices and modules, to IoT system monitoring, from IoT architecture, to IoT certification and validation.
- The third step consists in the actual design, identification, and description of one or more measurable metrics associated to each field – the KPIs. The field "IoT devices and modules" for example, can include a KPI measuring the number of standardized interfaces, another KPI calculating the mean time between outages, another KPI counting the number of detected errors, etc.

The common methodologies and KPIs presented in this document are based on the following eight dimensions:

1. **Dimension 1: Technology development** measuring the type of support and the effects generated by the IoT European Large Large-Scale Pilots' Programme on ICT vendor and suppliers of IoT technology.
2. **Dimension 2: Technology deployment and infrastructure** measuring the degree of adoption, integration and performance of IoT technology across the LSPs and the whole Programme.
3. **Dimension 3: Ecosystem strategy and engagement** measuring the extent to which an ecosystem strategy is in place and how well it is followed by the LSPs.
4. **Dimension 4: Ecosystem Openness and External Collaboration** measuring the degree of openness and accessibility of the LSPs ecosystem for third parties outside the Programme.
5. **Dimension 5: Marketplace and business impacts** measuring the LSPs' readiness for business transactions in terms of business effectiveness but also in terms of security and trust.
6. **Dimension 6: Societal and economic impacts** measuring the LSPs' societal and economic impacts in the short and long-term.
7. **Dimension 7: Policy and governance impacts** measuring the LSPs impact to the existing national and European policy issues related to IoT
8. **Dimension 8: Community support and stakeholders' inclusion** measuring how LSPs demonstrations are going to be actually adopted by the community in the long run.

The eight key dimensions and their relationship with the European IoT Large-Scale Pilots programme are illustrated in Figure 1.

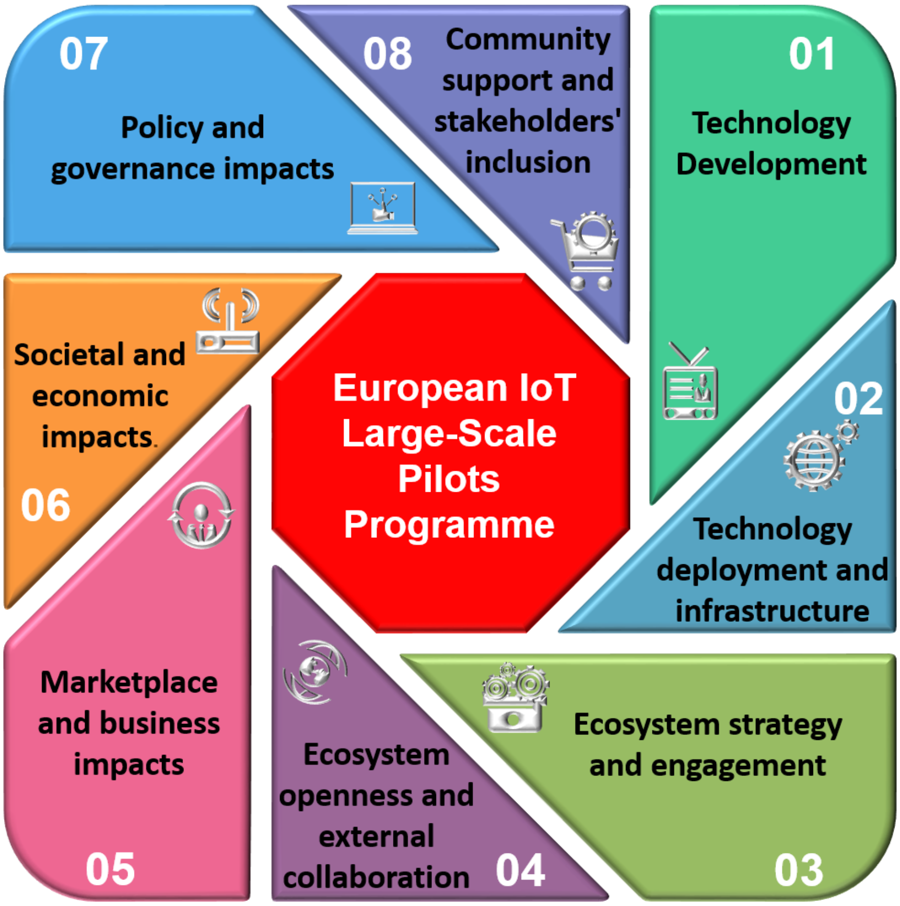

Figure 1: European IoT large-scale pilots programme dimensions

Tables 1 to 8 also provide a detailed description of each dimension and its associated fields.

Table 1: Dimension 1 - Technology development.

#	TITLE	DESCRIPTION / QUESTION TO BE ANSWERED
Dimension 1	**Technology development**	**Type of IoT technology used, the readiness level, maturity, and the state of the art.**
Field 1.1	IoT devices and modules	The functionality, complexity heterogeneity and level of intelligence of IoT devices and modules
Field 1.2	IoT platforms	Type of IoT platforms (Cloud-, edge-, industrial-, connectivity-, device- centric, etc.), their components (i.e. analytics, storage, management, etc.), features (i.e. end-to-end security, etc.) and level openness (i.e. open-source, open-architecture, closed ecosystem, etc.), interoperability and standardisation.
Field 1.3	IoT system monitoring	Ability to monitor autonomously the IoT system components over the lifetime of the IoT application deployment. Upgradability features and compatibility with legacy systems.
Field 1.4	IoT architecture	IoT topology used and mapping to existing IoT architectures.
Field 1.5	IoT system functional design	IoT system functional design methodologies to optimize performance, data exchange, connectivity, over all power consumption etc.
Field 1.6	IoT verification, validation, testing and certification	Existence of clear methodology, tools and procedure for IoT verification, validation, testing and certification to ensure consistency with expectations.

Table 2: Dimension 2 - Technology deployment and infrastructure.

#	TITLE	DESCRIPTION / QUESTION TO BE ANSWERED
Dimension 2	**Technology deployment and infrastructure**	**How well is the applied technology included and integrated across the IoT LSPs and how well it is performing?**
Field 2.1	Use of open technologies, devices and platforms	Ability to apply existing and widespread used technologies, devices and platforms
Field 2.2	Use of supported standards	Ability to count on existing, well-renowned and market-adopted standards
Field 2.3	Capacity to solve interoperability and connectivity issues	Ability to obtain interoperability and connectivity support for communications, data exchanges, etc.
Field 2.4	Scalability	Ability to rapidly adapt to an increased user-base
Field 2.5	Efficiency in the maintenance, deployment and life-cycle of services and software running.	Efficiency in the maintenance, deployment and life-cycle of services and software running.
Field 2.6	Integration with the existing and new infrastructure.	Ability to integrate the IoT technologies and platforms for IoT applications using new and existing infrastructure. Efficient deployment, sustainability and lifetime of IoT applications.

Table 3: Dimension 3 - Ecosystem strategy and engagement.

#	TITLE	DESCRIPTION / QUESTION TO BE ANSWERED
Dimension 3	**Ecosystem strategy and engagement**	**Is there an ecosystem strategy in place and, if yes, how well it is understood and followed by the LSPs**
Field 3.1	Ecosystem awareness	Capability to understand the ecosystem landscape, its own position within the landscape, its own vision vis-à-vis the overall ecosystem
Field 3.2	Stakeholders' engagement	Ability to reach out to the appropriate stakeholders and ability to engage them
Field 3.3	External partnerships and Collaboration	Ability to build alliances and strategies inside and outside the IoT ecosystem
Field 3.4	Public and government engagement	Ability to reach out and engage with public authorities and regulators

Table 4: Dimension 4 - Ecosystem openness and external collaboration.

#	TITLE	DESCRIPTION / QUESTION TO BE ANSWERED
Dimension 4	**Ecosystem openness and external collaboration**	**How open and accessible is the ecosystem for third parties outside the LSPs**
Field 4.1	Value chain openness	Is competition allowed to join in the value chain and, if yes, where/how
Field 4.2	Inclusiveness and participation for third parties	Effective ability for third parties to use the products and services and with which rights
Field 4.3	Openness of business models	Business models' ability to serve vertical-specific needs or horizontal/cross-vertical needs
Field 4.4	Open source strategy	Degree of open source elements in the ecosystem

Table 5: Dimension 5 - Marketplace and business impacts

#	TITLE	DESCRIPTION / QUESTION TO BE ANSWERED
Dimension 5	**Marketplace and business impacts**	**How well do the LSPs ensure business transactions in terms of security, trust, and business effectiveness**
Field 5.1	Business models	Ability to support diversified business models (capability to understand their different features, to serve their needs, adapt to their mechanisms, etc.) – Channels selected for acquiring and dealing with customers

Field 5.2	Market readiness and monetization mechanisms	Value Proposition readiness and validation - Billing and accounting mechanisms allowing stakeholders to extract revenue streams
Field 5.3	Business benefits	Ability to improve business metrics (operational costs, efficiency, customer care, marketing, and communication) in LSPs' addressable markets
Field 5.4	Market competitiveness	Ability to replace/improve existing solutions on the market or opening completely unexplored markets – Competition in the Marketplace
Field 5.5	Legal issues	Is legislation supporting the usability and diffusion of the proposed demonstration or impeding it?
Field 5.6	Privacy, trust and ethical issues	Mechanisms in place to ensure and measure trust/reputations, privacy and respect of other ethical issues. (End user point of view, privacy and trust by design)
Field 5.7	Experience Readiness Level (ERL)	The Experience Readiness Level (ERL) measures the capability of IoT systems to trigger a well-suited user experience.
Field 5.8	Holistic innovation	The combination of Science, Technology and the Arts stimulates innovation and demand, and put forward a holistic way to conceive radically novel products, services and processes that are also putting the human in the centre.

Table 6: Dimension 6 - Societal and economic impacts

#	TITLE	DESCRIPTION / QUESTION TO BE ANSWERED
Dimension 6	**Societal and economic impacts**	**What will LSPs' societal (end users' worktime/life and communities impacts) and economic impacts (indirect revenue and employment) be in the short and long-term?**
Field 6.1	Indirect revenue generation	To what extent LSPs are delivering solutions allowing end-users to expand and increase their business, indirectly fostering additional revenue generation among final end-users?
Field 6.2	Employment macro-impact	Ability of LSPs to generate potential new jobs internally and among end-users in their addressable markets, fostering employment growth
Field 6.3	User worktime/life impact	Ability of LSPs to develop solutions impacting end-user life (e.g. better quality of public services, time saving, quicker and easier access to information) and/or working activities (e.g. easier collaboration and access to information, elimination of repetitive tasks)
Field 6.4	Targeted social groups	To what extend LSPs impact more vulnerable community groups' (e.g. elderly, children, disabled people, minorities, etc.) life and activities?

Table 7: Dimension 7 - Policy and governance impacts.

#	TITLE	DESCRIPTION / QUESTION TO BE ANSWERED
Dimension 7	**Policy and governance impacts**	**How well do the LSPs contribute to the existing national and European policy issues related to IoT and promote IoT standards, while fostering SMEs and young entrepreneurs**
Field 7.1	European IoT ecosystem promotion and competitiveness safeguard	Ability of LSPs to align with strategic policy objectives in order to large scale deployments of IoT in Europe and benefit Europe's IoT industry
Field 7.2	IoT standards promotion	How effectively do LSPs contribute to the effort of coordinating and consolidating IoT standards?
Field 7.3	Trusted, safe, secure IoT environment promotion	To what extend LSPs contribute to the promotion of an IoT environment where security, privacy, safety, efficiency, and

		other legal or ethical issues are dually taken into consideration
Field 7.4	Impact on SMEs, start-ups and young entrepreneurs	How are LSPs making sure that start-ups and SMEs play a role in the new IoT paradigm? (How do they engage with them, how they provide clarify on legal considerations, how they encourage disruptive innovation, etc.)

Table 8: Dimension 8 - Community support and stakeholders' inclusion

#	TITLE	DESCRIPTION / QUESTION TO BE ANSWERED
Dimension 8	**Community support and stakeholders' inclusion**	**How well do the LSPs interact with the external community (both developers and citizens) and how easy is to access LSPs' materials and practices**
Field 8.1	Developers' community accessibility	What is the connection in place between LSPs and external developers' community and how easy is for developers to access and understand LSPs materials and solutions
Field 8.2	Education availability	What educational activities LSPs have in place to amplify their activities and foster the adoption of their solutions and services
Field 8.3	Accessibility levels	Is LSPs' support available in different languages and to impaired people?
Field 8.4	Community engagement	LSPs' activities to directly interact with citizens, via public community events and activities.

3.3 Data collection and methods of measurement

To derive the appropriate list of KPIs and measure the impact of the IoT European Large-Scale Pilots Programme, CREATE-IoT will follow a multi-step approach.

- It will first consider each LSPs project and carefully analyse its initial objectives as well as the actual achievements to date of each demonstration;
- It will then carefully review (and update, if necessary) CREATE-IoT's Task 01.02 on Common methodologies and KPIs to make sure it is fully adapted to the actual development and deployment of the LSPs and propose a detailed document structure of deliverable D01.04 Common methodology and KPIs for design testing and validation.
- Based on the two aforementioned steps, it will then develop a comprehensive methodology for acquiring the necessary information from the LSPs, identifying additional sources to obtain relevant insights on the LSPs and their background information;
- A list of areas and sub-areas of measurement (i.e. "Dimensions" and "Fields") will then be formalized and, for each sub-area, a list of KPIs, together with their definition, description, metric, collection and measurement methods and targets, will be finalized.

CREATE-IoT will make use of a panoply of data collection methodologies and several methods of measurements of the collected data to actually implement the KPIs defined in each dimension and associated field of measurement.

Collecting data and inputs from the LSPs and the European IoT Large-Scale Pilots' Programme

The inputs' collection for the actual implementation and measurement of the identified KPIs will occur primarily through the use of the following data collection methodologies. They are presented below in the order by which they will be employed. Depending on the complexity, domain and other specific aspects of the KPI in question, however, this order may vary and other supplementary forms of data collection may be also utilized.

- First of all, an extensive effort of **desk research and secondary research** will be carried out to investigate the **existing material** pertaining to the European IoT Large-Scale Pilots

Programme and each individual LSPs. Formal and informal contacts between CREATE-IoT, the European IoT Large-Scale Pilots Programme's coordinator and each LSP's coordinators will be used to exchange documents and provide evidence about the Programme's and the LSP's activities and progress towards the achievement of their objectives.

- A series of face-to-face interviews will be also conducted by CREATE-IoT with a number of IoT European Large-Scale Pilots' stakeholders and with representatives of each LSP. In particular, **direct, one-to-one interviews** will be conducted with LSPs coordinator and with work-package leader of work packages and tasks pertaining to the specific KPIs to be measured. These face-to-face interviews will be based on a flexible and broad questionnaire so to keep the conversation open and adjustable to any specific request that may arise.
- An element of quantitative research will be considered as well as an effective method of collecting data and information. One or more **on-line questionnaire(s)** will be organized by CREATE-IoT and administered across the European IoT Large-Scale Pilots Programme and the individual LSPs. This type of research method, however, will also be employed to reach out and obtain inputs and feedback from the wider IoT community and the IoT ecosystem outside and beyond the European IoT Large-Scale Pilots Programme. The questionnaire will consist in a series of mainly closed, multiple-choice questions to ease the compilation of the document and avoid the misunderstanding of the results' interpretation. It will be administered through the CAWI (Computer-Aided Web Interviews) methodology and the results will be analysed and subsequently measured by CREATE-IoT's team.

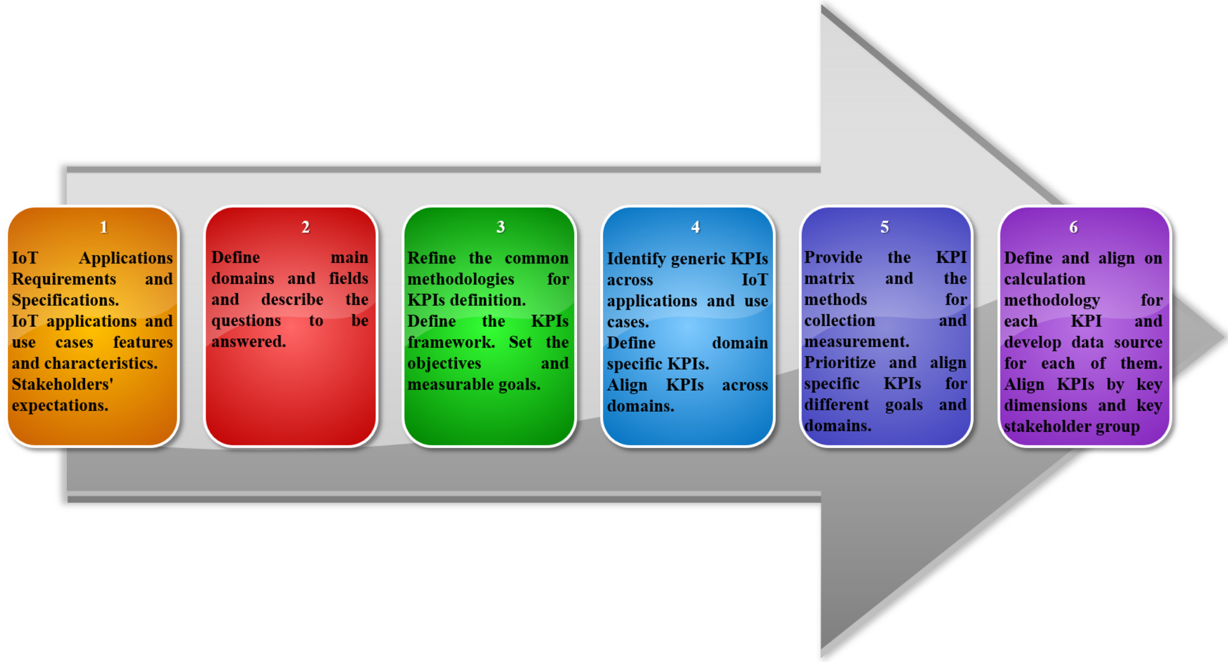

Figure 2: General framework for KPI generation.

Assessing the collected inputs and measuring the indicators

The inputs collected through desk and secondary research, one-to-one interviews and on-line questionnaires will be assigned a numerical score and when all inputs, or answers, are completed a total score is determined. This total score is the sum of the values assigned to a response in the questionnaire, or to a specific item of interest identified by desk research. The total score of all the questions or specific items of interests pertaining to a specific KPI are then regrouped and the value of the KPI calculated.

The KPIs values so calculated will then be normalized to a Likert scale, for example a one to five scale, with a score 1 will be mapped to "low", 2 "medium-low" and so on. Depending on the specific topic of each KPI, a series of benchmark values will be obtained from literature, existing research, similar projects and endeavours conducted in the past, as well as CREATE-IoT's partners

previous experience. For example, IDC's existing and past research on IoT markets and IoT market expenditure values can be used to benchmark the KPIs pertaining to the dimension "Marketplace and business impacts". Based on this benchmarking exercise, each indicator will be assigned a value in the Likert scale and further evaluated in terms of "Low", "Medium" and "High".

The last step will be to group the values of KPIs per each Field and calculate an aggregate score per Field. Similarly, a group of Fields belonging to the same Dimension will be aggregated and calculated in order to obtain an aggregate score per each of the eight dimensions.

The process described above is to be considered an iterative process and will be repeated at regular intervals during the whole of the duration of the CREATE-IoT project and of the European IoT Large-Scale Pilots Programme.

4. KPIs FOR DESIGN, TESTING, VALIDATING AND MEASURING LSPs' IMPACTS

In this section, we present the KPIs for the key dimensions and the main fields of measurement introduced in section 3. Each indicator is structured in a way to serve as a generic indicator, a domain-specific indicator or a cross-domain indicator.

- A generic indicator is designed to apprehend and measure performance-related aspects of virtually every project, initiative or endeavour. In their intrinsic nature, generic indicators are therefore applicable across any LSPs and pertain to any domain or vertical sector in which the project is deployed. For this reason, they focus on measurable items that are common in practically every project: the availability and use of technology, the relationship within and throughout the ecosystem, the degree of stakeholders' engagement, the impacts on the market, the economy and the society as a whole.
- In contrast, a domain-specific indicator refers to a precise industry, vertical market or area of expertise and is designed to explicitly apprehend the phenomena occurring in that domain. As an example, domain-specific KPIs for health-related projects will focus exclusively on indicators measuring the performance of health-related devices and services, the use of these devices and services by doctors and medical staff, the benefits and degree of usability of these devices and services by patients, etc.
- Cross-domain indicators are yet another, more complex, category of KPIs. Cross-domain indicators span two or more domains and are designed to capture commonalities, divergences, interrelations, areas of overlapping or duplications across several domains. Cross-domain indicators are particularly suitable to identify synergies and spin-off effects between and among domains. For instance, the performance of a specific project a certain domain can positively influence the performance of a second project in another domain but not vice versa.

The actual designing, definition and implementation of the three above-mentioned indicators' categories will occur in separate distinct phases. CREATE-IoT will first focus on generic indicators as they can be determined in a relatively easy way through desk research and by leveraging the CREATE-IoT partners' experience. In a second phase, the domain-specific indicators will be clearly identified and better specified. A first provisional list of domain-specific indicators will be provided by CREATE-IoT partners and will be finalized through several iterations with each LSP directly involved in the domain under consideration and with further interactions with domain- expert stakeholders. Finally, cross-domain indicators will be defined at a later stage once the impact and influence of generic and domain-specific indicators is clearly apprehended. Only then, in fact, it is possible to thoroughly investigate the interplay and interrelations between two or more domains and calculate meaningful values for KPIs spanning a multiple set of domains.

While certainly beneficial for a wide range of stakeholders across the European IoT Large-Scale Pilot's Programme, the KPIs for design, testing, validation and impact measuring will be a primary management and control tool for the LSPs themselves. By regularly measuring the indicators across the eight dimensions proposed in this document, each LSPs will be in a position to monitor its performance and progress vis-à-vis its own project's objectives and the objectives of the overall programme. In particular, each LSPs will be given the chance to obtain a clear-cut snapshot at regular intervals of its own project with respect to the following elements (just to mention a few of them):

- the maturity of the technology employed by its own LSP vis-à-vis the average level of technology maturity in use in the IoT ecosystem in a specific moment in time and in a given domain;
- the maturity of the ecosystem in which its own LSP operates vis-à-vis the overarching IoT ecosystem at play in a specific moment in time and in a given domain;

- the level of collaboration and cooperation of its own stakeholders in comparison to the type and extent of cooperation put in place by other LSPs in the same programme or by IoT similar initiatives in Europe and worldwide.
- the level of standardization and the interoperability issues experienced by its own LSP compared to the standardization and interoperability concerns experienced by other LSPs in the programme or by other IoT initiatives in Europe and worldwide.

This chapter presents the generic indicators already identified by CREATE-IoT. A first draft of domain-specific indicators is outlined in Chapter 5 and will be further refined and completed in the upcoming months, once the interactions with all the LSPs and with the European IoT Large-Scale Pilots programme intensify. In its third year, CREATE-IoT will be in a position to define and then measure the cross-domain indicators.

4.1 Technology development (Dimension 1)

The technology development dimension shall tell us how well the different constituent parts in IoT solutions are performing according to acceptance testing and requirements from the individual device level to the assembled system level.

4.1.1 IoT devices and modules (Field 1.1)

In this scope, KPIs about software development and software running will be differentiated. For example, it is necessary to measure software quality and detect errors during software development phases, as a previous step to execution. Nevertheless, also during software execution phase, possible errors or malfunctions need to be checked so as to provide feedback to the software development cycle.

The functionality, complexity heterogeneity and level of intelligence of IoT devices and modules.

Table 9: KPIs for IoT devices and modules (Field 1.1)

Name/Identifier	Description	Metric	Method of collection and measurement
Standardised interfaces	The number of standard interfaces for easy implementation.	Number	How many standard interfaces per component?
Mean time between outages	Mean time between outages because of a forced (or not) reboot, software update, malfunction, etc.	Time (seconds)	Monitoring mechanisms to detect the amount of time where device was down, with independence of the reason.
Number of errors	Number of identified IoT component errors for new releases.	Number	Carry out defined components acceptance tests according to the specifications for each new release. Log the number of errors per release.
Errors detected during execution	By monitoring malfunction of a device or auto-diagnostic with reporting.	Number of errors since last software release	Monitoring tools to detect malfunction, either remotely detection or auto-diagnostic. Is the software running? Is the software responding correctly? Deployment tests.
Component acceptance test	Percentage of the IoT components released, which fail to pass the acceptance tests.	Percentage	Carry out defined components acceptance tests according to the specifications for each new release. Calculate the fraction (percentage) of fails per release.

Release incidents	Undesirable incidents caused by introducing new component releases. Also, those who affect other components or parts of the IoT system.	Number	Logging the number of failure incidents attributable to new releases. The number of incidents per release.
Issue tracking	Number of errors/issues known/reported by software/service/project branch	Number of issues by project/branch	Usual software control systems (like Github, Gitlab, Bitbucket…) integrate issues tracking tools. These tools allow to collect (by developers, users, collaborators) possible issues and track the progress.
Time for error fixing	The time from the error message reported until the error is fixed.	Time	Identify when errors occurs/reported and when the error is fixed. Calculate the consumption of time per error fixing.
Mean time for error fixing	Mean time until issue/error is fixed by a service/software/project	Mean by project	Mean time to fix an issue based on the issue tracker of a project in an specific period of time or software release.
Service acceptance test	Percentage of service acceptance tests, which fail to obtain the customer's sign-off.	Percentage	Carry out service acceptance tests after each service. Calculate the fraction (percentage) of failed service acceptance tests.

4.1.2 IoT Platforms (Field 1.2)

Type of IoT platforms (Cloud-, edge-, industrial-, connectivity-, device- centric, etc.), their components (i.e. analytics, storage, management, etc.), features (i.e. end-to-end security, etc.) and level openness (i.e. open-source, open-architecture, closed ecosystem, etc.), interoperability and standardisation.

Table 10: KPIs for IoT platforms (Field 1.2)

Name/Identifier	Description	Metric	Method of collection and measurement
Wireless interoperability	The number of wireless standards supported by the IoT platform.	Number	How many different wireless standards are supported per platform?
Open source platform	Open source standards supported by the IoT each platform.	Percentage	What is the fraction (percentage) of open source standards implemented against the total number of standards implemented?
Scalability spec	The number of maximum IoT devices possible. Regardless of IoT device type.	Number	How many connected IoT devices/end-nodes per platform are possible according to the specifications?
Scalability demo	The number of maximum IoT devices possible. Regardless of IoT device type.	Number	How many connected devices/end-nodes per platform are demonstrated?
Smart end-nodes/edge devices	The number of smart edge devices, including cognitive and artificial intelligence.	Number	How many connected smart edge devices.
Standardised interfaces	The number of standard interfaces for easy implementation.	Number	How many standard interfaces per platform?
Security measures	Authentication, authorization and unique identification	Number	How many security levels and fetures per platform?

4.1.3 IoT system monitoring (Field 1.3)

Monitoring IoT implies a new problematic for traditional monitoring with devices where the energy consumed is a critical aspect. In these cases, monitoring efforts (energy, bandwidth, CPU) need to consider the potential impact in performance, whether the monitoring is implemented remotely or internally by each device.

Ability to monitor autonomously the IoT system components over the lifetime of the IoT application deployment. Upgradability features and compatibility with legacy systems.

Table 11: KPIs for IoT system monitoring (Field 1.3)

Name/Identifier	Description	Metric	Method of collection and measurement
System uptime	System availability and uptime percentage metric: Mean time between outages, Total fraction of defects, Direct coverage, Unit testing coverage.	Percentage	Logging the system uptime in a specific area and over a given period. Calculate the fraction (percentage) of system uptime.
Latency	The demand for low latency/delay systems are increasing (data collection, processing and transmission).	Time	Measure best and worst case latency for a specified scenarios. (Delay end-to-end?)
Loss Rate	Network transmission quality.	Percentage	Observe the loss rate.
Frequency	The frequency of updating information	Time	Measure (or according to specifications) the rate of information updates.
Transmission range	Transmission range of the IoT platform	Distance	Measure (or according to specifications) the coverage area.
Transmission capacity	The platform transmission capacity	Bit rate	Measure (or according to specifications) the transmission capacity for a specific scenario.
Location accuracy	The accuracy for location services (if applicable)	Distance	Measure the distance deviation.
Device performance	Device performance diversity.		Number of different sensor parameters available.
Lifetime	Lifetime for battery powered IoT units/systems.	Time	Measure (or according to specifications) the interval between power source change.

4.1.4 IoT architecture (Field 1.4)

IoT topology used and mapping to existing IoT architectures.

Table 12: KPIs for IoT architecture (Field 1.4)

Name/Identifier	Description	Metric	Method of collection and measurement
Standard architecture	Standard based IoT architectures.	Percentage	What is the fraction (percentage) of standard based IoT architectures implemented against the total number of architectures implemented?
Open architecture	Open and freely available IoT architectures used.	Percentage	What is the fraction (percentage) of open architectures implemented against the total number of architectures implemented?
End-to end security and privacy	Ensure end-to-end security/ privacy IoT architectures.	Percentage	What is the fraction (percentage) of ensured end-to-end security/privacy architectures implemented, against the total number of architectures implemented

4.1.5 IoT system functional design (Field 1.5)

IoT system functional design methodologies to optimize performance, data exchange, connectivity, over all power consumption etc.

Table 13: KPIs for IoT system functional design (Field 1.5)

Name/Identifier	Description	Metric	Method of collection and measurement
Application layer	The application layer of the functional model.	Yes/No	Functional design methodologies available for the application layer
IoT layer	The IoT layer of the functional model.	Yes/No	Functional design methodologies available for the IoT layer
Network layer	The Network layer of the functional model.	Yes/No	Functional design methodologies available for the network layer

4.1.6 IoT verification, validation, testing and certification (Field 1.6)

Existence of clear methodology, tools and procedure for IoT verification, validation, testing and certification to ensure consistency with expectations.

Table 14: KPIs for IoT verification, validation, testing and certification (Field 1.6)

Name/Identifier	Description	Metric	Method of collection and measurement
Test procedures	Technical testing according to IoT standards/ guidelines.	Yes/No	Are the tests carried out in line with prevailing IoT standards/ guidelines?
Functional layers	Layers according to IoT functional model.	Type	Which type of layers are implemented according to the functional model (Application layer, IoT layer, and Network layer).
Reference layers	Layers according to IoT reference model.	Type	Which type of layers are implemented according to the reference model
Risk and vulnerability	Risk and vulnerability analysis of the IoT infrastructure.	Fraction	Are a risk and vulnerability analysis of the IoT infrastructure carried out (passed versus no passed).?
Certification	Certification according to tests.	Yes/No	Are the constituent parts of the IoT system certified (type approved)?
Regulation compliance	IoT regulatory requirements compliance	Yes/No	Is the IoT application and implementation in line with the requirements of regulatory authorities (international, national, regional).

4.2 Technology deployment and infrastructure (Dimension 2)

The technology deployment and infrastructure dimension shall tell us how well the applied technology is included and integrated across the IoT LSPs and how well it is performing.

4.2.1 Use of open technologies devices and platforms (Field 2.1)

The use of open technologies, devices and platforms field includes the ability to apply existing and widespread used technologies, devices and platforms.

It is important to differentiate between open and standard. Open means can be accessed and used by different stakeholders, implementations, etc. Standard implies the interface is managed under a standardization body. For example: FIWARE Context Broker is open and based on an OMA

NGSI standard interface. But at the same time, it could be used through a proprietary networking protocol.

Table 15: KPIs for use of open technologies devices and platforms (Field 2.1)

Name/Identifier	Description	Metric	Method of collection and measurement
Internet gateway	IoT platform applications using internet gateway	Percentage	The fraction (percentage) of IoT platform applications supporting a Internet gateway, against the total number of IoT platform applications served.
Operating system	Operating systems by the IoT platform applications.	Percentage	The fraction (percentage) of operating systems implemented which support smartphones/tablets, against the total number of IoT platform applications.
Proprietary platforms and protocols	The software implementing functionality running inside a device/gateway. Or a protocol managing communication y any layer.	Number by device	Number of proprietary platforms/protocols running in each kind of device/gateway.
Open platforms	The software implementing functionality running inside a device/gateway. Or a protocol managing communication y any layer.	Number by device	Number of open platforms/protocols running in each kind of device/gateway.

4.2.2 Use of supported standards (Field 2.2)

The use of supported standards includes the ability to count on existing, well-renowned and market-adopted standards.

Table 16: KPIs for use of supported standard (Field 2.2)

Name/Identifier	Description	Metric	Method of collection and measurement
IoT Open platform	Open standards supported by the IoT platform.	Number	How many open standards are used and implemented?
Standard wireless interoperability	The number of wireless standards supported by the IoT platform.	Number	How many different wireless standards are supported per platform?
Standard interoperability interfaces	The number of interoperability interfaces	Number	How many different interface standards are supported per platform?
Use of existing standards	Compliance with the existing certification programs (e-g. ISA/IEC 62443 Cybersecurity Certificate Programs)	Number	How many different IoT use implementations are compliant with existing standards?
Security	IoT platform security level.	Percentage	The fraction (percentage) of wireless communication standards in compliance with data regulations data security, against all wireless communication standards used within the IoT platform.

4.2.3 Capacity to solve interoperability and connectivity issues (Field 2.3)

The capacity to solve interoperability and connectivity issues field includes the ability to obtain interoperability and connectivity support for communications, data exchanges, etc.

Table 17: KPIs for capacity to solve interoperability and connectivity issues (Field 2.3)

Name/Identifier	Description	Metric	Method of collection and measurement
Standardised interfaces	The number of standard interfaces for easy implementation.	Number	How many standard interfaces per platform?
Network interoperability	Network interoperability for communication and availability	Number	Number of interoperability standards used.
Semantic interoperability	Semantic interoperability for data management and control.	Number	Number of interoperability standards used.

4.2.4 Scalability (Field 2.4)

The scalability field considers the ability to rapidly adapt to an increased user-base.

Table 18: KPIs for scalability (Field 2.4)

Name/Identifier	Description	Metric	Method of collection and measurement
End-nodes	The maximum number of end-nodes possible.	Number	How many connected end-nodes are tested or specified?
Subscribers	The maximum number of subscribers.	Number	How many subscribers are tested or specified?
Coverage area (rural areas)	The maximum coverage area	Area	What is the maximum coverage in rural areas?
Coverage area (urban areas)	The maximum coverage area	Area	What is the maximum coverage in urban areas?

4.2.5 Efficiency in the maintenance, deployment and life-cycle of services and software running (Field 2.5).

Efficiency in the maintenance, deployment and life-cycle of services and software running. Nowadays it is clear how complicated managing the inventory of an IoT infrastructure could be. It might be even more complicated to maintain the infrastructure (potentially very heterogeneous) always correctly upgraded. Traditional methodologies for maintaining upgraded running software (download and burn a firmware to a device directly connected to a computer) have to be considered as a minimum requirement. New methodologies to automatize these tasks over the air must be also taken into account and supported.

Table 19: KPIs for efficiency in the maintenance, deployment and life-cycle of services and software running (Field 2.5)

Name/Identifier	Description	Metric	Method of collection and measurement
Manual deployment	Manual deployment of software over IoT devices.	Time by device in seconds	Time elapsed since a new software build is ready to make it available (up and running) by device.
Automatic deployment	Automatic deployment of software over IoT devices.	Time by device in seconds	Time elapsed since a new software build is ready to make it available (up and running) by device, without human intervention.
Manual deployment	Manual deployment of software over IoT devices.	Time to deploy a new service/firmware into the whole infrastructure	Time elapsed since a new software build is ready to make it available (up and running) in all the devices
Automatic deployment	Automatic deployment of software over IoT devices.	Time to deploy a new	Time elapsed since a new software build is ready to make it

		service/firmware into the whole infrastructure	available (up and running) in all the devices, without human intervention.

4.2.6 Integration with the existing and new infrastructure (Field 2.6)

The ability to integrate the IoT technologies and platforms for IoT applications using new and existing infrastructure. Efficient deployment, sustainability and lifetime of IoT application.

Table 20: KPIs for integration with the existing and new infrastructure (Field 2.6)

Name/Identifier	Description	Metric	Method of measurement
Seamless integration	Seamless integration with existing infrastructure.	1 - 4	Do the existing infrastructure need updates, changes, etc.? 1) None 2) Minor 3) Major 4) Not possible
Re-use	Re-use of existing infrastructure.	Percentage	What is the re-use of existing infrastructure?
Installation complexity	Installation complexity like individual/local adjustments etc.	1-10	Easiest 1, most difficult 10

4.3 Ecosystem strategy and engagement (Dimension 3)

The ecosystem strategy and engagement dimension shall tell us if there is an ecosystem strategy in place and, if yes, how well it is understood and followed by the LSPs.

4.3.1 Ecosystem awareness (Field 3.1)

The ecosystem awareness field refers to the LSPs' capability to understand the ecosystem landscape with its existing connections and relationships in place, while outlining their own position in it and visioning vis-à-vis the overall ecosystem and industry.

Table 21: KPIs for ecosystem awareness (Field 3.1)

Name/Identifier	Description	Metric	Method of collection and measurement
Players and roles	Understanding the ecosystems players and their roles	Textual (Open Q)	Face-to-face Interview
Connections	Understanding the existing connections and relationships among ecosystem players	Textual (Open Q)	Face-to-face Interview
Vision	LSPs' current collocation within Ecosystem	Textual (Open Q)	Face-to-face Interview
Roadmap	LSPs' ecosystems approach and planned evolution in the short and long-term	Textual (Open Q)	Face-to-face Interview
Ecosystem Members	Systematic mapping of actors within their own ecosystem	Number	Online survey; Face-to-face Interview. Number of start-ups identified; Number of SMEs identified Number of large companies/corporates identified Number of IoT platform providers Number of third-party service providers identified Number of hardware suppliers identified.

4.3.2 Stakeholders' engagement (Field 3.2)

The stakeholders' engagement field includes the ability to reach out to the appropriate stakeholders involved in the LSPs and ability to engage and motivate them, ensuring a solid and reactive operative framework.

Table 22: KPIs for stakeholders' engagement (Field 3.2)

Name/Identifier	Description	Metric	Method of collection and measurement
Stakeholders number	Number of stakeholders involved	Number	Online Questionnaire – Existing Material
Stakeholders' Industries and Skills	Stakeholders' sectors and capabilities	Textual (List)	Online Questionnaire
Partners Roles	Partners' roles within LSPs	Textual (Open Q)	Face-to-face Interview
Engagement Frequency	Frequency of partners' interactions and meetings	Textual (List)	Online Questionnaire
Engagement Mode	Mode/type of partners' meeting and interactions	Textual (List)	Online Questionnaire
Effort Parity	How LSPs' efforts are shared across partners	Textual (List)	Online Questionnaire
Reward system	How partners are rewarded and motivated for their LSPs' involvement	Textual (Open Q)	Face-to-face Interview

4.3.3 External partnerships and collaboration (Field 3.3)

The external partnerships and collaboration field includes the ability to expand the LSPs' network externally, building alliances and strategies, in order to foster LSPs' capabilities and solidity, while enforcing and facilitating go-to-market channels.

The more the stakeholders' ecosystems will cover different expertise, industry subsectors and technology areas, the more LSPs' strength and opportunities will grow. In addition, this field also includes the capability to involve trusted customers in after-sale activities, collecting feedback on operative systems and on-field products behaviours, while collaboratively developing new product features.

Table 23: KPIs for external partnership and collaboration (Field 3.3)

Name/Identifier	Description	Metric	Method of collection and measurement
External partnership agreements	Number of recorded formal or informal agreements between the project consortium and other companies or project consortia that establishes a two-way relationship	Number	Online Questionnaire – Existing Material
External Stakeholders' Industries and Skills	External Stakeholders' sectors and capabilities	Textual (List)	Online Questionnaire
External Stakeholders' Support	What added value external Stakeholders take to LSPs or which skill/capabilities gaps they fill	Textual (Open Q)	Face-to-face Interview
Customer Interaction	LSPs' ability to collect feedback on operative systems and on-field products, thanks to a continuous interaction with customers	Textual (List)	Online Questionnaire
Collaboration Strategy	Assessment of the processes in place to identify and approve new alliances and partnerships	Textual (Open Q)	Face-to-face Interview

4.3.4 Public and government engagement (Field 3.4)

The public and government engagement field includes the ability to reach out and engage with public authorities and regulators. These may be city councils or municipalities, but also public organizations (e.g. hospitals, retirement homes, schools, charity associations), industry-specific regulators, and trade associations.

Table 24: KPIs for Public and government engagement (Field 3.4)

Name/Identifier	Description	Metric	Method of collection and measurement
Municipalities connection	Number/country/role of Municipalities involved in the LSPs as partners or external stakeholders	Number – Open Question	Online Questionnaire – Face-to-face Interview
Public organizations connection	Number/type/role of Public organizations (e.g. hospitals, retirement homes, schools, charity associations) involved in the LSPs as partners or external stakeholders	Number – Open Question	Online Questionnaire – Face-to-face Interview
Regulators and Trade Associations connection	Number/type/role of Regulators and Trade Associations involved in the LSPs as partners or external stakeholders	Number – Open Question	Online Questionnaire – Face-to-face Interview

4.4 Ecosystem openness and external collaboration (Dimension 4)

The ecosystem openness and external collaboration dimension shall tell us how open and accessible is the ecosystem for third parties outside the LSPs.

4.4.1 Value chain openness (Field 4.1)

The value chain openness field reflects LSPs' openness to third parties suppliers and market channels, guaranteeing an equal access and same rights to all potential value chain actors

Table 25: KPIs for value chain openness (Field 4.1)

Name/Identifier	Description	Metric	Method of collection and measurement
Suppliers equality	Assessment of LSPs' ability to guarantee equal rights to potential suppliers, avoiding exclusive licenses/authorisations and geographical barriers.	Textual (List)	Online Questionnaire
Sale channels equality	Assessment of LSPs' ability to guarantee equal rights to their selected sale channels, avoiding exclusive licenses/authorisations, geographical barriers and cost disparities.	Textual (List)	Online Questionnaire
Sale channels conditions	Sellers' possibility to set their own prices, advertise and market their goods while avoiding unfair quality standards or production costs	Textual (List)	Online Questionnaire
Supplier information	Have end-users equal access to information? Are they influenced from external parties in their resellers choice? Is there	Textual (List)	Online Questionnaire

	any implicit costs for changing supplier?		

4.4.2 Inclusiveness and participation for third parties (Field 4.2)

The inclusiveness and participation for third parties field includes the effective ability for third parties to use LSPs products and services and with which rights.

Table 26: KPIs for inclusiveness and participation for third parties (Field 4.2)

Name/Identifier	Description	Metric	Method of collection and measurement
Third-party platform resources access	Possibility for third parties to access LSPs' platforms	Yes/No	Online Questionnaire
Licensing Model	Description of the licensing mechanisms in place to assure equal right access to third parties	Textual (Open Q)	Face-to-face Interview
Usage rights level	Description of the usage rights LSPs have in place on their materials/products/services	Textual (Open Q)	Face-to-face Interview

4.4.3 Openness of business models (Field 4.3)

The openness of business models field includes the business models' ability to serve vertical-specific needs or horizontal/cross-vertical needs.

Table 27: KPIs for openness of business models (Field 4.3)

Name/Identifier	Description	Metric	Method of collection and measurement
Business model replicability	Usage of business models on different cases	Number of verticals addressed	Ability for valid business models to be used on different verticals with similar value chains and stakeholders involved
Incumbent existence	Ability to transform the market	Incumbent number	Assessment on the critical mass of incumbents inside the ecosystem needed to disrupt and transform the market.
New Business model adoption	How fast or agile change can IoT business models sustain depending on applications and stakeholders' profiles in the IoT ecosystem	Number of types of business models and revenue streams.	Frequency of business model's changes or frequency in the number and type of revenue streams generated by LSPs.

4.4.4 Open source strategy (Field 4.4)

The open source strategy field includes the degree of open source elements in the ecosystem.

Table 28: KPIs for open source strategy (Field 4.4)

Name/Identifier	Description	Metric	Method of collection and measurement
Interoperability	Ability of the solution adopted to interact with external parties	End devices supported. Available open APIs visualization	Assessment on the degree of interoperability of the adopted solution, with respect to the potential use of the deployed system of third party stakeholders providing solutions at different layers.
Discovery	Promotion of resources and openness	Resource views	Ability of third parties to discover, locate and interact

			open source services on the platform
Platform usage	of third parties accessing to open APIs and resources	Resource usage	Ability of third parties to make use of open resources in the platform, tracking their activity and interactions.

4.5 Marketplace and business impacts (Dimension 5)

The marketplace and business impacts dimension shall tell us how well the LSPs have developed their value proposition, what business models are adopting and with which monetization mechanisms. At the same time, it will measure LSPs' ability to generate end-users, business/consumer benefits, while competing with existing players in their target markets.

4.5.1 Business models (Field 5.1)

The business models field includes the ability to support diversified business models (capability to understand their different features, to serve their needs, adapt to their mechanisms, etc.), while selecting channels for acquiring and dealing with customers in their target market.

Table 29: KPIs for business models (Field 5.1)

Name/Identifier	Description	Metric	Method of collection and measurement
Strategy	Business models (e.g. subscription, freemium, license, …) chose by LPSs to approach the market	Textual (List – Multiple Options)	Online Questionnaire
Flexibility	Ability to move from one business model to another one according to clients variable needs (e.g. consumption daily peaks)	Textual (List)	Online Questionnaire
Channel	Channels (e.g. personal website, sales agents, app-stores, etc.) selected for product/service going to market activities	Textual (List – Multiple Options)	Online Questionnaire
Retention	Ability to study customers' buyer behaviour (e.g. monitoring repeated orders, tracking early adopters in comparison to recent buyers), retain customers and engage them to follow you across a maturity roadmap (starting from limited pilots to different business cases)	Textual (Open Q)	Face-to-face Interview

4.5.2 Market readiness and monetization mechanisms (Field 5.2)

The Market readiness and Monetization mechanisms field refers to LSPs' value proposition readiness and solidity, their commercial strategy and billing/accounting mechanisms allowing stakeholders to extract revenue streams.

Table 30: KPIs for 4.5.1 Market readiness and monetization mechanisms (Field 5.2)

Name/Identifier	Description	Metric	Method of collection and measurement
Value proposition readiness	How near is LSPs' concept/idea to being commercially exploitable? Is that at a Proof of	Textual (List)	Online Questionnaire

	concept stage or already sold in marketplace?		
Value proposition solidity	Identification of IoT practices adopted by LSPs to verify their value proposition with target customers	Textual (List)	Online Questionnaire
Commercial strategy	Verification of LSPs' commercial strategy within the realm of IoT-enabled products and/or services to acquire customers (e.g. are sales materials available and channels activated?)	Textual (List)	Online Questionnaire
Revenue streams	Identification of the number of revenue streams. Characterization of all potential revenue streams associated to IoT-based business models adopted by each stakeholder	Textual (Open Q)	Face-to-face Interview
Incentivisation mechanisms	Presence of incentives associated to a specific revenue stream. Determination of the existence of incentives encouraging stakeholders to adopt a specific IoT business model.	Textual (Open Q)	Face-to-face Interview
Net revenue	Total value of IoT-enabled products or services sold by LSPs in initial years of activity	Number (€)	Face-to-face Interview

4.5.3 Business benefits (Field 5.3)

The business benefits field describes the LSPs' ability to disrupt end-users' daily activities and business metrics (e.g. operational costs, efficiency, customer care, etc.).

Table 28: KPIs for business benefits (Field 5.3)

Name/Identifier	Description	Metric	Method of collection and measurement
Business market needs	Type of benefits LSPs expect to deliver to their Business customers, compared with a benchmark elaborated by IDC based on external sources and expert assessment	Textual (List)	Online Questionnaire and IDC benchmark comparison
Business impact	LSPs' ability to track how their services/products are impacting their Business customers' daily activities, with a list of KPIs and associated measurements	Textual (Open Q) – LSPs' collected KPIs and metrics	Online Questionnaire
Consumer market needs	Type of benefits LSPs expect to deliver to their Consumer customers, compared with a benchmark elaborated by IDC based on external sources and expert assessment	Textual (List)	Online Questionnaire and IDC benchmark comparison
Consumer impact	LSPs' ability to track how their services/products are impacting their Consumer customers' daily activities, with a list of KPIs and associated measurements	Textual (Open Q) – LSPs' collected KPIs and metrics	Online Questionnaire

4.5.4 Market competitiveness (Field 5.4)

The Market Competitiveness field includes the ability to disrupt the competitor landscape in the addressable market, replacing/improving existing solutions on the market or in certain case opening completely unexplored new markets.

Table 29: KPIs for market competitiveness (Field 5.4)

Name/Identifier	Description	Metric	Method of collection and measurement
Competition level	Level of competition in LSPs' target market	Textual (List)	Online Questionnaire
Competitors and market share	LSPs' relative position in their addressable market competitive landscape	Textual (Open Q)	Face-to-face Interview
Organizational strategy innovativeness	Are LSPs' services/products proposing standalone offering or fitting into an existing commercial strategy?	Textual (List)	Online Questionnaire
Concept innovativeness	Do LSP's concept/ideas provide an incremental improvement or radically change/invent existing products and services?	Textual (List)	Online Questionnaire

4.5.5 Legal issues (Field 5.5)

The legal issues field will give us answers on whether legislation is supporting the usability and diffusion of the proposed demonstration or impeding it.

Table 31: KPIs for legal issues (Field 5.5)

Name/Identifier	Description	Metric	Method of collection and measurement
Legislation assessment	Identification of legislation in place for a given IoT topic per country and use case/domain to determine whether legislation is an incentive, a barrier or is not relevant.	Textual (List)	Online Questionnaire; Existing Material
GDPR	Compliance of use case and business model with GDPR	Textual (List)	Questionnaire; Existing Material
IoT Policy framework	Type of IoT policy framework followed LSP.	Textual (List)	Questionnaire; Existing Material

4.5.6 Privacy, security, trust and ethical issues (Field 5.6)

The privacy, security, trust and other ethical issues field will give us answers on whether LSPs do have mechanisms in place to ensure trust/reputations, privacy and respect of other ethical issues.

Table 32: KPIs for privacy, security, trust and ethical issues (Field 5.6)

Name/Identifier	Description	Metric	Method of collection and measurement
Platform lifetime protection	Assessment on the estimated lifetime protection of the IoT platform in place per each LSP (are security mechanisms such as schemes, key sizes and computational power in place?)	Textual (List)	Questionnaire; Existing Material
User compliance	The number of users compliant with each element of the security	Percentage	Questionnaire

	policy divided by the total number of users, multiplied by 100		
Value-at-Risk	Quantification based on the expected frequency with which attacks seem likely to happen and the loss given event (LGE) provoked by a single attack	Percentage	Questionnaire
Systems service level	Percentage of time that information systems services are available	Percentage	Questionnaire
Number of Compromises	Number of incidents during a given period in which network or systems security was compromised divided by industry benchmarking figures, multiplied by 100	Percentage	Questionnaire
Vulnerability Counts	The number of vulnerabilities found on policy compliant devices divided by the number of vulnerabilities found on policy non-compliant devices	Percentage	Questionnaire
Authorisation mechanisms	Protection against non-valid accesses (are authorisation mechanisms and in place and authorisation protocols adopted to protect against access through non-valid signatures?)	Textual (List)	Questionnaire; Existing Material

4.5.7 Experience readiness level (Field 5.7)

The Experience Readiness Level (ERL) measures the capability of IoT systems to trigger a well-suited user experience. The ERL is a complimentary approach to Technology Readiness Level (TRL).

A shift of attention from labs and drawing boards to involving existing and new communities at an early stage of IoT development is fostered and advocated. If the goal is the adoption of IoT by masses in full confidence, it's important we stop thinking about IoT as objects and start thinking of IoT as triggers for better lives. The Experience Readiness Level (ERL) is a new notion that introduces the focus on 'better lives' and moves the attention from the production to the consumption level of IoT.

ERL uses a co-creation framework, i.e. activities where customers, end users, application owners, artists and developers are involved as active participants in the design and development of personalized IoT applications, use cases, products, services, and experiences in IoT platforms ecosystems.

Table 33: KPIs for experience readiness level (Field 5.7)

Name/Identifier	Description	Metric	Method of collection and measurement
Design of experiential elements	Number of co-created concepts and sketches that express basic principles and technologies that will support the IoT experience	Number	Survey, reporting
Experiential platform developed	Number of prototypes and mock-ups developed by artists, scientists and technologists through co-creation	Number	Survey, reporting

Co-creation of experiences with expert consumers	Quality of experience of expert consumers immersed in participative experiences developed through co-creation and demonstrated through operational prototypes, user interfaces, participative experiences	Textual	Behavioural analysis based on audio-visual observation, interviews
Co-creation of experiences with novice consumers	Quality of experience of novice consumers immersed in participative experiences developed through co-creation and demonstrated through operational prototypes, user interfaces, participative experiences	Textual	Behavioural analysis based on audio-visual observation, interviews
Consumer-driven IoT experience	Quality of new applications and experiences co-created through demonstrations in operational environments	Usability Metrics (e.g. completion rate, task time, comprehension)	Users will be asked to explore an experience while thinking-aloud performing tasks and asked questions aimed at probing their understanding of the experience.

4.5.8 Holistic innovation (Field 5.8)

Europe strongly relies on innovation to compete globally and to make human activities more sustainable and our society more inclusive. It is not about technology as such but about a better life for all of us. To achieve that, the IoT ecosystem have to think in a more holistic way to conceive radically novel products, services and processes that are also putting the human in the centre. Despite this imperative to work across boundaries and silos, Europe is still addressing innovation without fully engaging the creative forces that lie at the crossings of the arts, science, and technology.

The combination of Science, Technology and the Arts stimulates innovation and demand, and highlights potential roadblocks to acceptance before they are encountered.

Table 34: KPIs for holistic innovation (Field 5.8)

Name/Identifier	Description	Metric	Method of collection and measurement
Open source platform	Open source standards supported by each IoT platform.	Percentage	Questionnaire for LSPs. What is the fraction (percentage) of open source standards implemented against the total number of standards implemented?
Human-centred innovations	Percentage of IoT platforms using legal, technical and organisational safeguards strengthening trust, security and end-to-end personal data protection and privacy and building meaningful connections human beings and smart, dynamic objects	Percentage	Questionnaire
Critical approach to IoT	Artistic research and imagination introduces a novel framing of a problem, concept, challenge or capability.	Textual	Artistic statements, briefs, or research reports.
Connections and trust	Connections built between vendors, users, citizens and creatives.	Number	Number of new connections and contacts generated through collaboration between vendors, users, citizens and creatives

New interdisciplinary collaborations	Number of creative prototypes developed and/or new creative collaborations across disciplines and sectors.	Number	Questionnaire for LSPs
Novel experiences, visibility, attention, participation	Number of artistic works produced and presented to an audience that create visibility and attention for IoT capabilities and consequences	Number	Number of attendees and attendances; media impact (audience research, questionnaires, interviews).
Literacy and demand	Combining diverse disciplines can elicit insights and stimulate literacy and industry demand.	Textual	Case studies and user research (questionnaires and interviews).

4.6 Societal and economic impacts (Dimension 6)

The societal and economic impacts dimension measures the societal (end users' worktime/life and communities' impacts) and economic impacts (indirect revenue and employment) in the short and medium-long term.

4.6.1 Indirect revenue generation (Field 6.1)

The Indirect Revenue Generation field includes LSPs' ability to indirectly foster their customers' revenue generation. This will allow end-users to expand their existing business (e.g. customers are able to launch new products/services on the market and overcome competitors, thanks to LSPs' solutions) or enter new markets, while testing different revenue channels.

Table 35: KPIs for indirect revenue generation (Field 6.1)

Name/Identifier	Description	Metric	Method of collection and measurement
Additional revenue boost	Are LSPs' services/products allowing end-users to increment their existing revenues (e.g. allowing them to sell more or beating competitors)?	Textual (List)	Online Questionnaire
New market boost	Are LSPs' services/products allowing end-users to launch completely new products and/or enter new markets?	Textual (List)	Online Questionnaire
Indirect revenue impact	How many additional revenues LSPs' services/products are generating for end-users on average?	Percentage Range	Online Questionnaire

4.6.2 Employment macro-impact (Field 6.2)

The Employment macro-impact field includes LSP's ability to generate potential new jobs both internally (within LSPs' stakeholders) and among customers in their addressable markets, fostering regional employment growth.

Table 36: KPIs for employment macro-impact (Field 6.2)

Name/Identifier	Description	Metric	Method of collection and measurement
Direct employment generation	How LSPs' activities are going to provide new employment opportunities within LSPs' stakeholder?	Textual (List)	Online Questionnaire
Employment effect	Are LSPs' products/services impacting their customers' workforce (i.e. will lead to new	Textual (List)	Online Questionnaire

	employment opportunities or will lead to cut existing workforce)?		
Indirect employment generation	In which measure LSPs' products/services will impact their customers' workforce?	Percentage Range/ Number	Online Questionnaire

4.6.3 User worktime/life impact (Field 6.3)

The Use worktime/life impact field includes the extent to which LSPs support and enhance end-users' quality of working and personal life.

Table 37: KPIs for user worktime/life impact (Field 6.3)

Name/Identifier	Description	Metric	Method of collection and measurement
Worktime – Time Saving	LSPs' ability to improve end-users' working efficiency, leading to time saving	Textual (List)	Online Questionnaire
Worktime – Error Reduction	LSPs' ability to reduce end-users' errors at work	Textual (List)	Online Questionnaire
Worktime – Repetitiveness Reduction	LSPs' ability to reduce end-users' repetitive tasks at work	Textual (List)	Online Questionnaire
Worktime – Information and Data Access	LSPs' ability to improve end-users' information and data access at work	Textual (List)	Online Questionnaire
Worktime – Collaboration and Sharing	LSPs' ability to improve end-users' collaboration and document/information sharing with colleagues and clients	Textual (List)	Online Questionnaire
Worktime – Workplace	LSPs' ability to improve end-users' workplace	Textual (List)	Online Questionnaire
Worktime – Education and Skills development	LSPs' ability to improve end-users' education and working skills development	Textual (List)	Online Questionnaire
Worktime – Task Organization	LSPs' ability to improve end-users' working task organization	Textual (List)	Online Questionnaire
Worktime – IT/OT tools usability	LSPs' ability to improve end-users' IT/OT tools usability	Textual (List)	Online Questionnaire
Life – Security Improvement	LSPs' ability to improve end-users' personal security	Textual (List)	Online Questionnaire
Life – Privacy & Personal Data Protection	LSPs' ability to improve end-user's privacy and personal data protection	Textual (List)	Online Questionnaire
Life – Citizen Involvement Participation	LSPs' ability to better involve citizens in city life and public administration	Textual (List)	Online Questionnaire
Life – Fitness and well-being	LSPs' ability to improve end-users' well-being and facilitate fitness activities	Textual (List)	Online Questionnaire
Life – Quality of life	LSPs' ability to improve end-users' quality of life	Textual (List)	Online Questionnaire
Life – Information and Data Access	LSPs' ability to improve end-users access to information and data	Textual (List)	Online Questionnaire
Life – Social inclusion	LSPs' ability to improve end-users' social inclusion	Textual (List)	Online Questionnaire
Life – Education and skills development	LSPs' ability to improve end-users' education and skills development	Textual (List)	Online Questionnaire

Life – Transportation solutions	LSPs' ability to improve end-users' demand and use of sustainable transport solutions	Textual (List)	Online Questionnaire
Life – Health	LSPs' ability to improve end-users' personal health and access to health service providers	Textual (List)	Online Questionnaire
Life – Entertainment	LSPs' ability to improve end-users' leisure	Textual (List)	Online Questionnaire

4.6.4 Targeted social groups (Field 6.4)

The Targeted Social Groups reflects LSPs' ability to address more vulnerable social groups' needs and challenges.

Table 38: KPIs for targeted social groups (Field 6.4)

Name/Identifier	Description	Metric	Method of collection and measurement
Socially excluded groups	LSPs' ability to help the social integration of socially excluded persons	Textual (List)	Online Questionnaire
Low income	LSPs' ability to enhance the general living conditions of low income groups	Textual (List)	Online Questionnaire
Ethnic or cultural minorities	LSPs' ability to address ethnic and cultural minorities' needs and challenges	Textual (List)	Online Questionnaire
Elderly	LSPs' ability to address elderly persons' needs and challenges	Textual (List)	Online Questionnaire
Disabled	LSPs' ability to address disabled's' needs and challenges	Textual (List)	Online Questionnaire

4.7 Policy and governance impacts (Dimension 7)

The policy and governance impacts dimension shall tell us how well do the LSPs contribute to the existing national and European policy issues related to IoT and promote the consolidation of IoT standards, while fostering SMEs and young entrepreneurs' role in the broad ecosystem.

4.7.1 European IoT Ecosystem promotion and competitiveness safeguard (Field 7.1)

The European IoT Ecosystem promotion and competitiveness safeguard field reflects the ability of LSPs to align with strategic policy objectives in order to large scale deployments of IoT in Europe and benefit Europe's IoT industry.

Table 39: KPIs for European IoT ecosystem promotion and competitiveness safeguard (Field 7.1)

Name/Identifier	Description	Metric	Method of collection measurement
Interaction with other similar initiatives	Degree of LSPs' interaction with other similar European and national projects, in order to foster collaboration and best practices sharing. This looking at the number of connections with other projects, the frequency of meetings and actions adopted.	Number/Textual (Open Q)	Face-to-face Interview
Validity on EU Member States	Identification of EU countries where the proposed initiative	Number/Textual (List)	Online Questionnaire

	can be meaningfully applied, being feasible from the regulatory perspective and sustainable from the business perspective.		
Proven replicability	Assessment of the different sectors and scenarios where LSPs' proposed architecture could be replicated and adopted	Textual (Open Q)	Face-to-face Interview
Global activities and strategies	Identification of the plans and strategies in place to succeed outside origin countries and EU, towards other regional worldwide markets	Textual (List)	Online Questionnaire

4.7.2 IoT standards promotion (Field 7.2)

The IoT standards promotion field reflects how effectively do LSPs contribute to the effort of coordinating and consolidating IoT standards across IoT vendors and providers.

Table 40: KPIs for IoT standards promotion (Field 7.2)

Name/Identifier	Description	Metric	Method of collection and measurement
Standard architecture	Use of standard infrastructure architecture	Standard	Assessment on the use or adoption of standardized solution for the infrastructure architecture
Standard service/applications	Use of standard Service/application interfaces	Standard	Assessment on the use or adoption of standardized solution for the service/application interfaces
Standard data formats	Use of standard data formats	Standard	Assessment on the use or adoption of standardized solution for the data formats
Standard working groups interaction	Assessment of how LSPs are interacting with European standard working groups	Textual (List)	Online Questionnaire
Contributions to standards	New proposals regarding architecture, services, data formats or interaction mechanisms made to standard bodies through active participation in working groups	Number	Online Questionnaire

4.7.3 Trusted, safe, secure IoT environment promotion (Field 7.3)

The trusted, safe, and secure IoT environment promotion field reflects LSPs' contribution to the promotion of an IoT environment where security, privacy, safety, efficiency, and other legal or ethical issues are duly taken into consideration.

Table 41: KPIs for trusted, safe, secure IoT environment promotion (Field 7.3)

Name/Identifier	Description	Metric	Method of collection and measurement
Acceptance validation	Extent to which the exploitation of security and privacy mechanisms towards best practices is duly integrated by LSPs	Textual (List – Multiple Options)	Online questionnaire; Face-to-Face interviews; Existing Material
Anticipation to new regulations	Identification of EU and national upcoming legislation or policy intervention in IoT-related areas	Textual (List – Multiple Options)	Online questionnaire; Face-to-Face interviews

Digital single market strategy	Degree of Compliance with the digital single market strategy (personal data protection, security, safety, liability, net neutrality)	Textual (List – Multiple Options)	Online questionnaire; Face-to-Face interviews
Policy/governance link	Ability and willingness to discuss and adopt the use of an IoT policy framework linked with IoT Governance in a coordinated and consolidated manner across IoT Pilots and activities	Textual (List – Multiple Options)	Online questionnaire; Face-to-Face interviews

4.7.4 Impact on SMEs, start-ups and young entrepreneurs (Field 7.4)

The impact on SMEs and young entrepreneurs field reflects LSPs' ability to involve start-ups and SMEs, fostering their growth and role in the new IoT paradigm.

Table 42: KPIs for impact on SMEs start-ups and young entrepreneurs (Field 7.4)

Name/Identifier	Description	Metric	Method of collection and measurement
Joint LSP calls	Identification of joint calls launched by LSPs, if any, in order to support SMEs and young entrepreneurs	Number of joint calls/ Available funding	Online Questionnaire
Involvement	Are SMEs, start-ups and young entrepreneurs directly involved in LSPs' stakeholders' ecosystem and related activities?	Number/Textual (List)	Online Questionnaire
Relevancy	Assessment of how relevant LSPs initiatives are to European SMEs (considered as final end-users), involving them in ongoing user acceptance testing and providing services/solutions which could accelerate their growth and development	Textual (List)	Online Questionnaire
SMEs oriented channels and strategies	Identification of LSPs' SME-specific marketing activities, pricing options, market channels, and strategies	Textual (Open Q)	Face-to-face Interview

4.8 Community support and stakeholders' inclusion (Dimension 8)

The community support and stakeholders' inclusion dimension describes LSPs' interaction with the external community, on one side with developers and on the other with citizens. It also includes LSP's education activities and accessibility improvement efforts in place.

4.8.1 Developers' community accessibility (Field 8.1)

The developers' community accessibility field reflects the connections in place between LSPs and external developers' community, highlighting the developers' accessibility level to LSPs material and practices.

Table 43: KPIs for access to developers' community (Field 8.1)

Name/Identifier	Description	Metric	Method of collection and measurement
Open APIs penetration	Identification of the percentage of published APIs that are open to external developers	Percentage (%)	Online Questionnaire

Activated developers	Measure of the effectiveness of the outreach and engagement activities involving external developers	Number of monthly unique visitors to API site	Online Questionnaire
Engaged developers	Identification of the amount of external developers engaging with the LSPs	Number of sign-ups to developer APIs)	Online Questionnaire
Active users	Identifying the number of active users	Number of monthly calls on Open API per developer)	Online Questionnaire
Outreach	Communication and engagement with the wider developer community	Number of virtual or in-person developers' events (e.g. hackathon) presented at or hosted by LSPs' stakeholders	Face-to-face Interview

4.8.2 Education availability (Field 8.2)

The education availability field includes all educational activities LSPs have in place to amplify their activities and foster LSPs' services/solutions adoption.

Table 44: KPIs for education availability (Field 8.2)

Name/Identifier	Description	Metric	Method of collection and measurement
Educational resources	Identification of the educational resources/material publicly available on LSPs' platform	Textual (List)	Online Questionnaire
Educational effectiveness	Assessment of the level of usage of the educational materials provided on LSPs' platform	Number of downloads/views	Online Questionnaire
Live training	Identification of live training (in-person or remotely) that LSPs put in place.	Annual Number and Type of training activities	Online Questionnaire
Live training effectiveness	Identification of the effectiveness and success of live training (in-person or remotely) that LSPs put in place.	Number of participants/registrants	Online Questionnaire

4.8.3 Accessibility levels (Field 8.3)

The accessibility levels field reflects to which degree LSPs' support is accessible to different languages speakers and impaired people.

Table 45: KPIs for accessibility levels (Field 8.3)

Name/Identifier	Description	Metric	Method of collection and measurement
Accessibility	Compliance of the interfaces with the	Percent	Average compliance of interface with the W3C Web Content Accessibility Guidelines (WCAG) 2.1
Language	Translation of communications and content into the main language of the key user groups.	Textual (List)	Online Questionnaire
Impaired user groups	Definition of specific groups with accessibility needs through	Number Percent	Number of individual needs lists developed and prioritized

	engagement with representatives and users		for specific needs during design phase and adjustment Level of integration of needs into design
User involvement	Assessment of how end-users' feedback on accessibility are collected and how they are directly involved in accessibility improvement activities	Textual (List)	Online Questionnaire

4.8.4 Community engagement (Field 8.4)

The community engagement field includes LSPs' activities to directly interact with citizens, via public community events and activities.

Table 46: KPIs for community engagement (Field 8.4)

Name/Identifier	Description	Metric	Method of collection and measurement
Public community events	Assessment of public community events organized or attended by LSPs	Annual Number and Type of Public Community events	Online Questionnaire
Public community events effectiveness	Identification of the effectiveness and success of public community events organized or attended by LSPs	Number of participants/registrants	Online Questionnaire
Citizens' involvement	Identification of LSPs' direct interaction with citizens (e.g. co-creation workshops, social media forums, marketing campaigns)	Textual (List)	Online Questionnaire

5. APPLICATION DOMAINS AND VARIOUS USE-CASES

This chapter presents five principal domains in which the European IoT Large-Scale Pilots Programme operates and where the LSPs are currently developing and deploying their demonstrations. For each domain, the major trends underpinning their current and future developments are sketched out, as well as their possible interactions with the latest technology developments, in particular with IoT technologies. Based on these initial considerations, a preliminary list of areas in which additional domain-specific KPIs need to be specifically designed is suggested. These initial proposals of KPIs will be further refined and completed based on a series of interactions with the LSPs and with domain-expert stakeholders.

5.1 Smart living environments for ageing well

Major market forces — an aging population, increasing prevalence of chronic conditions, access issues due to staffing shortages, and other pressing industry challenges — are compelling payers and providers to invest in connected health technology to deliver care more efficiently and to engage consumers to manage their health. This poses some constraints on a public health system and welfare state currently under pressure to contain costs and offer an increasing and more sophisticated and highly specialised number of services to a rapidly ageing part of society.

Latest technologies, IoT amongst them, provide the opportunity to automate some of the more resources and time-consuming tasks required to provide care for the ageing.

Seeking a passive way to measure patients' vital signs and other biometrics, more than 40% of healthcare organizations across the world will use IoT-enabled biosensors by 2019.

As the mantra for convenient access to high-quality, cost-effective healthcare grows, healthcare organizations are leveraging a wide range of connected health technologies to provide urgent, chronic, and preventive care to patients on demand anytime and anywhere

A panoply of different stakeholders will come into play when measuring the impact of IoT demonstrations in the smart living environment. These stakeholders would range from the individuals receiving health services, to the health organizations, carers, NGOs and supporting aid organizations and would obviously extend to the technology providers themselves. Several domain-specific requirements would have to be considered when designing KPIs explicitly adjusted to the smart living environment. Among them scalability, cost containment, ease of use and predictive analytics would certainly play a prominent role. Open standards would also be required to ensure all involved and interested parties have secured access in a highly-secured environment and preserving data privacy.

The list of additional KPIs specifically designed to meet the needs of smart living environments for ageing well could include the following:

- **Deployment of domain-specific technology and its ability to serve the users' requirements.** In this area, for example, domain-specific KPIs should measure the use of predictive analytics technologies and alarms/notification features and their capacity to predict health risks and send notifications when medical attention is required.
- **Infrastructure's quality and performance.** In this area, specific KPIs should be able to asses the quality, coverage and availability of the network (especially in remote or rural areas). Some KPIs should also be included to measure the degree of confidentiality and security allowed by the infrastructure put in place, as well as the adoption of open standards allowing easy access to all involved parties.
- **Impacts on patients and health services users**. KPIs would capture fundamental features such as ease of use for patients,

- impacts on quality of life, life expectancy increase, saved time in obtaining medical treatment and health services.
- **Impacts on general practitioners, medical staff and health service providers**. In this area, specific KPIs would be designed to apprehend phenomena related to the health service providers such as the reduction of emergency procedures at hospitals, reduction of total medications, reduction of emergency procedures, better use of hospital supplies, etc.
- **Socio-economic implications**: here a few KPIs should be considered to measure the overall impact of IoT solutions and implementations in smart living environments for aging well. As an example, KPIs measuring the patient's level of engagement in their own health, or the increase in mortality ages, or the ability to conduct a more engaged and autonomous life could be taken into consideration.

A more detailed, yet provisional, list of indicators in this domain is outlined in the following table:

Table 47 Smart living environments for aging well – provisional list of indicators

Name/Identifier	Description	Metric	Method of collection and measurement
Alarms/Notifications	Capacity to send notifications when monitored health indicators out of range or when medication required	Alarm/notifications per device/day	Online questionnaire; Face-2-face interviews
Cost containment	Self-sustainable solution	RoI	Online questionnaire; Face-2-face interviews
Ease of use	Simplicity of use for user interface to allow non-technical users confident, autonomous use and fast adoption	Take up rates in terms of number of users and number of interactions/day	Online questionnaire; Face-2-face interviews
Impact on life quality	Improvement on life quality of those benefitting from service	Reduced number of emergency interventions. Reduced number of General Practitioner visits (for check-ups, collection of prescriptions etc)	Online questionnaire; Face-2-face interviews
Reduction of emergency procedures/calls	Reduction of need for emergency procedures at hospitals. Consequence of prevention and predicting capabilities of system	Direct YoY comparison on same age/condition patients for those using the system and those not using	Online questionnaire; Face-2-face interviews
Medications provided using automated means (robots/drones)	Proportion of total medications provided via drones/robots	Percentage/Variation over time/Error rates/Socio economic Cost implications	Online questionnaire; Face-2-face interviews
Repeatable prescriptions being delivered to patients digitally and on time	Proportion of repeatable prescription delivered using automated mechanisms	Percentage/Variation over time/Error rates/Socio economic Cost implications – freeing up time at surgeries and General Practitioners	Online questionnaire; Face-2-face interviews

5.2 Smart farming and food security

Once considered a “traditional” industry with a relatively low permeability to IT, agriculture is rapidly opening up to the wider phenomenon of digital transformation. The farming and food domains, in particular, are expected to be radically transformed by the use of connected objects that will become more and more context-sensitive and will be identified, sensed and controlled remotely. The IoT is therefore expected to become a real game changer for food and farm and its widespread application could lead to dramatic improvements of productivity and sustainability across a wide range of crops and throughout the whole of the food value chain.

Challenges abound though in this domain: agri-food “things” are in fact living objects most of the times and attached devices have to work in difficult environments and come to terms with network connectivity issues in rural areas. What is more, this domain still exhibits insufficient levels of interoperability and user concerns about data ownership, privacy and security, as well as a lack of appropriate business models that could become suitable for small and very small organizations. As a result, widespread fragmentation and scattered uptake by a small group of early adopters characterize IoT applications in the farming and food sector in Europe, despite the great world-wide interest of IoT technology providers and investors.

Domain-specific KPIs explicitly designed to test and validate large-scale IoT demonstrations in the food and farm space, should focus on the following:

- Business case demonstration of IoT deployments in farming and food ensuring, among other things, improved productivity and sustainability in a large number of application areas (e.g.: increase of crop’s, seed’s and animals’ performance; reduced irrigation costs; better choice of crops and seed; better resistance to diseases; etc.)
- Deployment of domain-specific technologies ensuring the application and usability in harsh environments (e.g.: deployment of domain-specific sensors and actuators such as termo-gyrometers, luximeters, APRs, CO2 sensors, multispectral sensors, etc.)
- Meeting of user specific requirements: security, privacy trust, ownership, hard conditions, living objects (e.g.: ability to monitor real-time machines’ and animals’ workloads; geolocation of animals and equipment, ability to improve production cycles, distribution and maintenance, etc.)
- Meeting wider consumer specific requirements: food security, health, trackability, (e.g.: ability to support environmental certifications, ensure produce integrity, reduced time-to-market, better product quality and freshness, ability to improve and enforce anti-counterfeiting measures, increased transparency across the whole of the food sector from production to consumers, better consumer experience and increased customer loyalty).

A preliminary list of domain-specific KPIs in the farming and food sector could include, but not be limited to, the following indicators:

Table 48: Smart Farming and Food Security – Provisional list of indicators

Name/Identifier	Description	Metric	Method of collection and measurement
Environmental conditions	Land temperature and humidity	Celsius degrees; mg	Online questionnaire; One-to-one interviews; Existing material
Productivity and sustainability	Harvested crop yields per hectare; Value of crop production per household; No. of hectares (or hhs.) with improved practice	Kg per hectare; units of Euro; hectares	Online questionnaire; One-to-one interviews; Existing material

Effective use of specific technology	Deployment of domain specific sensors (number of termo-gyrometers; number of luximeters; number of CO_2 sensors.	Units	Online questionnaire; One-to-one interviews; Existing material
Consumer experience and safety	Number of product safety and quality certification per year; Number of products tracked per year; Number of products withdrawn from market per year	Units	Online questionnaire; One-to-one interviews; Existing material

5.3 Wearables for smart ecosystems

The worldwide wearables market will reach volumes of 240.1 million units shipped by 2021, resulting in a CAGR of 18.2%. In addition, the number of applications developed for or adapted to function on wearable devices will grow from 30,840 in 2015 to 606,610 in 2020, at a compound annual growth rate (CAGR) of 81.5%. Smart watch app availability dominates the forecast period at 98% of total app availability or higher in a given year, generally in line with projected device category shipment volumes. However, gaming and enterprise use cases enabled by augmented reality (AR) and standalone functionality will drive an upward inflection in smart eyewear shipments and app availability beginning in 2018. Enterprise-oriented application development targeting smart eyewear will be relatively robust, approaching half of all eyewear app availability during the forecast period, although the number is relatively small in absolute terms.

Existing IoT middleware, architecture and technology have mitigated the complexity of communication and integration among different platforms and can greatly support and further contribute to the widespread use of wearables. Indeed, large numbers of wearables and applications running on existing IoT platforms may lead to the creation of large smart ecosystems consisting of heterogeneous interfaces and including machine-to-machine and human intervention.

A preliminary list of domain-specific KPIs for wearables in smart ecosystems could include the following indicators:

Table 49: Wearables for smart ecosystems – provisional list of indicators

Name/Identifier	Description	Metric	Method of collection and measurement
Wearable Type	Wearable devices include any wearable device designed for the human body with a microprocessor. "Wearable" implies that the device operates in a hands-free fashion and the user can readily put it.	Units (number of wearables deployed in clothing, eyewear, watch, wristband, neuro-wearable, etc.)	Online questionnaire; One-to-one interviews; Existing material
Operating System	A high-level operating system (OS) tracked by IDC meets three conditions: the ability to run multiple applications concurrently, support third-party applications, and run applications independent of the network. Not all devices will have a high-level OS, with many relying on a real-time OS (RTOS), the details of which are not tracked by IDC. Note that IDC tracks the OS embedded in the device and not what OS the device can sync to.	Unit and percentage (number of operating system per type; percentage of operating system time on total: Android Android Wear Linux WatchOS RTOS Tizen PebbleOS)	Online questionnaire; One-to-one interviews; Existing material

Connectivity	Wearable computing devices sometimes include communications capabilities to connect to a network. It can also include other types of connectivity such as NFC and Bluetooth	Unit and percentage (number of connectivity features per type and percentage of connectivity features on total): 3G 4GNone WiFi WiFi/3G WiFi/4G NFC Bluetooth	Online questionnaire; One-to-one interviews; Existing material
Sensors	Type of sensors included in the device	Unit and percentage (number of sensors per type; percentage of sensor types on total - Heart rate sensor, temperature sensor, UV sensor etc.)	Online questionnaire; One-to-one interviews; Existing material
Features	Additional features can include a wide variety	Unit (number of features by type: Water proof, touch screen, external speakers, etc.)	Online questionnaire; One-to-one interviews; Existing material

5.4 Smart Cities and reference zones in EU cities

A relevant part of the focus on IoT developments is set into the Smart Cities use case. Apart from the previously defined and generic IoT KPIs, there are some relevant metrics directly tied to Smart Cities. These metrics cope with some use-case-inherent aspects, such as the connectivity required to transfer information from IoT devices to the Internet or the need for device optimization.

Smart Cities currently comprise everyday life services aimed at enhancing citizen's quality of life, and covering a wide plethora of situations. Proposing measurable KPIs able to evaluate different scenarios is a task that has been carried out from different perspectives, being FP7 project CityPulse a great summary, as it covers up to 101 different scenarios [5].

Each scenario might have different scope and, therefore, different KPIs would prevail, among a great list where security, coverage, number and density of devices, availability, scalability, energy efficiency or network processing can be cited. IoT developers and/or scenario managers should consider all implications of the selected use case.

The list of additional KPIs tailored for the special needs of Smart Cities and different from those explained on section 0 is presented below.

- **Energy efficiency**. Miniaturization, installation on places with limited/difficult access, node dispersion/concentration and multi-purpose utilization of nodes are highly restrictive requirements for IoT devices, forcing designers to push energy efficiency to the limits. Optimizing the device lifetime, communication consumption and minimizing maintenance costs are critical for Smart Cities.
- **Number of supported users.** The expected rise on the use of IoT devices implies potential constraints on user access and/or device communication reliability. From the network perspective, the increase in the number of connected IoT devices should be considered to avoid shortcuts and/or quality of service decrease. Even additional and IoT-specific new networks can be rolled out. Regarding IoT devices themselves, they should also rationalise their access to the network, either clustering themselves (and, thus, moving the connectivity problem to

gateways, which must be carefully designed to handle multiple devices behind) or optimising the frequency and amount of data transmitted.

- **Cost** IoT devices must be cheap and powerful. Nevertheless, the main cost achievement would be on OPEX terms, by enabling the cost reduction associated to the deployment and re-configuration of nodes, which will positively impact RoI figures.
- **Resilience.** Nodes must be able to recover from power or communication shortages without losing their data. This ability to recover from failure situations should, in addition, not impact their cost and efficiency assumptions.
- **Re-configurability.** IoT devices must have the ability to be re-configured, preferably over the air. Combining this aspect with cost and energy efficiency is critical to compose a successful use case. This feature will also pave the way for the reduction of maintenance costs.
- **Latency**. There are certain time-critical applications running on Smart Cities requiring strict real-time performance. User detection, either for access control or user-triggered lighting, for instance, would require prompt reaction from IoT devices. In these cases, latency becomes critical, both in device detection and communication.

5.5 Autonomous vehicles in a connected environment and smart mobility

Autonomous vehicles in a connected environment facilitating smart mobility requires ecosystems that fulfil a number of requirements related to usability, trust, safety, security, applications and services. Smart sensors, actuators and microprocessors in the vehicles and road infrastructure collect and process a variety of information, conveyed further through near real-time communication data to serve and ensure enhanced autonomous driving.

The technology realized according to levels of automation are ranged by SEA (Society of Automotive Engineers) from *(i) no automation* and *(ii) driver assistance* to *(iii) partial automation* for human driver monitors driving environment, and from *(iv) conditional automation* and *(v) high automation* to *(vi) full automation* for automated driving system monitors driving environment [7].

Automated driving is an important use case for IoT. In the context of IoT ecosystem, the communication can be categorized as communications of vehicle to everything (V2X) that covers vehicle to infrastructure (V2I), vehicle to vehicle (V2V), vehicle to device (V2D), and even vehicle to pedestrian (V2P).

The phase in of autonomous vehicles can give several positive effects. For example, decrease in vehicle accidents/crashes, more efficient traffic flow that will free up time for the passengers, environmental savings according to increased fuel efficiency and alternative energy resources facilitated, and increased mobility for elderly and disabled people [8].

Table 50: KPIs for autonomous driving.

Name/Identifier	Description	Metric	Method of collection and measurement
Road infrastructure	The road length where the road infrastructure is prepared for autonomous driving.	Distance	Measuring the total continuous road length infrastructure that are prepared for autonomous driving per area (city etc.).
Sales statistics	Record of autonomous vehicles sold.	Number	Measuring the number of autonomous vehicles sold, for given time period intervals, according to predefined vehicle transportation segments (private, public or freight transportation).

Mileage	Mileage measurements to get data on the actual use of the autonomous vehicles on the road.	Distance	Measuring the mileage of autonomous driving, for given time period intervals, according to predefined vehicle transportation segments (private, public or freight transportation).
Accidents	Transition to autonomous driving and its impact on the number of accidents.	Number	Measuring the number of accidents for a g on predefined road distances over time. The accidents need to be categorized according to injuries and severity level, plus predefined vehicle transportation segments (private, public or freight transportation).
Travel time	Transition to an autonomous vehicle fleet and its impact on the travel time (traffic flow).	Time	Measuring the traveling time for given period intervals, on predefined distances over time.
Traffic density	Transition to an autonomous vehicle fleet and its impact on the traffic flow.	Number/time	Measuring the number vehicles passing a checkpoint per unit of time.
Air pollution	Measurement of hazardous gas and particulate pollutants related to the use of vehicles.	Amount	Measuring the emissions of the different greenhouse gasses etc. in predefined areas over time.
Noise pollution	Measurement of noise pollution caused by vehicles.	Level	Measuring the noise level at given checkpoints over time.
Passengers	The number of passengers in the vehicle.	Number	The number of passengers, per trip, according to predefined vehicle transportation segments (private or public transportation).
Universal design	Are the autonomous vehicles supporting universal design? Register persons with disabilities using autonomous vehicles.	Number	Register the number of persons with disabilities that are using autonomous vehicles, according to predefined vehicle transportation segments (private or public transportation).
Auto repair visits.	Register the number of repair visits.	Number	Register the number of necessary repair visits according to sources of error.
Hacking	Register the number of SW hacker attempts and attacks.	Number	Register the number of detected SW hacker attempts and attacks.

6. CONCLUSIONS

This document presents an overview of the common methodologies and Key Performance Indicators (KPIs) for design, testing and validation set forth by CREATE-IoT within the framework of the European IoT Large-Scale Pilots' Programme. The document describes the evaluation methodologies and common KPIs for IoT applications and projects with the aim to enable IoT Large Scale Pilots' (LSP) stakeholders to assess the IoT pilot's progress towards the stated IoT FA objectives and pilots collectively. In this respect, the present deliverable forms the basis for the work with the LSPs for developing the methodology and promoting the importance of KPIs for continuous monitoring, and ensuring the availability of timely, accessible and comparable data and the development of interim performance indicators to inform internal and external stakeholders on the progress of an IoT LSP towards achieving planned outcomes. Overall, the KPIs presented in this deliverable are instrumental to guide each individual LSP towards its specific objectives and support each project towards the realization of large-scale demonstrations in their own IoT Focus Area and specific domain, i.e. smart living environments for aging well, smart farming and food security, wearables for smart ecosystems, smart cities and reference zones).

A top-down approach has informed the methodology designed to identify and define the necessary KPIs for the European IoT Large-Scale Pilots' Programme and the individual LSPs.

- First a number of broad areas of measurement has been identified. These areas have been called "dimensions" and have been based on "where" the major LSPs impacts are going to exert their effects.
- Secondly, a number of more specific and circumscribed sub-areas (called "fields") has been assigned to each dimension to further narrow down, and better delimit, the impact spheres
- Finally, the actual design, identification, and description of one or more measurable metrics associated to each field has been carried out and a first list of indicators has been proposed.

Three main categories of indicators were devised, each addressing a specific level of analysis:

- Generic indicators refer to areas of performance or evaluations that are common to all KPIs and all products, services and projects. These indicators will be applied to all LSPs and to the IoT European Large-Scale Pilots Programme as whole;
- Cross-domain indicators operate at a lower level by intercepting those processes and features pertaining to more than one domain and therefore potentially referring to more than one LSP but not to the Programme as a whole;
- Domain-specific indicators are designed for, and apply to, a single domain and are therefore used to measure the performance and impacts of one specific LSP.

The actual designing, definition and implementation of the three above-mentioned indicators' categories will occur in three distinct phases. CREATE-IoT will first focus on generic indicators as they can be determined in a relatively easy way through desk research and by leveraging the CREATE-IoT partners' experience. In a second phase, the domain-specific indicators will be clearly identified and better specified. A first provisional list of domain-specific indicators will be provided by CREATE-IoT partners but it will be finalized through several iterations with each LSP directly involved in the domain under consideration and with further interactions with domain- expert stakeholders. Finally, cross-domain indicators will be defined at a later stage once the impact and influence of generic and domain-specific indicators is clearly apprehended. Only then, in fact, it is possible to thoroughly investigate the interplay and interrelations between two or more domains and calculate meaningful values for KPIs spanning two or more domains.

The KPIs for design, testing, validation and impact measuring will be a primary management and control tool for a wide range of stakeholders across the European IoT Large-Scale Pilot's Programme and for the LSPs themselves. By regularly measuring the indicators across the 8

dimensions proposed in this document, each LSPs will be in a position to monitor its performance and progress vis-à-vis its own project's objectives and the objectives of the overall programme. At the same time, the common methodologies and KPIs presented in this deliverable and applied at project and programme level will be of help for the overall IoT ecosystem in Europe and beyond as they will allow the ecosystem stakeholders to verify the level of advancement, performance and impact of specific IoT demonstrations in well-defined domains. Similarly, European and national policy makers will benefit from the KPIs measured in this deliverable as they will indicate the areas of performance in need of corrective actions, as well as those areas that could be used as best practices and examples in other IoT-oriented endeavours.

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