Study on mapping Internet of Things innovation clusters in Europe

FINAL STUDY REPORT

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Resume

The Internet of Things is regarded as the next major breakthrough in the development of Information and Telecommunication Technologies and a clear opportunity to provide solutions for society, citizens, enterprises and governments. ICT businesses and research organisations have the strong drive to create ecosystems and to aggregate in innovation clusters. IoT solutions are often developed in value chains closely related to such clusters.

This study provides an extensive analysis of the European ecosystem, within which IoT solutions and applications are developed. It describes and assesses the processes and dynamics of IoT clusters, their key drivers, sustainability and key success factors. Many clusters targeted by the study are a response to industrial and sectoral crises in specific geographical areas, and involve public bodies. Cluster's members confirm that performance and sustainability are closely related to their industrial and ecosystem development.

In a forward-looking perspective, cluster stakeholders identified a number of key areas, in which the European Commission shall consider specific interventions, the most important of which being: an appropriate identification of IoT risks, encouraging the development of technological standards, supporting technology development, transfer as well as platforms to favour the creation of EU-wide communities and the development of its ecosystems.

L'Internet des Objets (en anglais: *Internet of Things*, IoT) est considéré comme la prochaine avancée majeure dans le développement des technologies de l'information et de la communication (TIC) et comme l'opportunité d'offrir à la société, aux citoyens, aux entreprises et aux administrations publiques de nouvelles solutions. Les compagnies et organismes de recherche actifs dans le domaine des TIC ont un fort potentiel pour créer des écosystèmes et se regrouper dans des pôles d'innovation. Les solutions reposant sur l'IoT sont souvent développées au cœur de chaînes de valeur en lien étroit avec ces pôles.

Cette étude offre une analyse approfondie de l'écosystème européen, au sein duquel des solutions et applications fondées sur l'IoT sont développées. Elle décrit et évalue les processus et dynamiques des pôles pour l'IoT ainsi que leurs forces motrices et les déterminants principaux de leurs durabilité et succès. Beaucoup des pôles étudiés ont été établis en réponse à des crises industrielles et sectorielles ayant affecté des zones géographiques particulières, et comptent parmi leurs membres des acteurs publics. Leurs parties prenantes rapportent que la performance et durabilité des pôles sont étroitement liées au développement de leurs industries et de leur écosystème.

Dans une réflexion sur l'avenir, les acteurs des pôles identifient un certain nombre de domaines clés dans lesquels la Commission européenne devrait envisager d'intervenir. Il apparaît particulièrement urgent d'identifier les risques liés à l'IoT, d'encourager la définition de standards technologiques, et de soutenir le développement et le transfert de nouvelles technologies ainsi que les plateformes favorisant la création d'écosystèmes et de communautés à l'échelle de l'Union européenne.

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Executive Summary

The Internet of Things Innovation Cluster Study investigates the landscape of physical and virtual clusters of enterprises, research organisations and academia working on the innovation, development and market deployment of IoT technologies and applications.

The Internet of Things is regarded as the next major breakthrough in the development of Information and Telecommunication Technologies and a clear opportunity to provide solutions for society, citizens, enterprises and governments. IoT solutions are often developed in value chains closely related to clusters.

This study provides an extensive overview and analysis of the European ecosystem, within which IoT solutions and applications are developed. It also provides an extensive review and assessment of the processes and dynamics of IoT clusters, of their foundations and life cycle, their factors of emergence, key drivers, common characteristics, as well as of their sustainability and key success factors.

There is a generalised trend of ICT businesses and research organisations to aggregate in innovation clusters, which are actively developing innovative IoT solutions. They create new applications, cross-border value chains and ecosystems to take advantage of the opportunities offered by technology and by the increasing mass of available data.

Renowned institutions, research bodies and think-tanks recognized IoT as a fast-developing technological area and application field, with a very high potential of responding to a widely diversified set of needs, from industrial applications to networking systems, to smart cities, from environmental problems to applications responding to individual needs. Market forecasts and technological roadmaps provide evidence and support to these trends.

In 2017, the International Data Corporation (IDC) forecasted worldwide spending on the IoT to reach USD 772 billion by end of 2018 with a compound annual growth rate (CAGR) of 14.4% over the 2017-2021 period.

Statista estimated that global Internet of Things services would amount to USD 273 billion in 2017 and that 5.2 billion consumer-connected things will be in use worldwide the same year. Furthermore, it expected that the number of installed connected devices would double between 2015 and 2020 from 15.41 billion to 30.73 billion. They number may continue to grow by nearly 2.5 times in the subsequent five years, until 2025.

The study has characterised the IoT cluster landscape by desk research, surveys and case studies. The latter were used to get a deeper understanding of the reasons for the establishment, operations and outcomes of these clusters. The main rationales are to respond to industrial and sectoral crises in specific geographical areas, often of large enterprises (such as Ericsson and Nokia). In most cases these clusters are driven by Public-Private Partnerships, but their sustainability does not rely on public funding. Clusters have the purpose to support specific industrial strategies, such as Industry 4.0; in some cases they are established within EU, national or regional research and innovation or development programmes and initiatives, such as Horizon 2020 or the European Structural Investment Funds.

In several cases, large players promoted and supported cluster creation. They include large multinational companies (LMCs) and large research and technology organisations, and are considered as the natural counterparts to government bodies and agencies engaged in their setup and support.

SMEs are very important players in clusters, which contribute to strengthening their productivity, competitiveness and innovative capabilities. Scholars explain that SMEs are important vehicles to generate innovation and to create employment. The case studies show that SMEs are as innovative as big enterprises, however, due to their small size and financial weakness, SMEs may not be able to sustain the relevant investment costs.

The case studies have demonstrated that government bodies and administrations are key stakeholders and contributors to territorial clusters, but they are not key to their sustainability: the usual patterns of public financial support are often considered unsuited to sustain cluster missions.

Most EU clusters have a transnational reach – as demonstrated by the large scale survey – and cover a range of activities on a national basis or have a regional and interregional focus. None of the surveyed clusters operates on a merely local basis.

IoT innovation clusters perform a set of overarching activities and deliver horizontal operational services to their members. The study shows that clusters are essentially business- and technology-oriented establishments essentially engaging in four different types of activities:

- Organisational and market services, which are services developing the clusters themselves as well as their relationships with external markets and ecosystems.
- Technical services, which facilitate the interaction of cluster members on horizontal technical and technological issues. They facilitate knowledge sharing, knowledge spill-overs and knowledge creation.
- Application services, clearly oriented towards the development of application software.
- Other support services, which are ancillary services to the technological, innovation and market process of cluster members and the clusters themselves.

Considering the IoT clusters application domains, the one with the highest weight in 2012 was smart industry and still it is in 2017. The second most important is smart living, while smart cities have increased significantly according to cluster inputs, becoming also the second most important domain after smart industry. Smart energy has slightly increased and smart environment has nearly doubled in the last five years.

The challenges that clusters face concern all the phases of their life cycle, i.e. launch, initiation, development and sustainability. The case studies show that most clusters are market-driven initiatives – even if not necessarily for-profit – with the exception of those that were established on the basis of a public grant. Clusters are successful if they create value for their stakeholders and if they are engaged in the constant monitoring and adjustment of their strategy and operations. Clusters need to support the technological knowledge exchange, solution finding and problem solving and deploy effective marketing and internationalisation initiatives for their members, running incoming and outgoing missions to explore new market opportunities.

The main drivers of clusters and their activities that the study identifies are:

- Open innovation and cooperative innovation;
- Level of demand for applications – the market;
- Supply of solutions and technology availability – supply;
- Clustering of research activities;
- Level of diffusion of data capturing technologies – sensors;
- Level of diffusion of data processing technologies.

Besides the cluster drivers, success factors guarantee the generation of added-value, innovative drive, benefits to members and to the general ecosystems, and sustainability over time. The main success factors emerging from the study are: Financing, funding and economic balance; Strategic best practices; Operational and management best practices; Technology and application-related best practices.

With the help of cluster stakeholders, the study has identified a number of key areas, in which the European Commission shall consider specific policy and support interventions. They include:

- EU governance of IoT;
- Identification of emerging risks associated with IoT and development of an agreed harmonised framework to address this issue;
- Standards mandates: the European Commission shall analyse, in cooperation with technical bodies and Member States the need for IoT-specific standards;
- Counselling on IP law and data ownership to address the issue of cross-border handling of data, highly sensitive in the case of certain IoT applications;
- Creation of/support to labs, testing or technological facilities;
- Monitoring of the privacy and personal data protection issues, an activity under the current GDPR;
- Technology transfer services;
- Public-Private Partnerships promotion, to develop IoT-enabled applications;
- Development of platforms cutting across sectors and industries;
- Promoting the international dialogue developing measures which favour EU-wide cooperation and international cooperation;
- Funding of IoT-related research and development and innovation and pilot projects with IoT applications.

This set of recommendations, for which the relevant section in this report provides further details and specifications, is fully consistent with the policy action areas of the European Commission and in particular of the European Digital Single Market Strategy.

Résumé exécutif

L'étude sur les pôles d'innovation pour l'Internet des Objets (en anglais : *Internet of Things*, IoT) dresse un panorama de ces regroupements physiques et virtuels d'entreprises, d'organismes de recherche et d'universités travaillant sur l'innovation, le développement de technologies et d'applications fondées sur l'IoT ainsi que et leur déploiement sur les marchés.

L'IoT est considéré comme la prochaine avancée majeure dans le développement des technologies de l'information et de la communication (TIC) et comme l'opportunité d'offrir à la société, aux citoyens, aux entreprises et aux administrations publiques de nouvelles solutions. Les solutions reposant sur l'IoT sont souvent développées au cœur de chaînes de valeur en lien étroit avec des pôles.

Cette étude offre un panorama et une analyse approfondie de l'écosystème européen, au sein duquel des solutions et applications fondées sur l'IoT sont développées. Elle décrit et évalue aussi les processus et dynamiques des pôles pour l'IoT, leur établissement et cycle de vie, leurs caractéristiques communes ainsi que les facteurs de leurs durabilité et succès.

Les entreprises et organismes de recherche dans le domaine des TIC ont une tendance générale à se regrouper dans des pôles d'innovation actifs dans le développement de solutions innovantes en lien avec l'IoT. Ces regroupements créent de nouvelles applications, des chaînes de valeur et écosystèmes transfrontaliers pour tirer profit des opportunités offertes par les technologies et le volume croissant de données disponibles.

Des institutions, organismes de recherche et groupes de réflexion renommés ont reconnu que l'IoT est un domaine technologique en pleine évolution avec un champ croissant d'applications et le fort potentiel de répondre à un ensemble varié de besoins, allant des applications industrielles aux systèmes de réseaux, en passant par les villes intelligentes, des problèmes environnementaux à ceux liés des utilisations particulières de l'IoT. Les prévisions d'évolution du marché et les feuilles de route technologiques fournissent des preuves et un soutien à ces tendances.

En 2017, l'International Data Corporation (IDC) prévoyait que les dépenses mondiales dans l'IoT atteindraient 772 milliards de dollars américains d'ici la fin de 2018, avec un taux de croissance annuel composé de 14,4% sur la période 2017-2021.

Statista a estimé que la valeur des services liés à l'IoT à l'échelle planétaire s'élèverait à 273 milliards dollars américains en 2017 et que 5,2 milliards de biens de consommation connectés seront utilisés dans le monde cette même année. En outre, il prévoyait que le nombre d'appareils connectés installés doublerait entre 2015 et 2020, passant de 15,41 milliards à 30,73 milliards. Leur nombre pourrait être multiplié par 2,5 au cours des cinq années suivantes, jusqu'en 2025.

L'étude a permis de dresser le panorama et de caractériser les pôles pour l'IoT au moyen d'une recherche documentaire, d'enquêtes et d'études de cas. Ces dernières ont été utilisées pour mieux comprendre les facteurs expliquant la création, le fonctionnement et les résultats de ces pôles. La principale motivation de ces pôles est de répondre à des crises industrielles et sectorielles dans des zones géographiques spécifiques, touchant souvent de grandes entreprises (telles qu'Ericsson et Nokia). Dans la plupart des cas, ces pôles sont fondés sur des partenariats public-privé, mais leur durabilité ne dépend pas des financements publics. Les pôles ont pour objectif de soutenir des stratégies industrielles spécifiques, telles qu'Industrie 4.0. Dans certains cas, ils sont établis dans le cadre d'initiatives et de programmes de recherche, d'innovation ou de développement européens, nationaux ou régionaux, tels qu'Horizon 2020 ou les Fonds structurels d'investissement.

Dans plusieurs cas, des acteurs de large envergure ont encouragé et soutenu la création de pôles. Il s'agit de grandes entreprises multinationales et d'importants organismes de recherche

et de technologie. Ils sont considérés comme les interlocuteurs naturels des organisations et agences gouvernementales engagées dans la création de ces pôles et dans leur soutien.

Les sont des acteurs fortement importants au sein des pôles qui contribuent à renforcer leurs productivité, compétitivité et capacités d'innovation. Des chercheurs expliquent que les PME sont des moteurs d'innovation et de création d'emplois. Les études de cas montrent qu'elles sont aussi innovantes que les grandes entreprises. Néanmoins, en raison de leur petite taille et de leur faiblesse financière, elles risquent de ne pas être en mesure de supporter les coûts d'investissement liés.

Les études de cas ont montré que les organisations gouvernementales et autres administrations publiques sont des acteurs et contributeurs clés des pôles territoriaux, mais participent guère à garantir leur durabilité. Les instruments publics traditionnels de soutien financier sont souvent considérés comme inadaptés pour aider les pôles à poursuivre leurs missions.

La plupart des pôles de l'Union européenne ont une portée transnationale - comme le montre l'enquête menée à grande échelle. Ils mènent un large éventail d'activités au niveau national ou démontrent une dimension régionale et interrégionale. Aucun des pôles étudiés ne fonctionne sur une base uniquement locale.

Les pôles d'innovation pour l'IoT mènent un ensemble d'activités globales et fournissent des services opérationnels horizontaux à leurs membres. L'étude montre qu'ils sont essentiellement des établissements à vocation commerciale et technologique qui exercent essentiellement quatre types d'activités :

- Des services liés aux organisations et aux marchés. Il s'agit de services tournés vers le développement des pôles et de leurs relations avec les marchés et écosystèmes extérieurs.
- Des services techniques qui facilitent l'interaction des membres des pôles sur des questions liés à la technique et aux technologies horizontales. Ils aident le partage, la diffusion et la création de connaissances.
- Des services d'application clairement orientés vers le développement de logiciels d'application.
- D'autres services de soutien. Il s'agit de services auxiliaires aux activités des membres du pôle liés aux technologies, à l'innovation et au marché.

Le domaine d'application des pôles pour l'IoT le plus important en termes de poids était en 2012 et encore en 2017 l'industrie intelligente. Le second est la domotique (*smart living*). Les villes intelligentes sont un domaine d'application où les pôles ont connu une forte augmentation du nombre de leurs membres. Elles sont d'ailleurs devenues également le deuxième domaine le plus important après l'industrie intelligente. L'énergie intelligente a légèrement augmenté et l'environnement intelligent (*smart environment*) a presque doublé au cours des cinq dernières années.

Les défis auxquels les pôles sont confrontés concernent toutes les phases de leur cycle de vie, à savoir leurs lancement, initiation, développement et durabilité. Les études de cas montrent que la plupart des pôles sont des initiatives répondant aux dynamiques des marchés – même s'ils ne sont pas nécessairement à but lucratif – à l'exception de ceux créés sur la base de subventions publiques. Les pôles sont considérés comme des réussites s'ils parviennent à créer de la valeur pour leurs parties prenantes et s'ils contribuent au suivi et à l'ajustement permanent de leur stratégie et de leurs opérations. Les pôles doivent soutenir l'échange de connaissances technologiques, la recherche de solutions et la résolution de problèmes. Pour également aider le déploiement d'initiatives de marketing et d'internationalisation efficaces pour leurs membres, ils facilitent les rencontres avec des acteurs externes soit sur place soit à l'extérieur afin d'explorer de nouvelles opportunités de marché.

L'étude identifie les principaux moteurs des pôles et de leurs activités :

- L’innovation ouverte et coopérative ;
- Le volume de demande d'applications de l’IoT, c’est-à-dire le marché ;
- L’offre de solutions et la disponibilité des technologies, c’est-à-dire l’offre ;
- Le regroupement des activités de recherche ;
- Le degré de diffusion des technologies de capture de données, c’est-à-dire la diffusion des capteurs ;
- Le degré de diffusion des technologies de traitement de données.

Outre ces forces motrices des pôles, leurs facteurs de succès garantissent la création de valeur ajoutée, un dynamisme innovant, des retombées pour les membres et les écosystèmes en général, ainsi que la durabilité dans le temps. Les principaux déterminants de réussite que l’étude a permis d’identifier sont : le financement et équilibre économique ; et, les pratiques exemplaires en matière de stratégie, d’opérations et de gestion, et de technologie et d’application

Avec l'aide des acteurs des pôles, l'étude a identifié un certain nombre de domaines clés dans lesquelles la Commission européenne devrait envisager d’intervenir et de mettre en place des politiques spécifiques. Il s’agit de :

- Une gouvernance de l’IoT à l’échelle de l’UE ;
- L’identification des risques émergeants liés à l’IoT et le développement d’un cadre harmonisé en réponse à ces problèmes ;
- Des mandats sur les standards. La Commission européenne devrait analyser, en coopération avec les organes techniques et les États membres, le besoin de standards spécifiques à l’IoT ;
- Conseils en matière de droit de la propriété intellectuelle et de propriété des données afin de résoudre les problèmes liés au traitement transfrontalier des données. Ce problème est d’autant plus accru pour certaines applications de l’IoT ;
- Création et soutien de laboratoires et autres infrastructures pour l’expérimentation et les technologies ;
- Suivi des problèmes liés à la vie privée et la protection des données personnelles désormais encadrée par le RGPD ;
- Services de transfert technologique ;
- Promotion des partenariats public-privé pour le développement d’applications fondées sur l’IoT ;
- Développement de plateformes impliquant plusieurs secteurs et industries ;
- Promotion d’un dialogue international pour le développement de mesures en faveur de coopérations internationales ou à l’échelle de l’Union européenne ;
- Financement de projets de recherche-développement et d’innovation dans le domaine de l’IoT, et de projets pilotes pour des applications fondées sur l’IoT

Cet ensemble de recommandations, que les chapitres correspondants du présent rapport développent en plus grands détails, est parfaitement cohérent avec les différents domaines d’intervention de la Commission européenne et en particulier avec la stratégie européenne pour le marché unique numérique.

1. Introduction

1.1 IoT and innovation clusters: an opportunity for the development of European society

The Internet of Things is regarded as the next major breakthrough in the development of Information and Telecommunications, as it has been recognised by institutions such as the International Telecommunications Union, by technological and market research organisation and by the European Commission.

IoT is a clear opportunity to provide solutions for society, citizens, enterprises and governments. IoT solutions are often developed in value chains closely linked to clusters. The IoT study accounted for in this report builds on the strong hypothesis that IoT clusters are developing around large enterprises, in local or regional industrial aggregations, science parks, universities, incubators and accelerators, FabLab communities, "makers" or other concentration of ICT players. Furthermore, it seems that many clusters were founded to act against sectoral and territorial "crises", combining the forces of entrepreneurial and government institutions. The verification of these hypotheses is the objective of this IoT innovation cluster study and are discussed in this report.

1.2 The IoT cluster study: an in-depth perspective on IoT innovation ecosystems

The rationale of the Internet of Things innovation cluster study was to provide a comprehensive picture and a thorough understanding of the European ecosystem within which IoT solutions and applications are developed. Specifically, the objectives of the study have been to

- Identify where European IoT clusters are located;
- Determine which clusters are more active, and in which technological, application and market areas;
- Provide an extensive review and assessment of the dynamics of these IoT clusters, of their foundation and life cycle, the factors of emergence, key drivers, common characteristics, as well as of their sustainability and key success factors.

The analysis has succeeded to create a comprehensive picture of the IoT cluster landscape in Europe and to provide information on their dynamics, sustainability, performance and output.

The IoT cluster study is complemented by an online platform, which is capable to show the dynamic dimensions of European Union IoT clusters landscape through maps and charts; it also allows IoT clusters and IoT operators from business, academia, research and administrations to upload their own data and information to the repository; finally, it enables the EU IoT community to connect, network, and share.

The IoT innovation cluster study has adopted a multidimensional, integrated and coherent research approach, designing and deploying as set of analytical tools to capture technological, organisational, market and economic features of clusters, including:

- A qualitative and quantitative desk research, based on databases such as ORBIS[1], the eCORDA repository[2], CORDIS[3]. The research of IoT clusters and relevant projects,

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[1] https://www.bvdinfo.com/en-gb/our-products/data/international/orbis

[2] eCORDA, the external CORDA is a subset of the COmmon Research DAtawarehouse, which collects proposal, evaluation and grant management data of all the operational systems automating key business processes around the EU Framework Programmes.

[3] https://ec.europa.eu/info/research-and-innovation/projects/project-databases_en

has used advanced data combination techniques such as triangulation[4]. The result of this activity is the core dataset for the study and of the online IoT cluster platform.

- The direct surveying of European Union IoT clusters and their members. Two different questionnaires in two separate survey waves were targeted at IoT clusters and at businesses, universities, research organisations, administrations. The data provided by the survey were integrated in the platform core dataset[5].
- A set of 20 case studies of a large set of EU IoT clusters, which explored the key qualitative dimensions of IoT clusters including the relationships with leading industrial partners and demand aggregators, the number of start-ups, the type of testing facilities, the quality of the cluster's ecosystem and the service providers, the main types of funding sources, the performance potential of start-ups operating within the cluster.

The evidence collected by the IoT innovation cluster study is presented in this report and in the dynamic online platform, which interactively displays the information about the different clusters. The platform is designed to facilitate stakeholder engagement and has the purpose to draw the attention of potential users defining a visibility plan and social media strategy.

1.3 The content of this IoT innovation cluster report

This final report draws on the four reports mentioned in section **Error! Reference source not found.**, covering the main research activities developed under this study, and additional information is available in those reports.

The reader will find:

- The executive summary, sketching the key outcomes (will be completed after the sign-off of the report)
- An introduction in Section 1, presenting the study and its context to the reader, sketching objectives, the approach, the evidence base and the results.
- In Section 2, an overview of IoT as a disrupting technology, displaying market trends, technological trends, the main technological areas. It also presents the reader an introduction to the general industry cluster theory as well as key statements from scholars in the field.
- In Section 3, a comprehensive information about the cluster study, its objectives, the methodology, classification and taxonomy, as well as certain constraints emerging from data availability.
- The quantitative and qualitative overview of the European IoT clusters in Section 4, which present and discusses which clusters, where they are, how many of them. Furthermore, the section discusses factors of emergence, dynamics, cluster members by type, the patterns of linking and of operations. It also presents the main areas of activity, the services, the infrastructures, as well as the evolution of the weights of enabling technologies and cluster services.
- A deep analysis of cluster operations and dynamics, discussing cluster challenges, drivers and success factors, discussed in Section 5 of the report.
- A brief overview of the EU policy framework related to IoT and IoT cluster, which is presented in section 6. The policy framework is used to determine priorities and furthermore, recommendations.

[4] Triangulation is a technique that facilitates validation of data through cross verification from two or more sources. In particular, it refers to the application and combination of several research methods in the study of the same phenomenon or entities. In the case of IoT clusters it requires a common identifier.

[5] The two survey waves are: The first direct survey wave report. (June 2018); The second direct survey wave report. (June 2018)

- Section 7 provides a set of recommendations, as specified in the terms of reference. These recommendations are all embedded in the evidence elaborated by the study.
- Section 8 provides a number of annexes with information about the outputs of the different tasks, synthetic tables about challenges, drivers and impediments, success factors. The annexes also provide some key information about the setup of the research activities: the survey process, the case study process.
- Section 9 proposes the glossary of the study.

2. IoT to disrupt Information and Communication Systems

The International Telecommunications Union in its report 2016 report Harnessing the Internet of Things for Global Development[6] recognises the high pervasiveness of this technology and confirms that the IoT represents a promising opportunity for more coherent policy-making and implementation. Different actors like governments, businesses, and consumers take advantage of IoT-enabled applications to adopt new business models, to improve effectiveness of service provision and production efficiency and to enhance the wellbeing of individuals.

The European Commission considers the Internet of Things (IoT) the next major Internet-enabled economic and societal breakthrough and embedded in a new ecosystems that cuts across vertical sectors[7] and implements the convergence between the physical and digital domains. A recent study by the European Commission's DG CNECT has identified and analysed cross-cutting business models for Internet of Things (IoT) and is available on the Commission's website[8] and has identified an initial number of key application areas, which include:

- Smart Health;
- Smart Cars;
- Smart Manufacturing and maintenance; smart retail
- Smart homes, living environment and workplaces; work safety;
- Smart Cities; smart public safety
- Smart multi-modal mobility and smart road infrastructure; smart transportation and logistics
- Smart construction and infrastructure;
- Smart agriculture farming and food security, and food traceability;
- smart assisted living and wellbeing;
- Smart energy management at home and in buildings
- Smart environment, environmental monitoring and (water) management.

Wearables are kind of horizontal appliances, usable in most of the application fields above.

Today, enterprises and organisations are using the IoT and Big Data to introduce new business models, to improve the delivery of services, to increase efficiency in production, and to enhance wellbeing and human welfare, such as life-monitoring and activity-monitoring devices. The Internet of Things, as with many other high-tech fields, such as Nanotechnologies, Information and Communication Technologies, robotics and smart manufacturing sees the need to optimise the benefits of their deployment and at the same time protect individual and collective rights and guarantee protection of risks to privacy and security.

2.1 Market trends

McKinsey[9] confirms that IoT is an economic growth driver, since it makes available smart products enhancing their functionalities. According to their market analysis, around €23 billion value added will be generated in Germany in 2020 with the intelligent networking of machines and devices. The United States also constitutes a prime example. Here, the number of smart

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[6] https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf

[7] A vertical sector is an industry in which comparable products or services are developed and marketed using similar methods. Broad examples of vertical markets are insurance, real estate, banking, heavy manufacturing, retail, transportation, hospitals and government. By contrast, a horizontal sector delivers products or services to different vertical sectors. ICT, and IoT

[8] https://ec.europa.eu/digital-single-market/en/news/cross-cutting-business-models-internet-things-iot

[9] https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-iot-as-a-growth-driver

homes increased from 17 million in 2015 to an estimated 29 million in 2017. The Internet of Things has also the concrete potential to radically change business models and value chains, since practically every product and device can be connected through the Internet.

In 2017 the International Data Corporation (IDC) forecasted worldwide spending on the IoT to reach $772 Billion by end of 2018[10] and the IDC Worldwide IoT Spending Guide forecasts worldwide spending to reach a compound annual growth rate (CAGR) of 14.4% through the 2017-2021 period[11].

Statista estimates the projected Internet of Things services spending worldwide from 2014 to 2017. In 2017, this figure is predicted to reach 273 billion U.S. dollars. It is estimated that almost 5.2 billion consumer connected things will be in use worldwide in 2017.

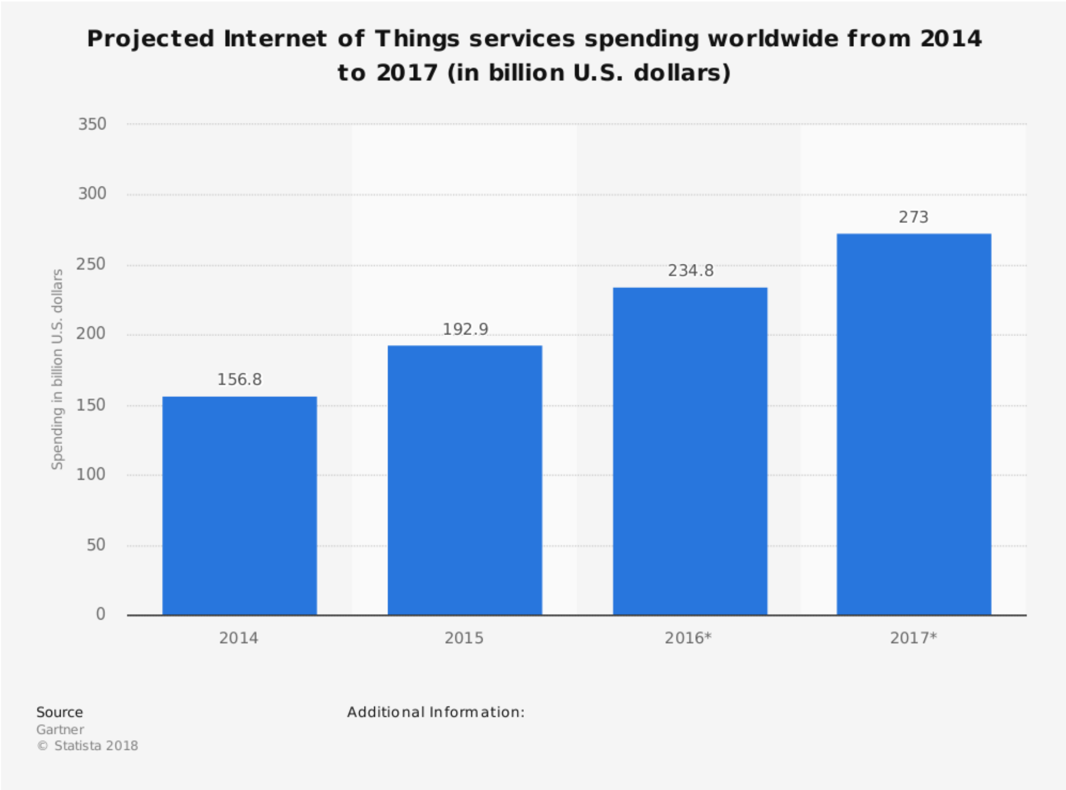

Figure 2-1: Projected IoT services spending worldwide 2014 to 2017 (Billion $). Source: https://www.statista.com

2.2 Technological IoT trends

The installed base of Internet of Things, i.e. the number of IoT devices in-use, is growing particularly fast and is expected to continue to grow at a sustained rate in the coming years, as shown in Figure 2-2 and Figure 2-3.

Statista[12] estimates the growth of the installed base of connected devices (Figure 2-2) to double from 2015 to 2020 from 15.41 Billion devices connected to 30.73 Billion and again to grow by nearly 2.5 times in the subsequent five years, until 2025.

[10] https://www.idc.com/getdoc.jsp?containerId=prUS43295217

[11] https://www.idc.com/getdoc.jsp?containerId=IDC_P29475

[12] https://www.statista.com

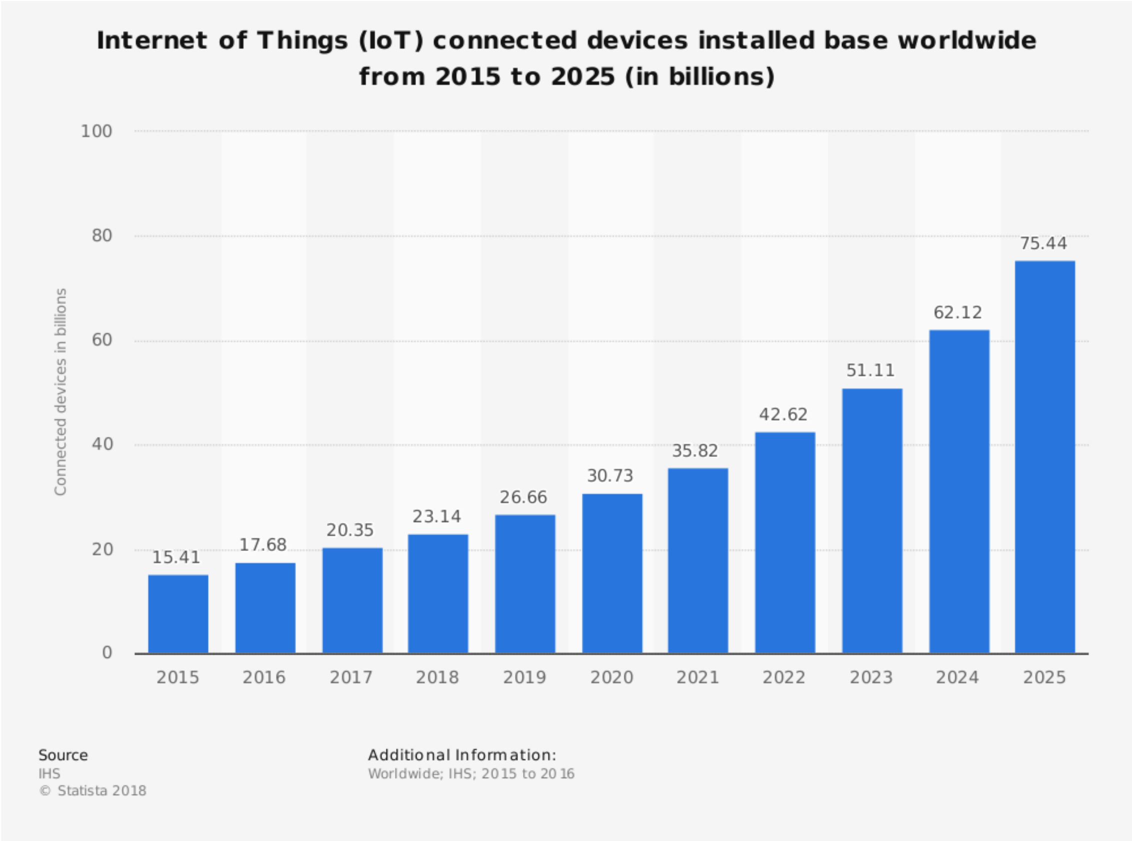

Figure 2-2: IoT connected device installed base from 2015 to 2025. Source: https://www.statista.com

Concerning the installed base of the Internet of Things (IoT) by category between 2014 and 2020 (Figure 2-2), according to Statista, an estimated 12.86 billion units will be in use in the consumer segment by 2020. The installed base of IoT devices is expected to jump from about five billion in 2015 to nearly 31 billion by 2020, with the consumer sector accounting for the majority of these units. The IoT installed base in the consumer sector is forecast to amount to 13.5 billion by 2020. The automobile industry is a promising sector for IoT and is forecast to account for about 14 percent of the IoT installed base in 2020. As of May 2015, companies of the automobile industry spent an average of around 93.5 million U.S. dollars on Internet of Things per year. Companies in the travel, transportation and hospitality industry have the highest annual spending on IoT – nearly 129 million U.S. dollars. Industrial manufacturing, banking and financial services and telecommunication are also industries with high spending on IoT.

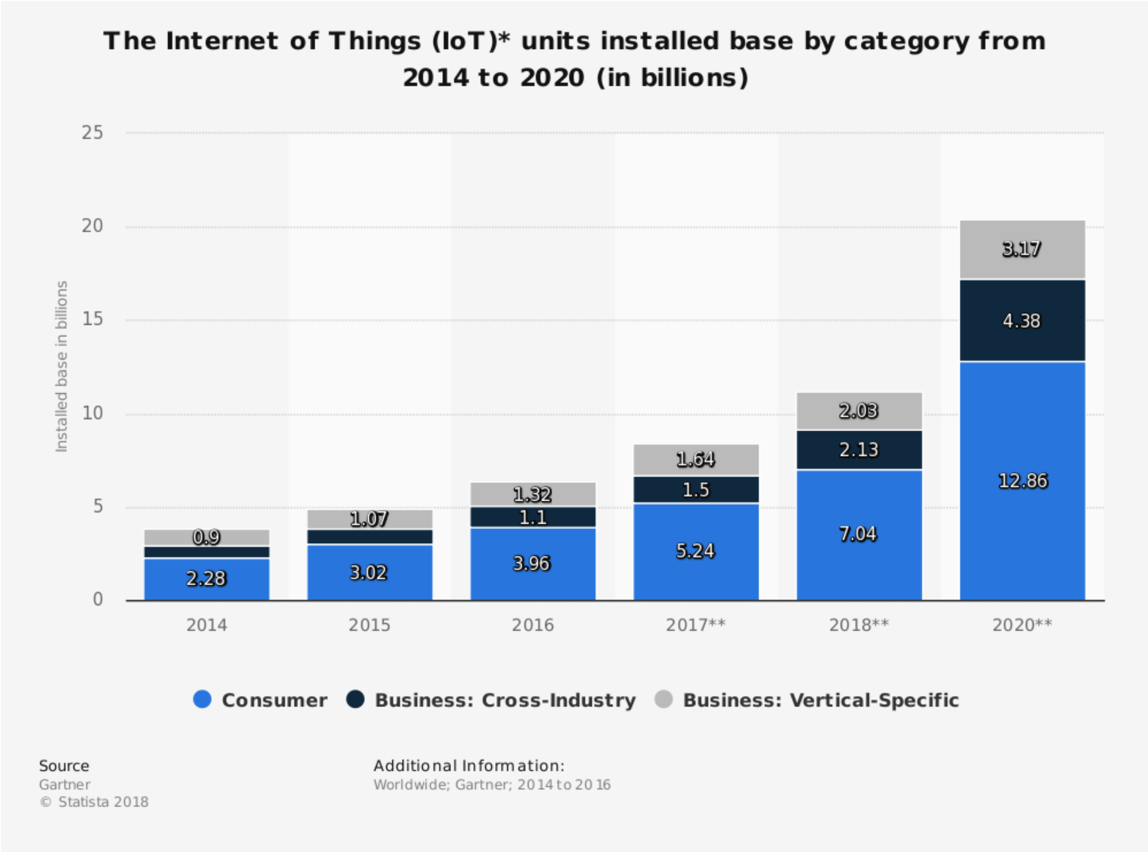

Figure 2-3: IoT installed base by category from 2014 to 2020. Source: https://www.statista.com.

2.3 IoT application development areas

Figure 2-4 below shows the share of developers worldwide in 2016 currently creating software for connected devices or the Internet of Things, by developer segment. As of that time, four percent of developers working for original equipment manufacturers were creating connected devices or IoT software.

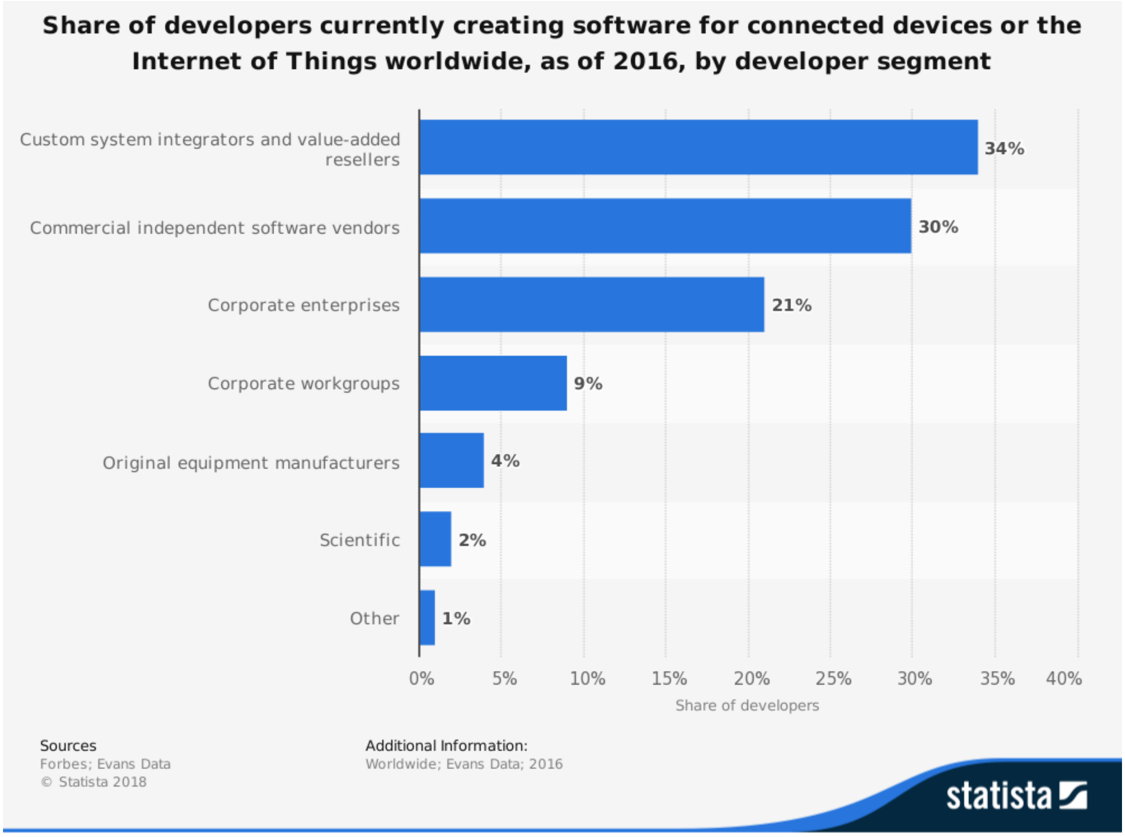

Figure 2-4: Share of developers currently creating software for connected devices or the Internet of Things worldwide, as of 2016, by developer segment. Source https://www.statista.com.

2.4 The general analysis of industry clusters

Industry clusters were originally discussed by Michael Porter in "The Competitive Advantage of Nations"[13] and go back to the underlying concept of agglomeration economies as developed by Alfred Marshall in the early twentieth century.

Porter recognises the natural tendency of enterprises to aggregate and demonstrates that cluster membership of enterprises can generate individual and aggregate competitive advantage through the productivity gains achieved through value chain integration and cooperative innovation. Particularly in regional and rural areas communities with strong inter-personal relationships favour innovative activities and Porter confirms the embeddedness of economic and innovation activities in social activities, which makes them more successful and sustainable.

Clustering enterprises and value chains has also a favourable impact on the creation of economic and technological critical mass, increasing relationships, opportunities and economies of scale. Clusters facilitate self-reinforcing processes of innovation and growth, as confirmed by Capello[14] and through physical proximity facilitate virtuous interactions and

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[13] Porter, M. E. The Competitive Advantage of Nations. New York: Free Press, 1990.

[14] Capello, R., 1999. Spatial transfer of knowledge in high technology milieux: learning versus collective learning processes. Regional Studies 33, 353–365.

enable collective learning mechanisms, as confirmed by Melachroinos and Spence[15] and Storper and Venables[16].

The classic Marshallian districts are characterised by a peculiar combination of competition and cooperation, i.e. their members have interest in joining forces on certain activities, but they may also compete on other lines and markets, an aspect which was confirmed by the IoT study, in particular the case studies.

IoT clusters are clusters in their own right. However, the study has shown that it is extremely difficult to make a clear distinction with the overall ICT clusters. In many clusters, ICT and IoT focus are one the development of the other or they simply coexist, without a clear border between the two activities, and without a clear distinction of economic indicators, research and innovation activity indicators and human and technological resources indicators. In other words, it is often not possible to distinguish between employees, R&D investment, researchers that belong to IoT from the overall ambit of ICT. The two domains often overlap and cannot be clearly separated since their building blocks – data capturing, data processing and transmission, data analytics, hardware and software – are tightly intertwined. The IoT cluster study refers to both types, the ones explicitly focusing IoT and the more general ICT clusters, which do not make a direct reference to IoT but still undertake activities in that area.

The typical IoT cluster of the study involve enterprise members, Large Scale Enterprises (LSEs), Small and Medium Enterprises (SMEs), start-ups, academic and research organisations, technological centred, business associations and national, regional and local administrations with very different roles and configurations. Being part of a cluster allows SMEs to compete with large enterprises, leveraging the critical mass that can be generated by the clustering and the new value chains[47].

As mentioned, cooperation in the IoT clusters analysed may be intentional as well as implicit. However, all clusters scrutinised create a connecting layer between their members and provide horizontal support services, in particular internationalisation and sales.

The case studies, as described in their report[17] have also shown that, besides the internal values chains, they are also developing cross-cluster value chains, leading to the specialisation of the entire cluster.

2.5 Clusters as Innovation Hubs: the value of proximity

According to Moretti[18], there are no obvious reasons why innovative industries are located where they are. They cluster near each other in specific locations to take advantage of what economists call the forces of agglomeration. These factors are thick labour markets, i.e. places with a good choice of skilled workers; the presence of specialised service providers and, most important, knowledge spill overs.

- Innovative companies locate or move where the talent is and there is a “thick market”, i.e. a large offering of skilled people. Innovative enterprises need the choice and act as attractors of talents generating favourable critical mass of skills offered and requested, improving the quality of matching. The “thick market” effect is one of the main reasons for the concentration of innovative clusters in specific places worldwide, for example .
- Ecosystems and venture capitalists. One advantage of US innovation hubs has to do with funding and with the “leanness” of the legal system. “By the mere act of moving

[15] Melachroinos, K.A. and N. Spence (2001) Manufacturing productivity growth across European Union states: 1978-94. Environment and Planning A 33:1681-1703.

[16] Storper, M. and A.J. Venables (2004) Buzz: face-to-face contact and the urban economy, *Journal of Economic Geography* 4: 351-370.

[17] The IoT cluster case studies report. (June 2018)

[18] Moretti, Enrico. The New Geography of Jobs. Mariner Books 2013

into a high-tech cluster, a firm in effect becomes larger overnight, because it can draw on specialised local expertise". From the point of view of the providers of specialised services, geographical proximity of innovative enterprises – their clients – is crucial. It is an important factor that keeps the ecosystem geographically together. Moretti also confirms that "The aspect of the Venture Capital industry that I find most remarkable is how local it still is. Venture capitalists used to talk about the 'twenty-minute rule': a venture capitalist only considers financing companies that are located within a twenty-minute drive of his office". In spite of the fact that the industry has become more global, proximity is very important.

- The economics of knowledge spill overs. Innovative companies want to be close to their competitors, because new ideas are rarely born in a vacuum. Social interactions among creative workers tend to generate learning opportunities that enhance innovation and productivity. Furthermore, always according to Moretti, knowledge are subject to a "home bias", i.e. inventors and innovators are likely to cite inventors and innovators that liv nearby. Scientists and inventors are more familiar with knowledge produced by those who work near them, presumably because of the proximity factor.

The conclusion is that innovative firms have an incentive to locate near other innovative firms. These effects have gained importance over time and while it is commonly believed that the development of communications has made physical proximity less important to the creative process, in fact the opposite is true.

2.6 Clusters and the industry life cycle

Enrico Moretti[19], in his comprehensive analysis of agglomeration economy, clustering and labour mobility, confirms that "clusters can't afford to cling to a declining industry but need to leverage their unique strengths to reinvent themselves before the tipping point is reached and the local ecosystem enters a downward spiral". He confirms that the secret of success and sustainability is adaptation, since the forces of agglomeration are no guarantee that they will keep their market and innovation leadership for ever.

Comparing the cycles of the Detroit cluster – automotive – and Silicon Valley (San Francisco), Moretti's analysis shoes that differently from the former, which has been declining until these days, Silicon Valley has been experimenting and adapting to the ever-changing technological landscape, focusing on professional services and finance and later to high tech.. Moretti says that "Detroit's mistake was its failure to redirect its ecosystem into something new when it still had an ecosystem".

2.7 Summary of section

IoT is a fast-developing technological area and application field, with a very high potential of solving a very diversified set of needs, from industrial applications to networking systems, to smart cities, environmental problems to individually relevant functions. Market forecasts and technological roadmaps reinforce these trends.

Innovation clusters are actively developing innovative IoT solutions, creating new value chains, also cross-border, to take advantage of the opportunities offered by technology and by the increasing mass of data.

Clusters are a very effective way to sustain sectors and ecosystems, also supporting the development of Small and Medium-sized Enterprises, be it through networks, be it through the aggregation around larger technological institutions or enterprises. Recent academic research has confirmed the importance of physical proximity to sustain the creative process.

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[19] Moretti, Enrico. The New Geography of Jobs. Mariner Books 2013. Chapter "Forces of Attraction".

The next section presents the overall IoT innovation cluster study, its approaches, conceptualisations and analysis, and is based on literature reviews, surveys, discussions with experts, etc. as described in the introduction.

3. The Internet of Things innovation cluster study: principles

This section discusses the concepts and setup of the IoT cluster study: first of all, it presents the methodological setup and the IoT taxonomy. Furthermore, it presents the findings and, where appropriate, analyses the results of the desk research to scan and characterise the cluster landscape, the direct surveying and the case studies. The report presents the main aspects of cooperation, the main quantitative dimensions, the cluster members, the organisation, the services and activities.

3.1 The IoT innovation cluster study objectives

The objective of this study is to provide a good and deep understanding of the ecosystem for IoT and IoT innovation and in particular for IoT clusters. It describes the dynamics (factors of emergences, key drivers, common characteristics) that lead to the creation of ecosystems and clusters, delivering comprehensive information about these clusters. It carefully maps the geographical areas of these IoT innovation clusters operating within the European Union, as well as their main IoT or ICT specialisation. Scholars of industrial economics, such as Michael Porter[20], initially considered IoT innovation clusters as geographic entities that encompass start-ups, accelerators, incubators, investors, research centres, smart communities etc. operating in one of the IoT areas. However, the study has shown that there are also virtual, non-geographic clusters, which can rely on online platforms to sustain joint value chain activities and cooperate.

The European Commission has recognised the technological and market trends synthesised in Section and wishes knowledge and analytical support to take the appropriate measures to support the development of IoT solutions to reap their economic and societal potential, to foster new market opportunities for EU suppliers and at the same time enhance their acceptability and adoption by end-users and citizens.

3.2 The study methodology

The IoT cluster study was developed on the basis of a fully-fledged, integrated methodology using different approaches and instruments. These instruments concerned not only desk and database research, but also engaged IoT stakeholders to capture their points of view and inputs.

The study constructed a large panel of IoT players, going beyond those who are direct beneficiaries of EU policy measures or work with EU instruments, but considering actors at large, their needs and inputs, even if not necessarily related to their direct knowledge of EU policy making.

The study is based on an integrated approach based on several empirical phases:

- **Cluster mapping**, a desk research, web searching and data analysis and review of IoT and ICT clusters (semantic data analysis, literature review) to identify them and present the main qualitative and quantitative variables[21].
- **Direct surveying of IoT clusters**, to collect additional and complementary data through online survey.
- **20 Key IoT Cluster Case studies**, including interviews with cluster stakeholders, focusing on drivers, success factors, obstacles, policies and regulation.

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[20] Porter, Michael E. The competitive advantage of nations. The Free Press. 1989.

Michael E. Porter. Clusters and the new Economics of Competition. Harvard Business Review. November–December 1998.

[21] The main sources used were: the Internet, EU research and grant online databases (CORDIS), the protected EU grant database eCORDA, the public global business database Amadeus/ORBIS.

- **Development of a dynamic online platform** to show the information related to the different clusters. This platform is essential to the dynamic presentation of the cluster data and it allows IoT innovation clusters to register and deliver their data to the European IoT community. Users can access it through the link [www.iotclusters.eu]
- **Stakeholder engagement** with the purpose of drawing attention of potential users to the online platform and study results, defining a visibility plan and social media strategy.
- **Recommendations** on how to support the further existence or creation of such clusters in Europe as part of the final report.

As shown in Figure 3-1 depicting the methodology, the approach fully integrates the different tasks, linking the related research work and feeding the results and outcomes of one task into the other, each of them completing the results of the previous empirical phases. In particular, the development of the platform will significantly draw on the logic of the cluster mapping and on the variables surveyed through the online questionnaire. On the other side, Task 2, Task 3 and Task 4 will complement the results of Tasks1 and allow for a re-ranking of the clusters based on the new obtained results.

In particular the consolidated and harmonised datasets from the database and desk search and from the survey waves are to be presented on the IoT innovation clusters web platform.

Figure 3-1: Methodological Overview of the IoT Study (Source: JIIP)

On the left-hand side, we see the cluster mapping through database and web analysis, the direct surveying of clusters (two waves) and the qualitative assessment that occurred in the IoT cluster case studies.

The central section displays the external activities related to the study, mainly the dynamic online platform which exhibits the maps and data collected and synthesised.

On the right-hand side, we see the policy recommendations and the study's conclusions.

3.3 The ex-ante classification of IoT clusters

The IoT innovation cluster study required some preliminary definition of concepts and an overview of the classes of innovation clusters and their IoT activities. In other words, the initial documentary and desk research and several preliminary interviews provided a starting point for the methodological design and for the layout of the field research tools.

This section discusses the concept of IoT and IoT innovation cluster, presenting background information and specific study information to put Internet of Things and the relevant clusters into a more general theoretical and practical study context.

This section also provides fundamental information about the study, its logical and conceptual structure, the core taxonomy to classify and link IoT and IoT clusters, as well as an overview of the methodological design.

The initial desk and field analysis has ex-ante identified four fundamental classes of clusters:

- **Institutionalised clusters:** associations of actors who work towards a common goal within an agreed formal or informal governance structure. A formal governance structure is a pre-requisite for any policy intervention concerning the cluster.
- **Geographic clusters:** clusters in the traditional Marshallian and Porterian conception, as described in Section 2.4 of this report, where sets of companies that act in a certain geographical area and possibly with a clear reference to IoT, or IoT start-ups in a certain city. They may have a structure and governance, or not.
- **Virtual clusters:** where different actors, which can be part of different thematic areas, collaborate in an action and towards a common goal without being co-located.
- **Thematic clusters:** clusters that independently from their location, deliver products, technologies or services related to ICT or the Internet of Things. The aggregation factor may be a specific technology, technological platforms, application and/or (open source) software projects.

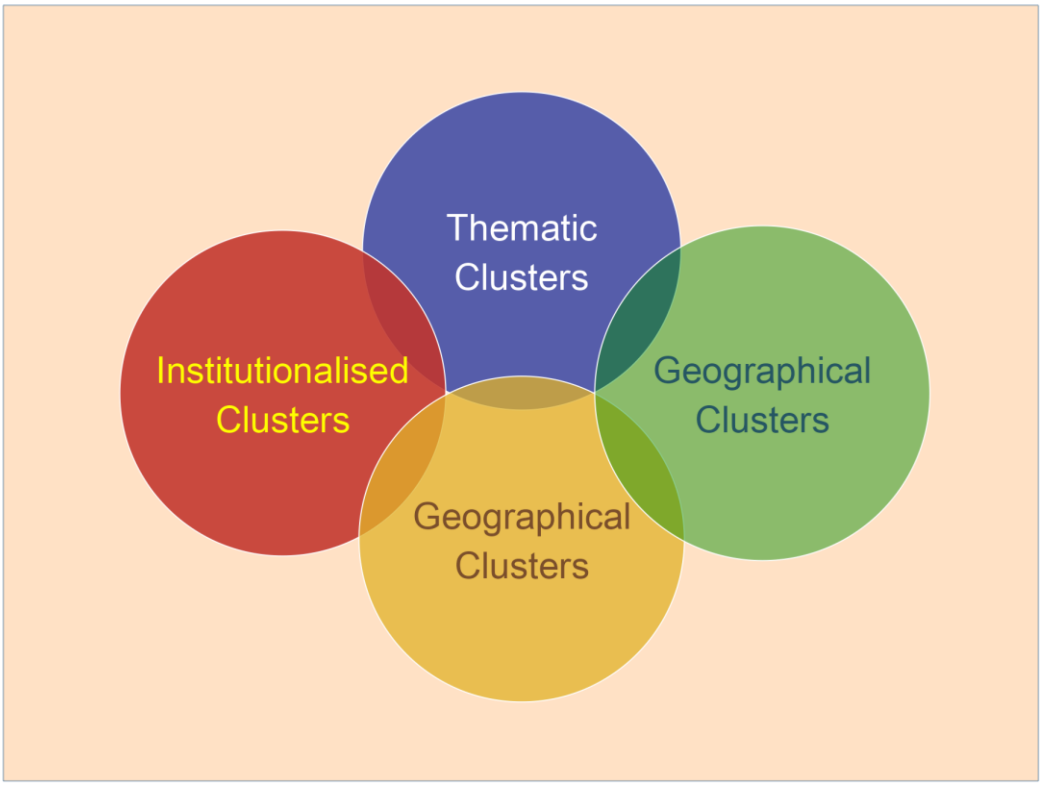

Figure 3-2: The ex-ante classification of cluster. Source: JIIP consortium

Figure 3-2 shows the possible overlap of the clusters in the different types. For policy-making purposes it is important to be aware of whether the cluster is formalised and/or has an agreed governance structure, without which the cluster as such cannot be the target of policy measures.

The database search, desk research and direct surveying activities have resulted in the following set of clusters, which were classified by type and shown in the following Table 3-1.

Table 3-1: The IoT study cluster sample by type. Source: JIIP consortium

Cluster type	Number of clusters	Share of total
Geographic clusters	22	5.66%
Institutionalised clusters	115	29.56%
Thematic clusters	209	53.73%
Virtual clusters	43	11.05%
Totals	389	100.00%

The desk and data sources research task of the IoT innovation cluster study has identified an overall number of 389 clusters at the cutting date in 2018. Over half of the clusters targeted by the study are thematic clusters, nearly 30% belong to institutionalised clusters. Slightly over 11% and nearly 6% belong to virtual and geographic clusters respectively.

It must be said that the 389 clusters do not claim to include all clusters in the EU, but it provides a solid foundation for the initial database, which may be increased in the operation stage of the EU online platform.

3.4 The classification of cluster based on the case studies

The case studies, described in detail in the case study report[22] and contributing to the qualitative facts and analysis presented in Sections 4 and 5 allowed to develop a different classification of clusters specifically focusing on their origin, scope and strategic objectives. This classification includes:

- **Technological communities**, created around a specific information and communication technology, which shapes the relationships between its members.
- **Research-driven clusters**, which involve the industrial, research, academic and technology players around a research venture.
- **Integration of ICT players and test-beds**, clusters that are originated from the need of ICT enterprise to join forces with user or user communities to develop applications.
- **Sector/industry-specific clusters**, which have the purpose to address the needs of specific industrial areas (food and telecommunications)
- **Cluster for sectoral development in a region or local area**, with the purpose to boost the development and growth in a certain Region or geographical area leveraging the potential of Electronics-IT and Telecommunications sector.
- **Industrial districts in the classic conception** of Alfred Marshall and Michael Porter as described in Section 2.4, as physical places where firms and workers specialised in a main industry or value chain[23], work and live.

3.5 The IoT taxonomy

We felt that our study would significantly benefit from the adoption of a IoT taxonomy, presenting the main categories for the IoT application domains, for enabling technologies, type

[22] The IoT cluster case studies report. (June 2018)

[23] "The value chain is defined very simply as a series of production tiers, each tier producing items that are substitutable in terms of the function they assume in a final product or service. This chain culminates in a specific product or service in which all of the value of components and processes has accumulated. The units of production in each tier of our value chain formulation are firms and organisations". https://www.oecd.org/sti/ieconomy/22572212.pdf

of organisations developing and implementing IoT solutions and systems, and, finally, the IoT stakeholders.

Our taxonomy is built assuming that the scope of IoT covers from the basic technologies to the applications so that everything related to ICT and everything related to where the “smart” word appears can be or is considered to be part of IoT. At the same time IoT is present in many of the European Commission initiatives, not only related to IoT like in the LSPs, but also related to the Digital Innovation Hubs, ENOLL networks and son on.

Due to the broad extension of the term defining a taxonomy for IoT has not been a simple task. In this study a pragmatic approach was followed for defining a taxonomy with the help of domain experts of IoT that is presented below. From this taxonomy a set of key words have been delineated to standardize the searches and queries across different data sources in order to ensure consistency in the data collection process.

The following chart[24] of IoT taxonomy has been adopted to show the main technological and cluster elements and concepts used in the study. It connects application domains with IoT/ICT cluster information, IoT-specific enabling technologies, roles of IoT organisations in technological empowerment and the classification of IoT stakeholders.

The taxonomy is useful to relate the key elements and concepts used in the study and characterising the IoT domain.

[24] For further reference and details, the full report of Task 1 provides a complete overview of the details of application domains (Smart living, Smart cities, Smart industry, Smart environment), Enabling technologies, type of organisations, and other stakeholders.

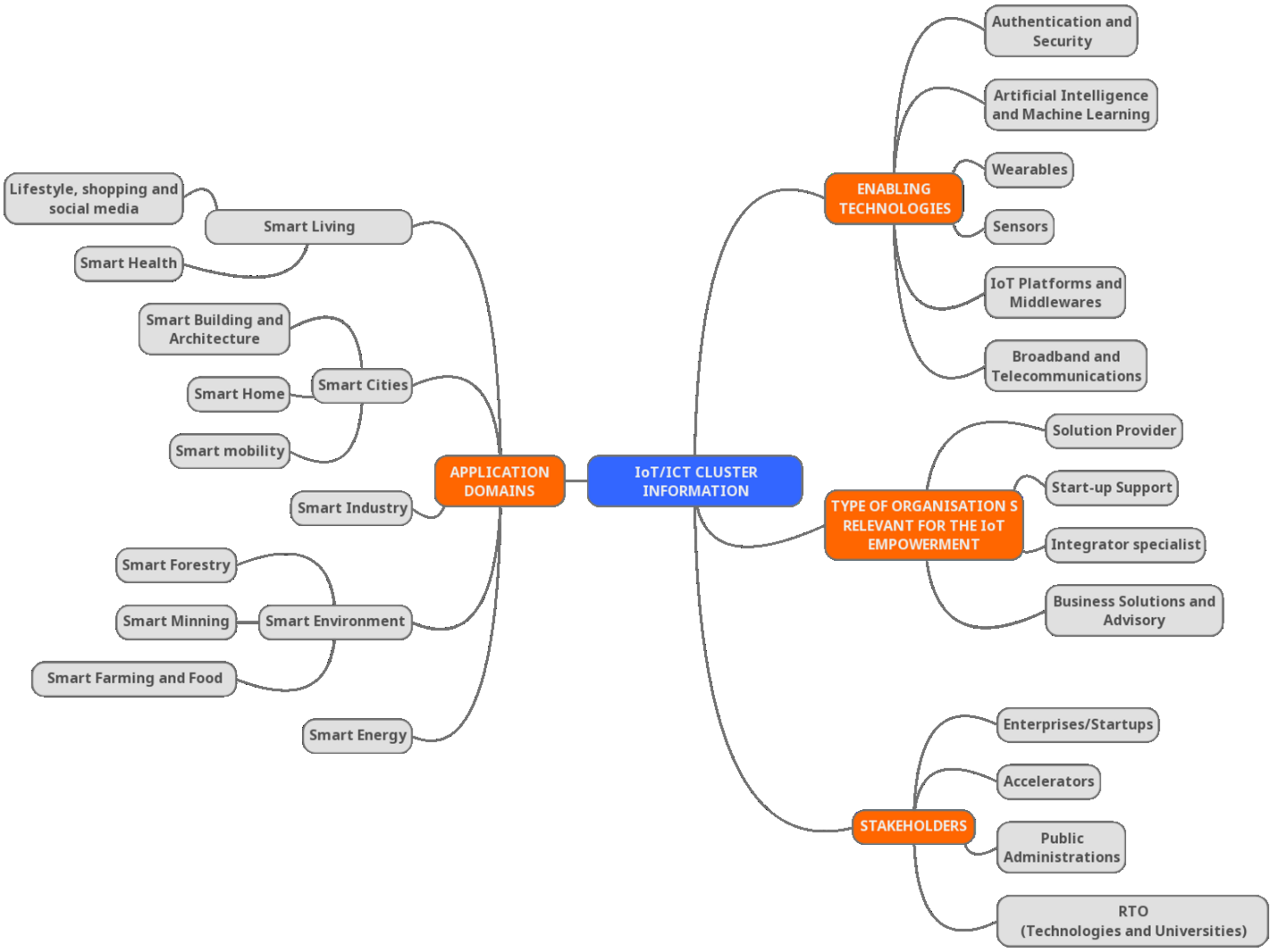

Figure 3-3: Taxonomy of IoT clusters. Source: JIIP consortium.

In the following chapters we discuss the elements of the taxonomy and propose a number of examples to illustrate their meaning and content.

3.5.1 Discussion of the Taxonomy: Application Domains:

- **Smart Living**: Smart Living is a trend encompassing advancements that give people the opportunity to benefit from new ways of living. It involves original and innovative solutions aimed at making life more efficient, more controllable, economical, productive, integrated and sustainable. This is a trend that covers all the aspects of day to day life, from domiciles and workplaces to the manner in which people are transported within cities. In short, Smart Living involves improved standards in several aspects of life, whilst striving for efficiency, economy and reduction of the carbon footprint.[25] Under this umbrella this study considers those which are currently more specific to the citizens which currently are:
    - **Lifestyle, shopping and Social Media**: This concept tries to group all activities related to actual Leisure of the citizens. The organisation under this category

[25] https://s3.amazonaws.com/ieeecs.cdn.csdl.content/mags/so/2018/03/mso201803.issue.pdf?AWSAccessKeyId=AKIAJTY5DYTIP3VEXGMQ&Expires=1527803399&Signature=qDZsyJyqlyHXMBywauFnKflx1XY%3D&lf1=1611691199f257959191045c67105322

provide apps and services which are directly used by the citizens daily as a way of interaction with society and in their environments.

- **Smart Health**: According to Blue Stream Consultancy[26], "*smart healthcare is defined by the technology that leads to better diagnostic tools, better treatment for patients, and devices that improve the quality of life for anyone and everyone*." The key concept of smart health includes eHealth and mHealth services, electronic record management, smart home services and intelligent and connected medical devices.

- **Smart Cities**: *"Cities using technological solutions to improve the management and efficiency of the urban environment."[27]*. We have also included three additional sub-categories addressing some of the current major challenges:
  - **Smart Building and Architecture**: "Smart buildings certainly bolster that impression with solutions that respond to and optimize our use of resources, reducing consumption. While individual benefits are no a small thing, intelligent buildings really have an eye to minimizing the environmental impact. Sustainable skyscrapers can draw on the Internet of Things to manage and connect, and on intelligent building technology like energy-efficient windows, aerodynamic design for low-maintenance ventilation and even smart elevators that generate energy for the building. A building that thinks with us – and the environment."[28].
  - **Smart Home**: "*A smart home is a residence that uses internet-connected devices to enable the remote monitoring and management of appliances and systems, such as lighting and heating."[29]*
  - **Smart mobility**, refers to a set of initiatives that have as objective improve mobility within the cities to ensure that it does not impact negatively in the daily life of its citizens as in its economic development. This mobility improvement is not limited to traffic but address all means of transport, walking, bicycle, public and private transport, with a common target: reducing costs, pollution and travel time.

- **Smart Industry**: "*Smart Industries are industries that have a high degree of flexibility in production, in terms of product needs (specifications, quality, design), volume (what is needed), timing (when it is needed), resource efficiency and cost (what is required), being able to (fine) tune to customer needs and make use of the entire supply chain for value creation. It is enabled by a network-centric approach, making use of the value of information, driven by ICT and the latest available proven manufacturing techniques.* "[30]

- **Smart Environment**, is centred in the use of Green TI (Green Computing and Information Technology) to develop intelligent environments capable of optimizing the natural resources and protecting the environment, reducing the emissions and waste in a sustainability manner whilst controlling and rationalizing energy consumption. As part, but not limited to this, the following sub-categories are defined:
  - **Smart Forestry**: '*The concept considers the whole forest and wood products chain, including material and energy substitution effects that are - according to current accounting practices – not attributed to forestry.'[31]*

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[26] http://bluestream.sg/smart-healthcare

[27] https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en

[28] http://www.urban-hub.com/smart-buildings/

[29] https://internetofthingsagenda.techtarget.com/definition/smart-home-or-building

[30] https://smartindustry.nl/voorbeeld-pagina/

[31] https://www.efi.int/sites/default/files/files/publication-bank/2018/efi_fstp_6_2018.pdf

- **Smart Mining**: Smart mining, also known as telerobotic mining, includes remote-controlled robotic machinery for reducing the risk for miners and improving mineral extraction.
- **Smart Farming and Food**: Smart Farming and food represents the application of modern Information and Communication Technologies (ICT) into agriculture and food production and tracking. Climate Smart Agriculture (CSA) aims to enhance the capacity of the agricultural systems to support food security, incorporating the need for adaptation and the potential for mitigation into sustainable agriculture development strategies.[32]

- **Smart Energy**: '*Smart Energy Systems take an integrated holistic focus on the inclusion of more sectors (electricity, heating, cooling, industry, buildings and transportation) and allows for the identification of more achievable and affordable solutions to the transformation into future renewable and sustainable energy solutions.*'[33]

3.5.2 Discussion of the Taxonomy: Enabling Technologies:

- **Authentication and Security**: Authentication is a process that is used to confirm that a claimed characteristic or attribute of an entity is correct and true.
  'IoT devices constantly producing communications, require careful security and privacy considerations. Authentication of critical data, and baseline triggers for action are the emerging security focus. Communications could be interrupted given a variety of factors and unless there is an assurance that corresponding devices are legitimate, there is no basis for secure operations.'[34]

- **Artificial Intelligence and Machine Learning**: '*Both terms often seem to be used interchangeably but they are not the same thing. Artificial Intelligence is the broader concept of machines being able to carry out tasks in a way that we would consider "smart". Machine Learning is a current application of AI based around the idea that we should really just be able to give machines access to data and let them learn for themselves.*'[35]

  - **Wearables**: '*A wearable, in its simplest form, is defined as an item or object that is suitable for wearing. Clothes, jewellery, watches, glasses, and shoes all fit within this category*'.[36]

    In terms of IoT environment the Wearables term is defined as '*A technological infrastructure that interconnects sensors to enable monitoring human factors including health, wellness, behaviours and other data useful in enhancing individuals' everyday quality of life. It is no longer sufficient to design standalone wearable devices, but it becomes vital to create an IoT ecosystem in which worn sensors seamlessly synchronize data to the cloud services through the IoT infrastructure*.' [37]

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[32] http://www.fao.org/climatechange/epic/activities/what-is-climate-smart-agriculture/en/%20-%20.WvweW5q-kdU

[33] https://www.researchgate.net/publication/317122110_Smart_Energy_and_Smart_Energy_Systems

[34] https://www.verizon.com/about/sites/default/files/state-of-the-internet-of-things-market-report-2016.pdf

[35] https://www.forbes.com/sites/bernardmarr/2016/12/06/what-is-the-difference-between-artificial-intelligence-and-machine-learning/#3a663ee82742

[36] S. D. Guler, M. Gannon, and K. Sicchio, Crafting Wearables. Berkeley, CA: Apress, 2016

[37] https://pdfs.semanticscholar.org/57b7/240f0b2d1395c08c7dee868a4754510ba9be.pdf

- **Sensors**: '*Sensor is a device that takes input from the physical environment and uses built-in compute resources to perform predefined functions upon detection of specific input and then process data before passing it on. Smart sensors*[38] *enable more accurate and automated collection of environmental data with less erroneous noise amongst the accurately recorded information. These devices are used for monitoring and control mechanisms in a wide variety of environments*.'[39]

    - **IoT Platforms and Middlewares**: An IoT platform is a collection of hardware and software components to support a particular need for IoT.

      '*Internet of Things middleware is software that serves as an interface between components of the IoT, making communication possible among elements that would not otherwise be capable*.'[40]

- **Broadband and Communications**: Broadband is a high-capacity transmission technique using a wide range of frequencies, which enables a large number of messages to be communicated simultaneously.

  '*Broadband represents the vital final piece of the puzzle. The need for always-on bandwidth combined with potentially huge numbers of networked objects – some estimate many billion individually connected devices – imply an immense data throughput on networks. European Commission predictions suggest that some applications could involve the networking of up to 70 billion devices Europe-wide. In this, the communications economics and economies of scale that broadband brings are key for success*.'[41]

3.5.3 Discussion of the Taxonomy: Types of Organisations:

- **Type of organisations relevant for the IoT empowerment:** Within the study specific emphasis has been provided to identifying potential enterprise ecosystem that sustains the IoT overall. This is form by Solution providers and Integrator specialists, which focus on providing the required knowledge and technologies to deploy IoT solutions. On the other hand, the business solutions and advisory concept, comprises consultancy organisations which aid in the definition of IoT Strategies for organisations and then recommend potential roadmaps for IoT Adoption, which will require the participation of Solutions providers and integrators specialist and also organisations that have business solutions that may have IoT related technologies or concepts. Finally, the Start-up support concept, comprises organisations which provide adequate mentoring, financing, strategy, infrastructure resources among others in the conceptualization and productization of solutions that can give pace to the creation of Start-ups.

- **Stakeholders:** IoT ecosystem including stakeholders' definition is extensively described in the following section.

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[38] https://whatis.techtarget.com/definition/sensor

[39] https://internetofthingsagenda.techtarget.com/definition/smart-sensor

[40] https://internetofthingsagenda.techtarget.com/definition/IoT-middleware-Internet-of-Things-middleware

[41]http://www.broadbandcommission.org/Documents/Media%20Corner%20Files%20and%20pdfs/Broadband%20drives%20the%20Internet%20of%20Things.pdf

3.6 Considerations about the data

Before getting into the core data the IoT innovation clusters it is important to provide some overall information on the specific characteristics of data, their segmentation, search and availability. The latter issue of data availability is a substantial challenge when calculating indicators. While this has been observed in other projects as well (e.g. the “Start-up Hubs Europe” mapping[42]), data collection is even more challenging in an IoT-context, given the fast-changing nature of IoT and its cross-sectoral character. It is also worth mentioning that Information obtained from the different sources is very heterogeneous, so checking the consistency of data has been an important and substantial effort.

Few of the variables under analysis could be obtained at cluster level, in most cases only the list of companies belonging to the cluster. It has been then possible to present results at cluster level as the sum of the results of the companies forming part of the cluster. However, this has been a very time-consuming task, since in order to complete this information, manual searches company by company have been carried out in the Bureau van Dijk/ORBIS database to complete the results. Additionally, the search for specific companies forming part of a cluster has shown that not all required variables could be obtained through this additional step.

The current research shows that a number of variables could not be obtained from general sources and publicly available databases, in particular due to the difficulty of precisely targeting the IoT perimeter.

Another challenge is that a cluster is usually composed of heterogeneous sets of entities like Multi-National Corporations (MNCs) and large corporates, SMEs, start-ups and Research Centres and Universities (RTOs), so summing the data about all of them can provide biased results in the characterisation or ranking of the clusters, i.e. a cluster with a huge number of MNCs or large companies will appear in the ranking in an upper level that another one mainly composed by start-ups. Moreover, it is not always clear where exactly the IoT-sections of MNCs are located and how large their commitment to IoT is, as this data might even be confidential for strategic purposes.

The mentioned aspects must be taken into account when analysing the following tables in order not to reach skewed conclusions.

[42] http://www.startuphubs.eu/

4. The IoT Innovation cluster study: the quantitative and qualitative results

This section discusses the detail of the main findings of all the research lines of the IoT cluster study: it presents the findings and, where appropriate, analyses the results of the desk research to scan and characterise the cluster landscape, the direct surveying and the case studies. The report presents the main aspects of cooperation, the main quantitative dimensions, the cluster members, the organisation, the services and activities.

The IoT innovation cluster study adopted two integrated approaches to collect quantitative information on the EU IoT innovation cluster domain: the desk research, documentary research and database review on the one hand and the direct cluster survey on the other.

Obviously, these research instruments have different approaches and target different groups, even if they provide information on IoT actors in clusters in a completely complementary way. The quantitative data from the database research and from the two direct survey waves were consolidated in the overall dataset used by the online IoT innovation cluster platform.

In this section the IoT report we present the quantitative and qualitative results of the investigation work and it is important to note that the terms of reference ask for two types of quantitative data

- Descriptive data and dimensional data, which depict situations and the size of cluster-related elements and phenomena. For example, the distribution of clusters, the number of associable start-ups, the amount of cluster members and the application domains and the IOT-related technological services.
- Analytical data and information, including assessments and judgmental statements, which are capable of being analysed.

Both types are necessary to describe the IoT innovation cluster landscape and should be considered appropriately.

The following paragraphs show the IoT innovation clusters and member companies identified through the desk and database search as of May 2018 and has identified data about structures, organisations and operations.

4.1 The number of IoT clusters and organisations in the desk research and the direct surveys

This descriptive section requires a methodological premise: not all data and facts are there to be analysed or to draw conclusions directly. Naturally, and as the terms of reference of this study clearly state, some information is just there to describe the landscape or to map findings, such as the respondents to the direct surveys and not to highlight logical and causal links.

The results of the database and website research as well as the targeting of the two direct survey waves identified led to the identification of 389 EU IoT innovation clusters and their 12,023 member companies, as shown in Table 4-1.

Table 4-1: Clusters identified in the database and web research. Source: JIIP consortium.

EU IoT innovation clusters	389
Member Companies of the EU innovation clusters	12,023

Obviously, the study does not claim to have captured all existing European Union however, their number provides a good basis to portrait the EU IoT innovation cluster landscape. This

basis will be further expanded once the online platform [http://www.iotclusters.eu/iot-clusters-in-europe] will be in operation.

As already emphasised in Section 3.6, the available information from public sources and databases was and is not enough to undertake the full characterisation of the IoT clusters, therefore it was mandatory to integrate and complete the dataset through the direct surveys, which collected

- Data to characterise IoT clusters, presenting their distinctive features.
- Judgmental data on clusters and their operations.

Table 4-2: Cluster responses and their segmentation by respondent type. Source: JIIP consortium.

Direct cluster surveying respondents	1169
Companies/Enterprises	597
Higher Education Institutions	134
Research and Technology Organisations	153
Not specified	114
Other	171

As shown in the table, over 50% of the 1169 respondents to the two survey waves are companies, and well over 25% universities (12%) and research organisations (13%), indicating that businesses are one of the key players in IoT and ICT clusters, which has been confirmed by the case studies.

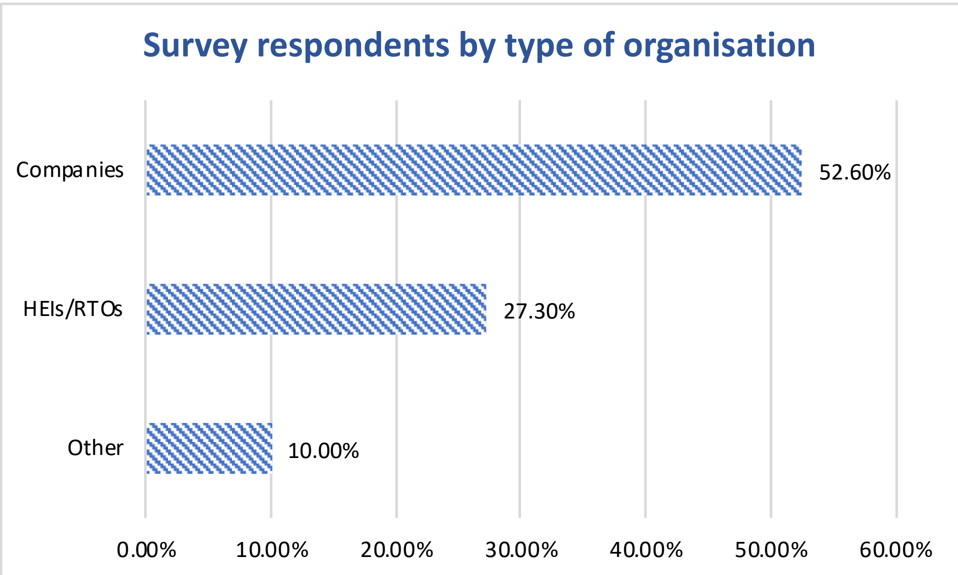

Figure 4-1: Survey respondents by type of organisation. Source: JIIP consortium.

The study's surveys were targeted at IoT players and ICT players and, since the available sources of contacts did not provide any details about their cluster membership, the questionnaires provided an appropriate question. Table 4-3 below shows the distribution of respondents to the direct survey, who have confirmed their membership in a cluster.

Table 4-3: Survey respondents by type declaring cluster membership. Source: JIIP consortium.

	Declare cluster membership	Total respondents	Percentage of respondents belonging to clusters
Businesses	246	597	41.21%
RTOs	97	134	72.39%
Academic institutions	67	153	43.79%
Other actors	95	114	83.33%
Not specified	-	171	
	505	1 169	43.20%

Over 40% of the businesses, 70% of the research and technology organisations, and 40% of academic institutions confirm that they are linked to clusters. The surveys were based on a fundamentally unbiased sample and demonstrates that over 40% of survey participants belong to clusters, consistent with the conclusions of scholars that confirm that business tend to move close to other innovative firms and into dynamic and fast-developing ecosystems with thick talent markets and a rich service offering, as confirmed by Moretti[43].

It is interesting to check to which types of clusters the survey respondents declared to belong to. Figure 4-2 confirms the trends in aggregation economies: nearly 65% of the surveyed enterprises declared their membership in clusters, thus demonstrating that clustering is important.

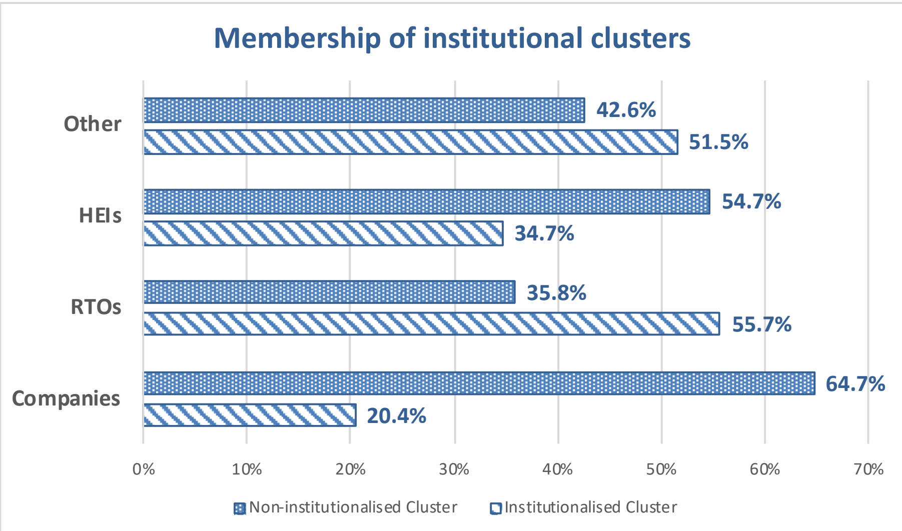

Figure 4-2: Cluster Membership in institutionalised and non-institutionalised clusters (Companies N=246; RTOs N=97; HEIs N=67, Others N= 95). Source: JIIP Consortium

Of the companies declaring the membership in a cluster 64.7% belong to institutionalised clusters and only slightly over 20% to institutionalised clusters, which is explained by the fact that businesses tend to adopt a more opportunistic attitude toward collaboration and prefer less regulated settings rather than regulated ones.

43 Moretti, Enrico. The New Geography of Jobs. Mariner Books 2013. Chapter “Forces of Attraction”.

The case of universities is similar, were over half of survey participants declare their membership in non-institutionalised clusters, quite the opposite in respect to RTOs, which obviously prefer regulated ecosystems rather than non-regulated ones.

One explanation for the academic attitude is scientists and researchers tend to be very independent in defining the priorities of their activities and may limit their commitment to their integration within very structured settings.

Figure 4-3 shows the segmentation of survey respondents who declared the membership in virtual or geographic clusters. The latter are those related to the studies of Alfred Marshall and, later, Michael Porter, as described in Section 2.4. remarkably, all survey participants appear to prefer geographical clusters rather than virtual ones. This is particularly true for companies, and shall be related to the issue of proximity described in Section 2.5 as well as to the general attitude towards clusters confirmed in the cluster case studies and reported in Sections 4.2 to 4.7.

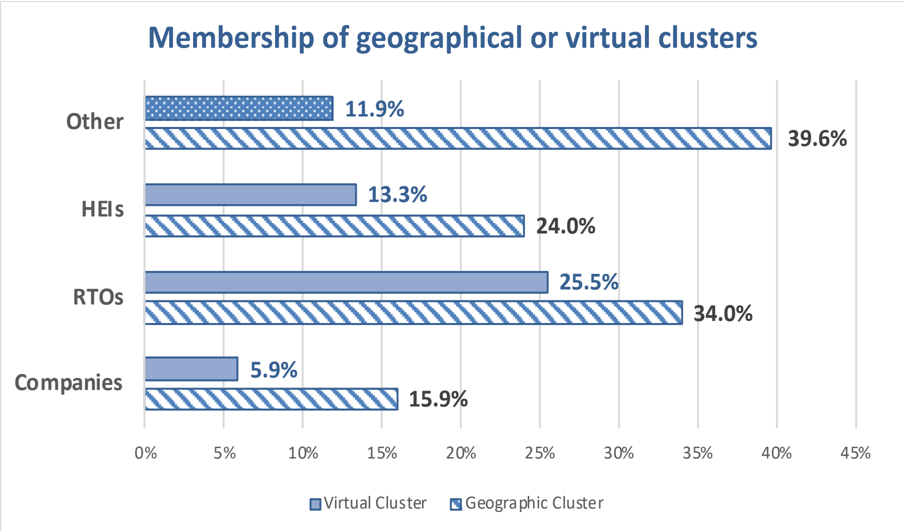

Figure 4-3: Cluster Membership in geographical and virtual clusters (Companies N=63, RTOs N=63, HEIs N=28, Others N= 52). Source: JIIP consortium.

Membership in virtual clusters seems relatively limited, except for RTOs, but still their participation in geographical clusters is higher. The mainstream RTO strategic approach of industrial support – for example the one of the Fraunhofer Institute[44] – is based on their embedding in their surrounding ecosystems of Small and Medium sized Enterprises. This applies to many clusters in- and outside the IoT innovation cluster case studies, such as the Innovation Cluster Eindhoven, Flanders Food, the Hungarian Alliance Cluster, the Italian MEDISDIH Apulian Mechatronic Technological Cluster and Digital Innovation Hub, etc. For further details on the case studies, please see Sections 4.3 to 4.11, as well as Section 5, as well as the IoT cluster case studies report as delivered in June 2018.

4.2 Where in the EU are IoT innovation clusters?

The initial core task of the present study was to identify and locate Internet of Things innovation clusters in the European Union.

The map, which allows certain degrees of customisation and personalised filtering, is available on the platform.

44 The Fraunhofer Institute is supporting innovation in Small and Medium Enterprises and adopts a mixed model of location – in industrially concentrated areas – and networking. https://www.fraunhofer.de

The map visualisation shows the main locations and the number of clusters in each of them. The dynamic platform's filtering functions allow to select different segments of clusters, zooming in the clusters in each location will be displayed individually and the users has the possibility to visualise the pop-up windows with the individual cluster information.

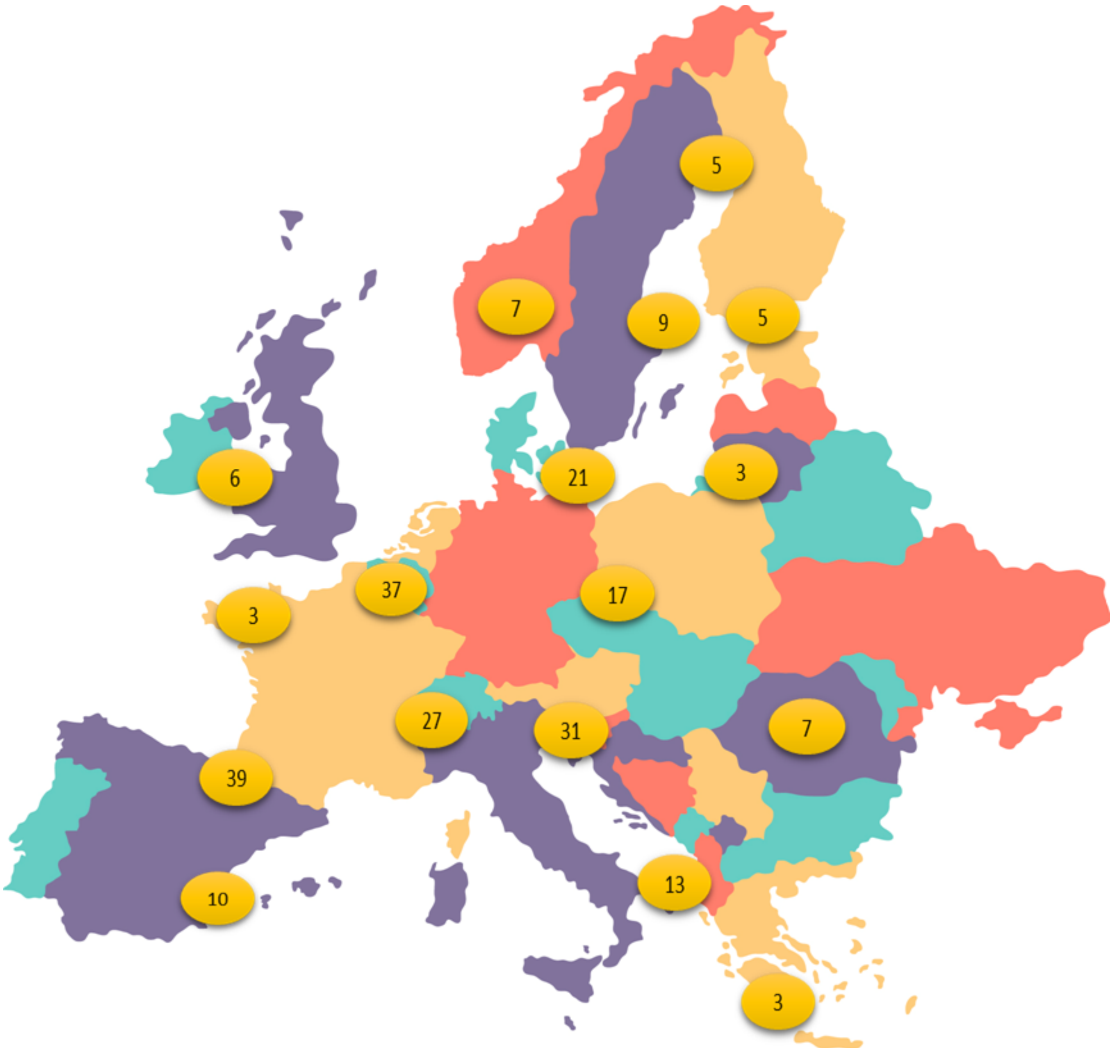

Figure 4-4: IoT Innovation cluster platform: the map of clusters in the EU. Source: http://www.iotclusters.eu

The number of IoT innovation clusters is specified in Table 4-1, with the entities identified by the desk research, while Table 4-2 shows the responses to the direct online surveys.

The different perspectives and segments of the European IoT cluster landscape are available on the online platform, displaying the data in different way.

As an example, Figure 4-5 displays the distribution of the platform clusters across the EU. Most clusters are located in Spain (46), in France and Germany (28 and 23 respectively), Italy (24), Belgium (15).

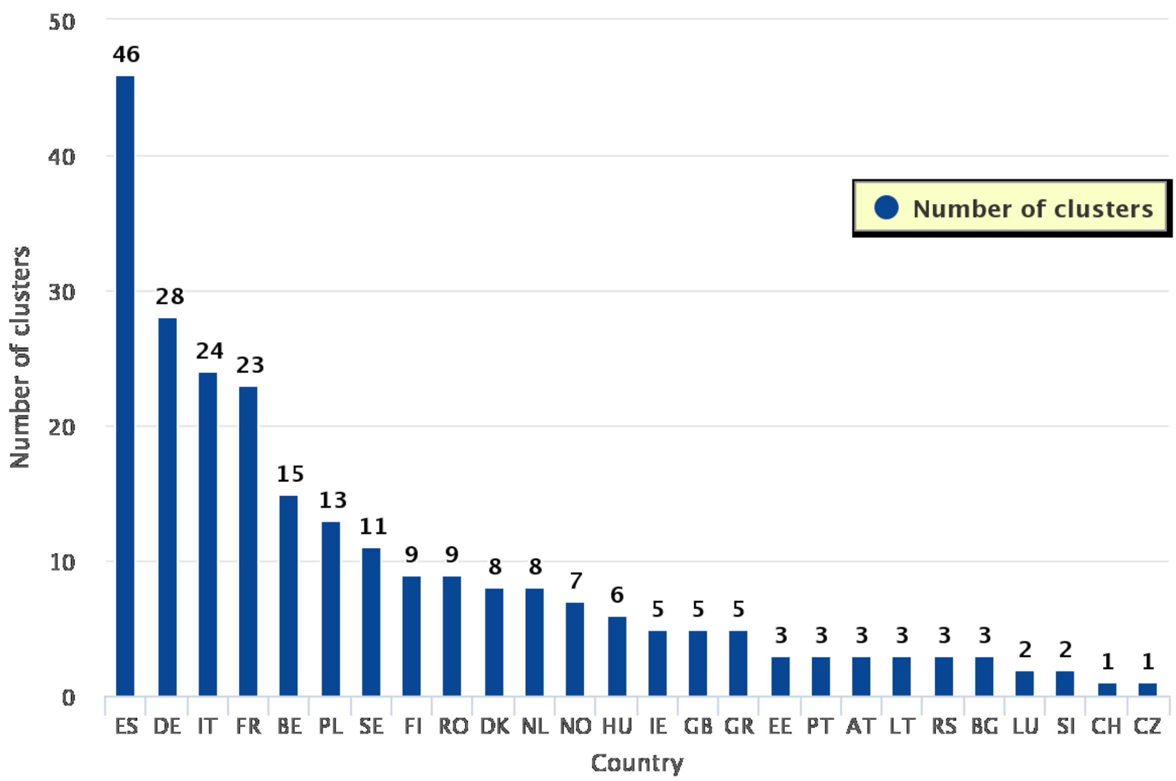

Figure 4-5: Cluster and cluster types per country. Source http://www.iotclusters.eu. JIIP consortium.

(Note. Link to be deleted in the final version)

4.3 Why are innovation clusters established?

The analysis of cluster documentation and the case study report[45] pictures the fundamental drivers of the institution of clusters and the reasons for their establishment. The most frequently mentioned ones are:

- Response to industrial and sectoral crises in specific geographical areas, also related to the crises of large enterprises (such as Ericsson and Nokia). In most cases these clusters are driven by Public Private Partnerships, but their sustainability does not rely on public funding.
- EU-supported PPPs targeting specific issues, such as the Future Internet PPP.
- Clusters initiated on the initiative of administrations in the different countries or regions, for example, the German Länder put in place strong initiatives at the beginning of the 2000's.
- The introduction of the Industry 4.0 strategy, creating Public Private Partnerships to pursue this specific industrial policy line.

The case studies have demonstrated that public bodies are essential stakeholders and contributors to territorial clusters. However, they are not key to cluster's sustainability, for at least two reasons: the uncertainty of endowment funds and operation funds over time (they are normally assigned via a public competition) and because of the limited suitability of project work, as that financed by public programmes, to sustain cluster missions. None of the clusters has significant expectations to receive a significant level of funding, which is capable to sustain

[45] The IoT cluster case studies report. (June 2018). JIIP Consortium.

them. Further details on the single case studies are available in the relevant report[46]. The role of public bodies will be further analysed in section 4.5.

The review and analysis of the case studies has allowed us to draw up a new cluster classification, related to their genesis and strategic setup. These classes complement the ex-ante classes as described in Section 3.3 of this report.

- **Technological communities**, which can be assimilated to open source community, are oriented towards the creation of implementation of technological solutions , developing open source software platforms. These clusters, such as FIWARE and ECLIPSE, have a different origin than the geographical and sectoral clusters and some of them are virtual.
- **Research-driven clusters**, which involve the industrial, research, academic and technology players in a region or in the relevant field gathered around technologies and their investigation. In these clusters the role of the academia is often significant.
- **Integration of ICT players and test-beds**, which are clusters that are driven by technological initiatives that need testbeds for a specific research and innovation project, like Smart Santander and that, have become sustainable IoT deployment initiatives. In other words, to respond to a funding opportunity a technology provider and integrator has teamed up with a local institution for a targeted implementation project and the link has become a permanent and sustainable partnership.
- **Sector/industry-specific clusters** like Flanders food or the Finnish Industrial Internet Forum FIIF, which have the purpose to address the needs of specific industrial areas (food and telecommunications). These clusters closely cooperate with the local industry to support their innovation needs.
- **Cluster for sectoral development in a region or local area**, with the purpose to boost the development and growth in a certain Region or geographical area leveraging the potential of Electronics-IT and Telecommunications sector are less close to technologies as such but aim to their application. Their networking effort favours the assimilation and efficient usage of the sector's technologies, fostering socio-economic and societal impacts through the development of the Information and Knowledge Society.
- **Industrial districts in the classic conception** of Alfred Marshall and Michael Porter as physical places where firms and workers specialised in a main industry or value chain[47], work and live. They are supported by an industrial environment, possibly a physical ecosystem, and characterised by market and non-market mechanisms, with significant informal competence and knowledge exchange. Relationships are based on personal knowledge and trust. Industrial districts often have common infrastructures.

4.4 The geographical reach and size of reviewed IoT clusters

The clusters analysed by the study's direct survey have in many cases a transnational reach, or they cover a range of activities on a national basis or have a regional and interregional focus. Only less than one-third as only a regional reach and no cluster operates on a merely local basis.

The study examined the absolute number of IoT enterprises in innovation clusters and the relative share of IoT enterprises among all enterprises part of the clusters and concluded that

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[46] *Ibidem*.

[47] "The value chain is defined very simply as a series of production tiers, each tier producing items that are substitutable in terms of the function they assume in a final product or service. This chain culminates in a specific product or service in which all of the value of components and processes has accumulated. The units of production in each tier of our value chain formulation are firms and organisations". https://www.oecd.org/sti/ieconomy/22572212.pdf

the absolute number of IoT enterprises in 2017 has grown 2,5 times in respect to 2012 and the share of companies engages in IoT has increased from 26.5% to 44.5%.

As mentioned in the previous section 1.1 and in the subsequent section 4.5.4 dedicated to them, start-ups are a proxy of innovation vitality and cluster dynamics. Between 2014 and 2016 the number of start-ups climbed from 144 to 230 and finally to 329 in the surveyed EU IoT innovation clusters, nearly 2.3 times, hinting strongly at the fact that the overall growth of IoT firms in clusters has been mainly driven by new firm formation.

4.5 The actors and roles in the IoT clusters of the study

In this section we are going to present how cluster players engage with and operate within their ecosystems. There is more detailed evidence, specific to each research line, i.e. the database and desk search, the direct survey waves and the cluster case studies in section **Error! Reference source not found.** of this report.

4.5.1 The role of large players

The case studies and the related desk research[48] provide key information on cluster composition and organisational setup. It shall be noted that case studies are in-depth investigation of specific clusters to obtain qualitative causal links and explanations concerning the cluster phenomenon and, as such is indicative because of the descriptive elements rather than statistical significance. Therefore, their logical analysis is meaningful as such and related to the representativeness of selected case studies[49] and not because of the frequency of occurrence.

As shown by the results of the desk research and the case studies, in a few instances the cluster creation was initiated, promoted and supported by large players. These large players, such as large multinational companies (LMCs) but also large research and technology organisations, are considered the natural counterparts and to the start-up of development of policy-making initiatives, since they are at least more visible and own clearer innovation strategies.

Cluster case study interviewees in Germany and Italy have pointed out that large enterprises and research and technology organisations in many instances have practically “faded out”, without taking up and developing their original role and leaving the floor to the smaller players. This tells us that IoT, ICT and clusters in general are successful and sustainable only insofar they provide value to the single participants and to the overall agglomeration. Just like any operator on the market, be it the IoT market or the relevant research and innovation market, or even the education and training system market supplying businesses, research organisations, public administrations, clusters need to provide value to their members to sustain their engagement. If a cluster loses its large-scale stakeholders it means that it does not create value for them to stay beyond a formal presence. Obviously, there are major differences in clusters which see a significant involvement of large players and those in which SMEs are the core players together with cluster management authorities in that the latter are significantly more flexible but require additional effort to reach construct value chains and to establish enough critical mass.

An IoT cluster can dwell on small enterprises and be sustainable, there needs to be awareness, however, on the main strategic shift from the original setup.

[48] The IoT cluster case studies report. (June 2018). JIIP Consortium.

[49] The case studies’ selection has followed the geographical criterion in first instance and subsequently the criterion of application area.

4.5.2 The role of public bodies

Our IoT case studies confirm that very frequently, public bodies are involved in IoT/ICT clusters as key actors in territorial development strategies and implement programmes, also because of their clear role and mandate in defining local and regional industrial and reindustrialisation policies. Public bodies have a key role in defining the framework conditions in terms of regulations, environment, education and training and research and innovation and provide specific support to internationalisation initiatives. In addition, public partners are a key enabling factor of clusters, but not a factor of sustainability as shown in the analysis of operational factors and particularly in Sections 4.7, 5.4 and 6, and in the IoT innovation clusters case study report (2018). These issues related to public support to clusters are confirmed by the paper of Gilles Duranton, who states that "First, clustering is not a choice variable that policy-makers can easily manipulate. Second, this intermediate outcome is only weakly related to the final prosperity objectives that local policy-makers should be interested in"[50]. In the same line Martin, Mayer and Mayneris have confirmed the inability of French cluster policies to reverse the relative decline of total factor productivity at work for firms targeted by the policy[51].

Although the formation of clusters is essentially a "bottom up"[52] process, in countries such as Serbia the process of creating clusters is supported and facilitated by national or regional government policies through structural, technological, innovation measures as well as direct financial support. These measures are considered as a key factor for launch and trust building.

In other countries, public bodies and administrations have been playing a key role in promoting ICT and IoT clusters, for example the industry 4.0 initiatives in Germany. Public bodies are certainly an important player in clusters for their institutional, development and regulatory responsibilities but, as reported in the IoT cluster case study document, they cannot support cluster attraction and aggregation or sustainability in the long run.

4.5.3 The role of SMEs

IoT cluster case study participants[53] confirm that SMEs are very important players in clusters and clusters are a means to strengthen their productivity, competitiveness and innovative capabilities. Scholars like Makedos[54] explain that SMEs have proved to be important vehicles of employment and fundamental factors of the innovation. The case studies show that SMEs are as innovative as big enterprises, nevertheless, due to their small size and financial weakness, SMEs may not be able to cover on their own the cost of purchase of research results.

SMEs cooperating in clusters and constructing and rearranging value chains are in most cases able to self-fund and absorb research knowledge structuring exchange of information and generating the necessary critical mass, which gives them the possibility to fill the technology knowledge gap and to compete. The case studies confirm that clusters are capable of

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[50] Duranton, G.. California Dreamin': The feeble case for cluster policies. Review of Economic Analysis 3 (2011) 3 – 5.

[51] Martin, P, Mayer T. Mayneris, F. Public Support to Clusters. A firm level study of French "Local Productive Systems". Elsevier Regional Science and Urban Economics (41) 2011. 108-123.

[52] In Serbia, several clusters have been initiated over the years, however, there is no explicitly defined cluster policy. They are still frequently targeted the goal of objective of several national policy document above all as outlined in the Strategy of development of competitive and innovative small and medium-sized enterprises for the period 2008-2013.

[53] The IoT cluster case studies report. (June 2018). JIIP Consortium.

[54] Ioannis Makedos, "The Collaboration of SMEs through Clusters as Defence against Economic Crisis," Economics Research International, vol. 2014, Article ID 407375, 9 pages, 2014.

aggregating SMEs and boost their ability to perform on markets. Porter[55] particularly emphasised that businesses can self-develop and cooperate either with one another or with university institutions and research centres, with the objective aim to grow larger and become international.

4.5.4 Start-ups in IoT clusters

The recent scientific literature on start-ups acknowledges that they are an extremely important player in innovation, economic growth and job creation. According to publications of the Organisation for Economic Co-Operation and Development – OECD[56], start-ups have made an extremely relevant contribution to innovative performance and job creation across countries. OECD research has also demonstrated that only a small portion of start-ups manage to grow very fast. Even if the enabling factors of innovative entrepreneurship are still being explored, and it is unclear for policy makers which levers can be activated in this domain, the role of start-ups is undisputed. The analysis of Criscuolo, Gal, & Menon[57] of quantitative data on business demographics, i.e. birth, growth and death of enterprises provides insights on young firm dynamics, provides important insights on young firm dynamics Innovative start-ups are considered a driver of social mobility.

The IoT clusters study case studies have demonstrated that start-ups have a very particular relationship with IoT clusters, and interviewees confirm that they can take advantage of clusters only under certain conditions. Clusters need to take account of start-ups' specific characteristics and needs. Case study participants have underscored that start-ups are small and lack critical mass, that they are unable to allocate significant amounts of funds to cluster fees and to allocate significant resources to open activities, such as internationalisation missions, as they are putting most of their efforts into making the start-up phase a success, rather than engaging in community building.

Clusters stakeholders confirm that start-ups are very important to push forward the development of technologies but also the IoT topic itself, drive innovation and application adoption in IoT. Disruptive innovations in IoT usually come from start-ups and SMEs, which are less inclined to take part in clusters. For start-ups and SMEs being member of a cluster means devoting efforts for which they usually don´t have resources. Some actions could be taken in order to be closer to SMEs and start-ups ecosystems.

Considering the results of the database search and the case study report, the IoT start-up landscape at this moment is quite fragmented. Many IoT players and cluster stakeholders have confirmed that start-up numbers and start-up activities heavily depend on the specific setup and development of the cluster and on its main technological and operational characteristics[58].

The database search described in the Task 1 report of the study produced relatively limited information about the start-ups dynamics. On the contrary, the case studies, even though statistically not representative, have produced the descriptions of interesting experiences such as the one of the German VDC cluster[59], that counts on 98 start-ups and about 250 members.

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[55] Michael E. Porter. Clusters and the new Economics of Competition. Harvard Business Review. November–December 1998.

[56] Calvino, F., C. Criscuolo and C. Menon (2016), "No Country for Young Firms?: Start-up Dynamics and National Policies". OECD Science, Technology and Industry Policy Papers n. 2016/29. OECD Publishing, Paris. Doi: http://dx.doi.org/10.1787/5jm22p40c8mw-en

[57] Criscuolo, C., P. N. Gal and C. Menon (2014), "The Dynamics of Employment Growth: New Evidence from 18 Countries". OECD Science, Technology and Industry Policy Papers, no. 14. OECD Publishing, Paris. Doi: http://dx.doi.org/10.1787/5jz417hj6hg6-en

[58] The cluster rules may be more or less favourable to a start-up environment, so are the large or medium enterprises that operate in it.

[59] https://www.vdc-fellbach.de

The particular setup foresees reduced fees and start-up dedicated programmes and activities. The start-up landscape emerging from the cluster scan is extremely diversified and expresses different needs.

In the Finnish FIIF cluster[60] the Start-up and non-profit organisations participation is free of charge and these members can take advantage of the services provided. Due to a high number of participating companies, the funding has, so far, well covered the expenses.

The interviewed Clusters[61] suggest putting in place specific rules for SME and start-up participation, to take advantage of their innovative capabilities, still easing their participation. As mentioned, start-ups are much more focused on their individual success, rather than on their cluster membership and prefer ad hoc collaborations. Clusters need to be made really attractive to them in terms of advantages and of reduced associated costs, be it membership costs or transaction costs[62].

The report on the database sources[63] shows that the countries with the highest number of start-ups active in IoT clusters are:

- UK
- France
- Germany
- Spain and
- Italy.

Obviously, these numbers are biased by the available sources and it is very difficult to come up with correct figures related to start-ups in clusters, also because in most cases this type of information is not collected at all by clusters, as discussed in Section 3.6.

4.6 The start-up landscape in IoT clusters: thematic weights

The data analysis carried out in the database desk analysis of the study[64] has produced the following distribution of the start-up's thematic areas.

The IoT-related themes in which start-ups are most active are mentioned in the table below. Notably, start-ups principally focus on IoT platforms and middleware, smart home and smart energy, sensors and navigation, and health and wearables.

The lowest IoT focus areas are smart cities, smart mobility, broadband and communications and authentication and security. Some of these IoT focus areas, interviewees said, require a critical mass that start-ups don't have (yet): broadband and telecommunications, authentication and security. Table 4-4 provides the current picture of the thematic focus of the IoT cluster landscape.

Table 4-4 Thematic Distribution of Start-ups. Source: JIIP consortium.

Thematic	Landscape	Number of Start-ups
IoT Platforms and middleware	15.86%	108
Smart home / smart energy	12.33%	84

[60] https://fiif.fi

[61] The IoT cluster case studies report. (June 2018)

[62] In economics and related disciplines, a transaction cost is a cost incurred in making an economic exchange. A number of different kinds of transaction costs exist. Search and information costs are costs such as those incurred in determining that the required good is available on the market, who has the lowest price, etc. Bargaining costs are the costs required to come to an acceptable agreement with the other party to the transaction, drawing up an appropriate contract, etc.

[63] The desk research and sources investigation report. (October 2017 and June 2018)

[64] *Ibidem*.

Thematic	Landscape	Number of Start-ups
Sensors and navigation	11.45%	78
Health and wearables	10.57%	72
Consulting and support	8.66%	59
Lifestyle and social media	7.64%	52
Start-up support	7.34%	50
Artificial intelligence / machine learning	6.75%	46
Authentication and security	5.43%	37
Broadband and telecommunications	4.26%	29
Smart mobility	3.67%	25
Smart cities	3.38%	23
Smart farming	2.64%	18

4.7 How are the links within EU IoT innovation clusters organised?

The analysis of direct survey results of clusters and case studies[65] have discussed the organisational setup of these structures. The case studies confirm that the prevailing mode of cooperation between IoT cluster members is a horizontal one. This means that links are established on an opportunity-driven, ad-hoc base and do not build on, or develop any hierarchical structures between their collaborating members.

This confirms that IoT cluster membership is voluntary and based on specific market opportunities and/or technological opportunities, as shown by the case studies in Section 4.5. It is very rare that clusters and cluster members operate like tiers of suppliers grouped around several leading enterprises, i.e. that these multiple leading enterprises act as drivers of value chains and suppliers cluster around them.

None of the analysed clusters operates with a classical “hub and spoke” structure, where one single market leader gathers tiers of suppliers around it, driving and sustaining the cluster.

[65] The IoT cluster case studies report. (June 2018)

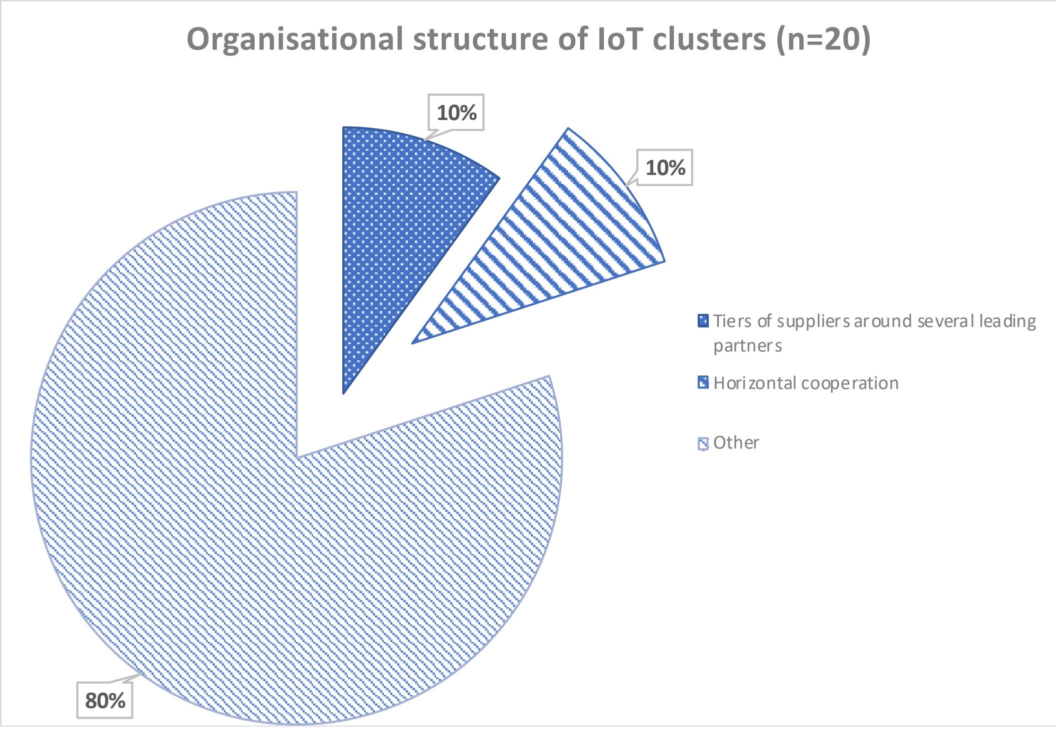

Figure 4-6: Organisational structure of IoT clusters. Source: JIIP consortium.

4.8 The actors in EU IoT innovation clusters

The direct surveys of IoT clusters have inquired the overall composition of actors by type, investigating the change of the number of cluster members between 2012 and 2018.

Figure 4-7, built with a double scale to show absolute numbers and percentage variations, shows that, while the overall number of partner institutions has increased of all actor categories, their composition has not changed significantly between 2012 and 2017. It should be noted that the direct survey, although collecting the answers of about 22 clusters, covered an overall number of 500 to 600 company, academic, research and institutional members, with an average number of members of around 30, thus creating a representative evidence base.

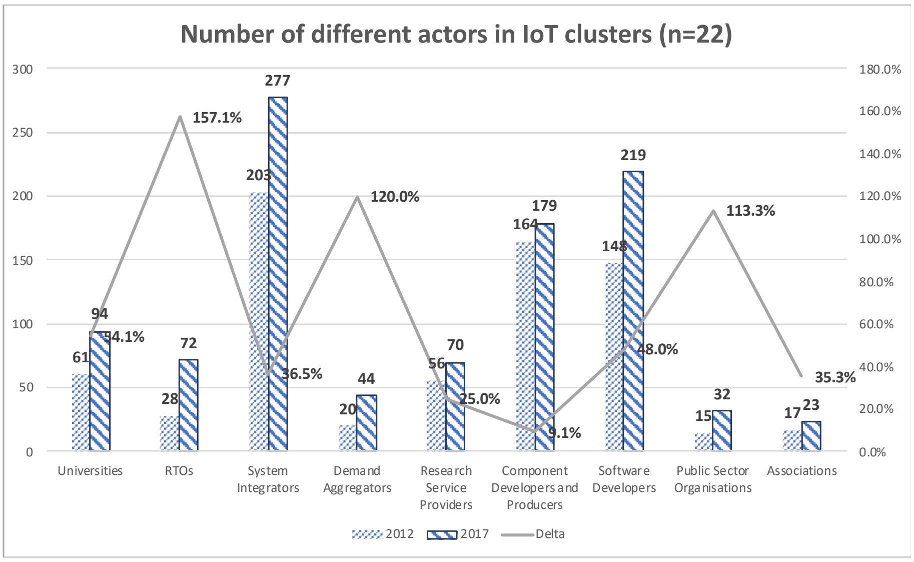

Figure 4-7: Number of IoT cluster members by type (2012 – 2017). Source: JIIP Consortium

Between 2012 and 2017 targeted clusters, universities and academic institutions increased by 54.1% to the number of 94, research and technology organisations by 157.1% to the number of 72, demand aggregators by 120% to the number of 44, public sector organisations by 113.3% to the number of 32, software developers by 48% to the number of 219, and system integrators by 36.5% to the number of 277.

As shown by the same chart, between 2012 and 2017 clusters observed that the lowest increase was of research service providers (+25% to the number of 70), component developers and producers (by 9.1% to the number of 179) and associations (+35.3% to the number of 23).

In absolute terms the most important players in investigated clusters are system integrators, software developers and component developers and producers, with the other members playing minor ancillary roles and confirming that clusters are mainly driven and sustained by market and technology-oriented business players, more than by anybody else.

4.9 The main IoT innovation cluster services and infrastructures

It is definitely important to have a comprehensive picture of the types of services and infrastructures provided by EU IoT clusters. This section provides a comprehensive overview of these cluster characteristics on the basis of the direct surveying of clusters and of the case studies.

As provided by the relevant study reports[66], IoT innovation clusters deliver a set of overarching activities and horizontal operational services to their members, as shown by the case studies. IoT clusters are essentially business- and technology-oriented establishments and essentially four different types of services and service infrastructures were identified:

1) Organisational and market services, which are services developing the cluster itself as well as its relationships towards the external markets and ecosystems.
2) Technical services, which facilitate the interaction of cluster members on horizontal technical and technological issues. They facilitate knowledge sharing, knowledge spill-overs and knowledge creation.
3) Application services clearly oriented towards the development of application software.

[66] The first direct survey wave report. (June 2018)
The second direct survey wave report. (June 2018)
The IoT cluster case studies report. (June 2018)

4) Other support services, which are ancillary services to the technological, innovation and market process of cluster members and of the cluster itself.

The first section 4.9.1 provides a qualitative overview of the services and the second section 4.9.2 provides quantitative information on cluster services, as provided by cluster stakeholders and through the data analysis.

4.9.1 Cluster services and infrastructures

This section provides the reader an overview of the core services provided by IoT clusters, as derived from the direct surveying and the case studies. These services are the "raison d'etre" of IoT clusters and the core of the value proposition by the clusters themselves, improving their appeal to their stakeholders, actual and potential members.

The main **organisational and market services** include:

- Joint representation of cluster members before third parties.
- Community and ecosystem development. Promotion and "marketing" of the cluster members and partners known in the international, national and regional circles, international cooperation.
- Developing and supporting synergies between companies, large and SMEs, start-up mentorship and coaching.

Technical services

- Working groups, technical and non-technical events. Technological information procurement and dissemination.
- Lead a structured process of coordination, sharing idea generation, iteratively and interactively investigating and integrating cluster stakeholder needs. Match-making, supporting networking of members and partners, technological and service portfolio management.
- Technological support and training, research and testing of proprietary technologies.
- Sharing of resources and circulating job opportunities, as well as cooperating with educational institutions to develop skills.
- Technology Transfer, providing general expert advice in the use of technologies and applications, especially for SMEs.

Application services

- Specific services with a major focus on the development of specific technological applications or experimentation working instances and they seek feedback from cluster members on the validity and suitability.
- Development Process, from rapid prototyping to R&D, and even further to pre-commercial research programmes.
- Data models and Catalogues of generic enablers with code modules and libraries

Other support services

- Intellectual Property Rights Management, Regulatory developments concerning IoT issues.
- Grant Information, Procurement & Dissemination, grant application support.
- Labs for external users to setup the basic virtual infrastructure
- Market places to disseminate current commercial offerings
- Device certification.

The next section provides additional details provided by clusters and cluster members of the service setup and the service trends as well as the preferences.

4.9.2 Quantitative overview of cluster services

The direct surveying of IoT clusters and of IoT enterprises, as accounted for in the direct surveys report[67], provides rich information about the portfolio of services, topics and technology areas of European Union IoT clusters.

The portfolio of services offered to IoT firms in the observed clusters is dominated by technology related themes, as shown by Figure 4-8.

"Technology development" is offered in almost three quarters of the clusters and "Technology integration" by 68% of the respondents. Further services with noteworthy shares are "Skill oriented trainings" and "Provision/Support to access venture capital/private equity" (42% each).

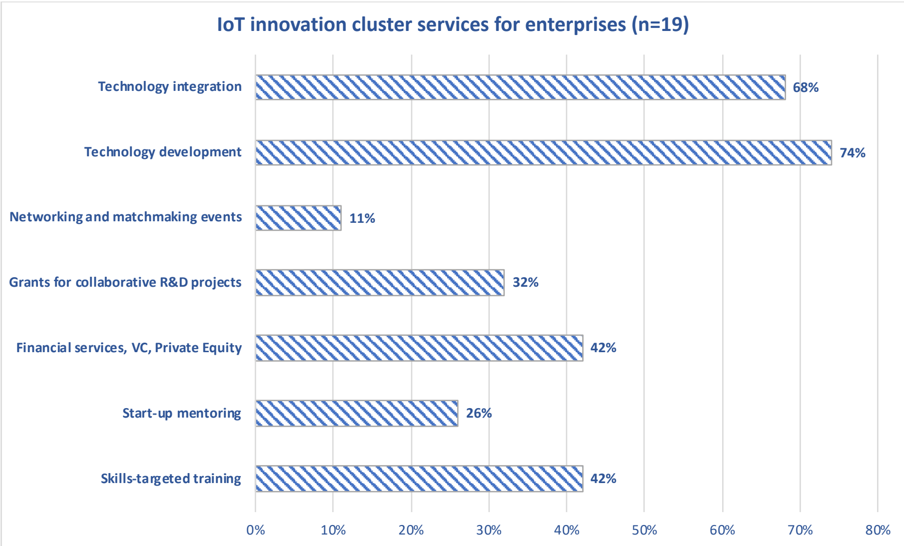

Figure 4-8: Cluster Services to IoT Firms. Source: JIIP Consortium

The weights of the cluster research are clearly oriented towards market and technology objectives: technology integration and technology development. Horizontal support activities, such as financial services and training are also quite important.

Services less strongly oriented towards market and technology such as collaborative R&D grants, start-up mentoring and networking and matchmaking events are clearly related to the need of clusters to focus on activities, which deliver real business benefits to their stakeholders.

Furthermore, the analysis[68] of IoT stakeholder opinions has targeted the infrastructures offered by clusters. The main ones provided to members are primarily oriented towards technological services as presented in Figure 4-9. We have already pointed at the technology and market orientation of IoT clusters and this is demonstrated by the prevalence of facilities for technology integration (63%) and facilities for technology development (74%), followed by R&D and testing facilities (58%). These priorities once again strengthen the orientation towards technology, market application and innovation. All other elements, from accelerators to science parks and incubators, to open science have a clearly lesser weight, albeit innovation and technology transfer still rank quite high.

[67] The first direct survey wave report. (June 2018)
The second direct survey wave report. (June 2018)

[68] *Ibidem*.

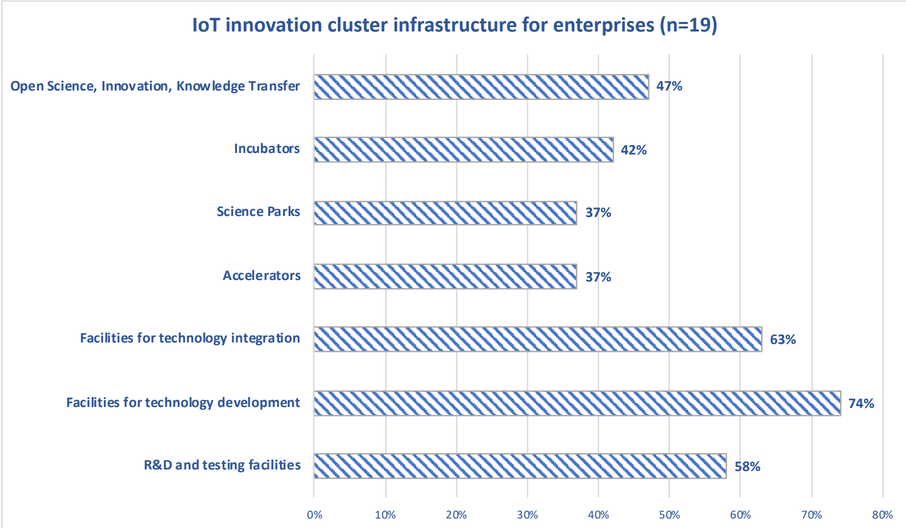

Figure 4-9: Cluster Infrastructures for IoT Firms. Source: JIIP Consortium.

The review of the data of this section allows a clear-cut conclusion on the key driver of cluster creation, management and sustenance: a strong orientation to technology application, markets and related innovation. This conclusion is strengthened by the statements of several IoT clusters participating in the case studies[69], such as the limited effort put into publicly funded project work.

4.10 The dynamics of IoT enabling technologies and application domains

The IoT innovation cluster review and analysis based on the study's direct survey provides the map of the technologies and application domains and their dynamic evolution between 2012 and 2017. This information is an important complement to section 4.9, which points at patterns of behaviour: it targets the IoT technology offering of clusters and their members.

The following figures present the opinions of cluster members on the weights of the different technologies in their offering. These are based on the statements of IoT stakeholders captured in the direct surveys[70] and captures the evolution of these weights from 2012 to 2017.

In Figure 4-10 IoT cluster members have indicated the importance of different technologies and their trends. In 2012 broadband and telecommunications was the most important technological field (24%), and still is in 2017, even if its weight has declined to slightly over 21%. The case studies[71] also confirm that broadband and telecommunications are an essential success factor for IoT. The second most important technology in 2012 were IoT platforms and middleware and its weight has increased to nearly 20%. Wearables have increased their importance from about 10% to over 16%. Sensors are a very important technology in 2017 (nearly 17%) but their increase since 2012 has been lower (12%). Artificial intelligence and Machine Learning is not one of the most important technologies, but it has recorded a significant increase in weight (from 7.5% to 11.1%). Authentication and security technologies are fundamentally stable (around 12% in 2012 and 2017).

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[69] The IoT cluster case studies report. (June 2018)

[70] The second direct survey wave report. (June 2018)

[71] *Ibidem*.

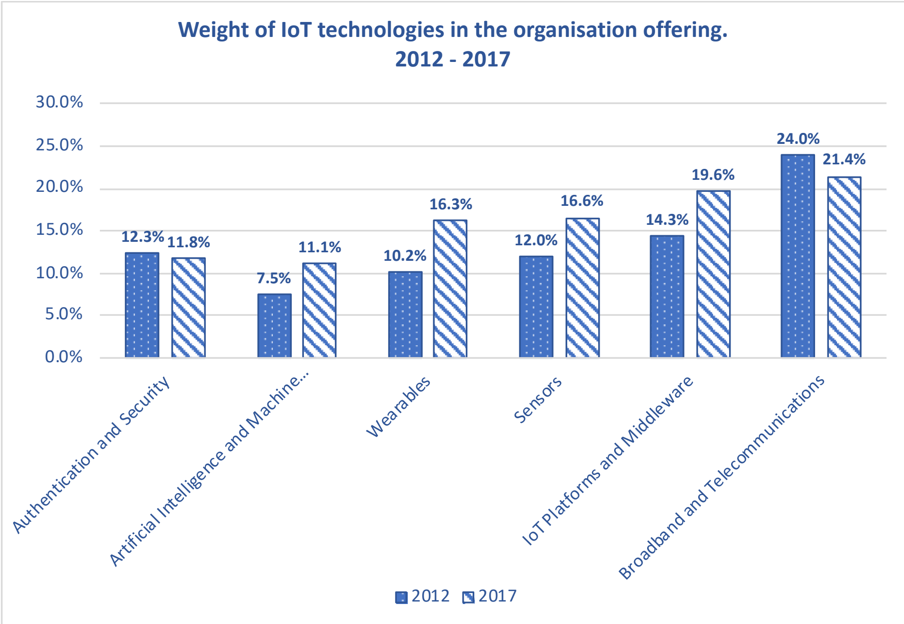

Figure 4-10: Weight of IoT technologies in the organisation offering. Source: JIIP Consortium.

In 2017, therefore, the most important IoT technologies remain broadband and telecommunications, and IoT platforms and middleware, wearables and sensors. AI is gaining importance and authentication and security is stable.

IoT is not only technologies but also application domains. Figure 4-11 displays the distribution of the opinion of IoT stakeholders, i.e. enterprises, universities and research organisations on the weight of the different application domains if IoT.

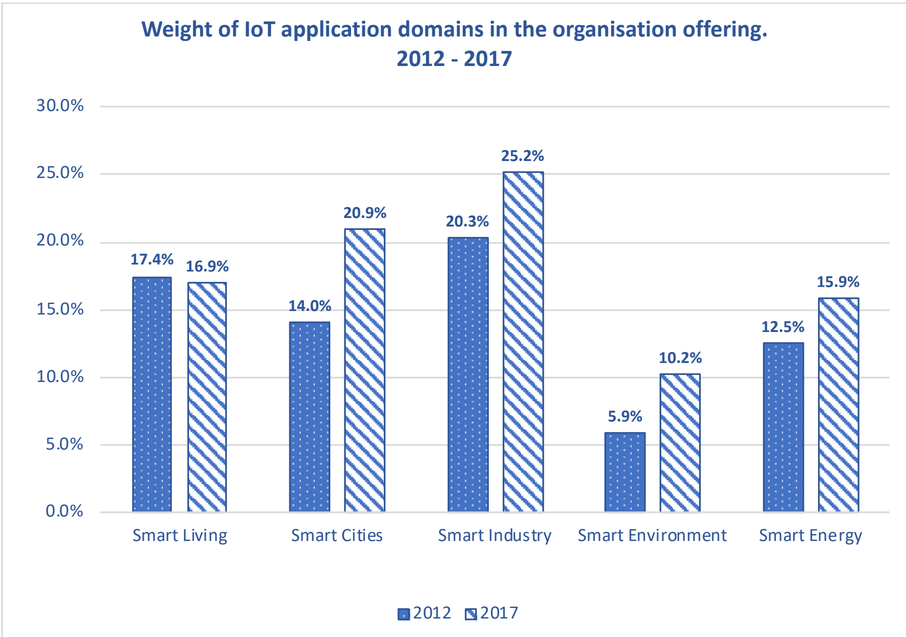

Figure 4-11: Weight of IoT application domains in the organisation offering. Source: JIIP Consortium.

The most important application domain of IoT cluster members in 2012 was smart industry (over 20%) and still is in 2017, strengthened by the Industry 4.0 policy. The second most important in 2012 was smart living, which is essentially stable in 2017 (around 17%). Smart cities have increased from 14% to nearly 21% in five years, becoming also the second most important domain after smart industry. Smart energy has slightly increased from 12.5% to nearly 16% and smart environment has nearly doubled from 6% in 2012 to over 10% in 2017.

4.11 The perspective on IoT enabling technologies by different IoT players

The analysis of the survey responses used a number of cross-tabulations to map different views and perspectives on different IoT users. To display these multidimensional relationships, we used a visual coding.

Table 4-5 displays the expectations of companies, universities and RTOs participating in the direct surveying in respect to different IoT enabling technologies from 2012 to 2017.

Companies expect some limited increase of the weight of Authentication and Security and of IoT platforms and middleware. They expect a very high decrease in broadband and telecommunications. The strongest increase perceived by enterprises is in sensors and wearable and a moderate increase is expected in Artificial Intelligence and machine learning.

Universities, who focus on knowledge creation and basic research, expect a major increase in the weight of IoT platforms and middleware, sensors and wearables, and AI and machine learning, and more modest increases in weights of Authentication and Security and Broadband and telecommunications.

Research and technology organisations, who are targeting applied research and development and cooperate with enterprises on market oriented technological activities. RTOs expect a very high increase of the weight of IoT platforms and middleware and a high increase in sensors, wearables and AI and machine learning. They also expect a decrease in broadband and communications and a high decrease in authentication and security.

Overall, there is some convergence of all types of stakeholders on wearables and sensors weight growth and, on the other end, the limited weight of authentication and security and broadband and communications, even if with different levels of intensity.

Table 4-5: Increase of weight of IoT enabling technologies by actor type. Source: JIIP Consortium.

2012 - 2017	Companies	Universities	RTOs
Authentication and security	+	++	- - -
AI and machine learning	++	+++	+++
Wearables	+++	++++	+++
Sensors	++++	++++	+++
IoT Platforms and Middleware	+	++++	++++
Broadband and Telecommunications	- - - -	+	-

Coding	
Very high increase	++++
High increase	+++
Moderate increase	++
Increase	+
Decrease	-
Moderate decrease	- -
High decrease	- - -
Very high decrease	- - - -

Table 4-6 makes a similar association of IoT actors' expectations on the change in weight of IoT application domains. Here we notice relatively prudent expectations by companies on smart cities, smart industry and smart energy and expectations on a stronger increase in smart environment. Both companies and RTOs present a very negative outlook on smart living, differently from universities.

Table 4-6: Increase of weight of IoT application domains by actor type. Source: JIIP Consortium.

2012 – 2017	Companies	Universities	RTOs
Smart living	- - -	++++	- - - -
Smart Cities	++	++++	+++
Smart Industry	++	+++	++++
Smart Environment	+++	+++	+++++
Smart Energy	++	+++	+++
Coding			
Very high increase	++++		
High increase	+++		
Moderate increase	++		
Increase	+		
Decrease	-		
Moderate decrease	- -		
High decrease	- - -		
Very high decrease	- - - -		

We would like to emphasise that, as with other data that present facts, Table 4-5 and Table 4-6 present information, which counts as evidence, based on responses of nearly 1200 direct survey participants form the three stakeholder categories.

4.12 Summary of section

There is a large set of diversified IoT innovation clusters in the 28 European Member States. The study has successfully targeted 389 EU IoT innovation clusters and about 12000 cluster member companies. The direct survey has involved 1169 IoT actors, which partially overlap with the previous ones. Obviously, the direct surveying implied a deeper interaction with and analysis of each of the IoT players. A significant share of survey respondents confirms their IoT cluster membership, the majority of companies belongs to institutionalised clusters.

A reproduction of one of the main maps of the IoT innovation clusters platform, which will show the dynamic placement of clusters in Europe, linking the chart to the constantly updated database.

Following the study specifications and using the database data collected in the desk research stage, the section presents six key activity indicators: entrepreneurialism, employment, size in terms of number of enterprises and turnover. The analysis presents a set of drivers of the establishment of IoT clusters, which prompt industry and institutional actors to aggregate their activities to integrate value chains and to pursue the achievement of critical mass. These drivers include the creation of technological communities, such as those around open source projects; research-driven clusters; aggregation of developers and test-beds; sector-specific clusters that have the purpose to develop applications for specific industries, such as food or automotive; classic industrial districts.

The IoT clusters analysed in most cases have a wide geographical coverage, even those who were created to tackle local industry problems are reaching out at national and international level. A wide review was provided on the roles in clusters, with a specific reference to start-ups.

In respect to the patterns of organisation and cooperation, the most frequent one is horizontal cooperation, which means that most of the clusters are not based on hierarchical cooperation.

The analysis has also identified the main services and their types, which IoT innovation clusters provide to their members. These services are described both in qualitative and quantitative terms.

Another important aspect reviewed in this section is the weight of IoT enabling technologies and the relevant application domains. The section presents the main trends in application areas, reviewing the different points of view of the actors participating in the study: Companies, Universities, Research and Technology organisations.

5. Cluster challenges, drivers and success factors for IoT cluster development

The purpose of the IoT innovation cluster study is to present the EU cluster landscape and its characteristics, based on the evidence collected through the research lines as described in Sections **Error! Reference source not found.** and **Error! Reference source not found.**.

In this section we are going to elaborate on the factors that drive cluster creation, on the challenges they face and on the success and sustainability factors. The discussion uses the inputs received from the case studies[72] to identify and discuss the key issues stakeholders raise. Success factors are particularly important, since they ensure the output, the sustainability and development of a cluster.

5.1 Cluster challenges

The challenges cluster face become success factors once they are effectively tackled through processes, which may become good practices. These challenges concern all the phases of a cluster's life cycle – i.e. cluster launch, initiation, development and sustainability. The section is based on the IoT innovation cluster case studies, which are, as possible, related to results of the landscape desk research and on survey data.

As with all case studies, they should be used for their deep explanatory strength and not for their statistical representativeness.

The case studies show that most clusters are market-driven initiatives – even if not necessarily for-profit – with the exception of those who were established on the basis of a public grant.

Case study participants all agree that clusters are successful if they create value for their stakeholders and if they are engaged in the constant monitoring and adjustment of their strategy and operations. Clusters need to support the technology dialogue, solution finding, and problem solving and deploy effective marketing and internationalisation initiatives for their members, running incoming and outgoing missions to explore new market opportunities.

The key challenges IoT innovation clusters are:

- Individual cluster members need to develop in terms of employment and turnover to be able to effectively take part in cluster integration activities.
- Clusters need to reach the sufficient critical mass of members and activities to reach the appropriate balance between size, in terms of number of members and cluster activities.
- Involvement and commitment of strategic players, to reach an actual involvement in cluster activities. This is particularly important in respect the sharing of information and putting information in common on a mutual sharing and trust basis.
- Overcoming the rigidity of large enterprises, who need to rely on procedures that allow limited flexibility at times, is necessary for the successful cooperation with small and medium enterprises.
- Harmonising the pace of implementation and development of cluster activities, in particular as start-ups are concerned who may perceive cluster dynamics and processes as very slow, which may threaten their economic sustainability.
- Work on efficiency and on the optimisation of transaction costs to avoid exceedingly high costs to make them work, i.e. balancing operation costs with individual and cluster level cost.
- Individualistic approaches in clusters Members may still pursue individual competition paths.

[72] The IoT cluster case studies report. (June 2018)

- Mainstream activity of LSEs. They may not be compatible with the promotion of the participation of local SMEs and with need of local industrial development.
- Technological and communication infrastructures. The performance of infrastructures is a key success factor for IoT. Insufficient level of service is a strong hampering factor.
- Appropriate strategic and operational processes. IoT cluster management and members consider it as essential that the successful cluster has shared processes in place, which allow to assess direction and performance continuously.

These factors were discussed with the different IoT cluster case study participants, who have identified them as key issues to be addressed by the cluster management and shared with their members. A synthesis table is presented in Annex 8.2.

5.2 Key drivers and impediments for IoT development

Drivers and impediments were an important focus of the direct survey in first instance and of the case studies as well. The inquiry proposed a number of potential issues related to the implementation and development of IoT specifically. The survey participants were proposed a Likert scale to provide their assessment of the different drivers and impediments proposed.

Figure 5-1 visualises the responses of the 1169 respondents on the factors that affect the development of IoT. The stripe pattern on the right-hand side of the chart displays the percentage of respondents that indicate that the factor is highly relevant, the next solid pattern on the left indicates those who believe that the factor is somewhat relevant.

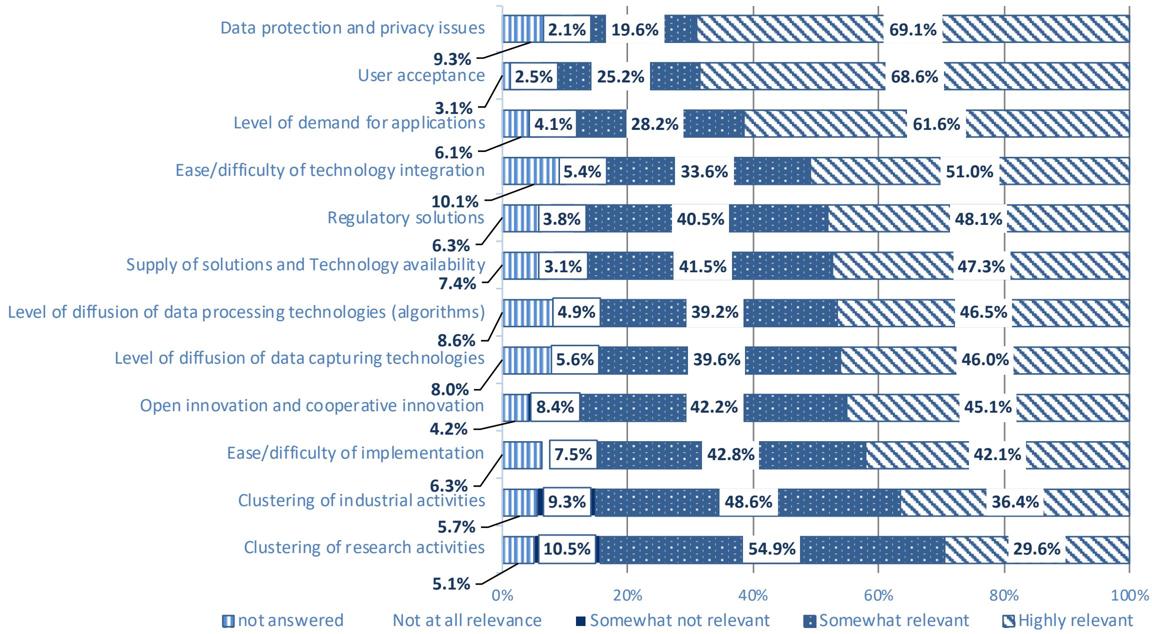

Figure 5-1: Key factors affecting the development of IoT. Source: JIIP consortium.

Observing the patterns, the chart indicates that the top priorities are Data protection and privacy issues, related to the enforcement of existing personal data protection rules (GDPR); User acceptance, building on user trust in the systems and applications and their safety and security; and the level of demand for applications, a factor depending on markets, scenarios, overall economic performance.

The least important factors affecting the development of IoT are clustering of research activities, clustering of industrial activities, ease/difficulties of implementation, and open innovation and cooperative innovation.

Correspondingly, Figure 5-2 shows the perception of IoT actors participating in the survey about key drivers and impediments. Also, in this case the chart was constructed to provide a visual representation of the assessment responses by survey participants.

The bars with the solid patterns display impediments, the ones with the diagonal pattern display enablers. The chart shows that stakeholders consider as drivers:

- Open innovation and cooperative innovation;
- Level of demand for applications – the market;
- Supply of solutions and technology availability – supply;
- Clustering of research activities;
- Level of diffusion of data capturing technologies – sensors;
- Level of diffusion of data processing technologies.

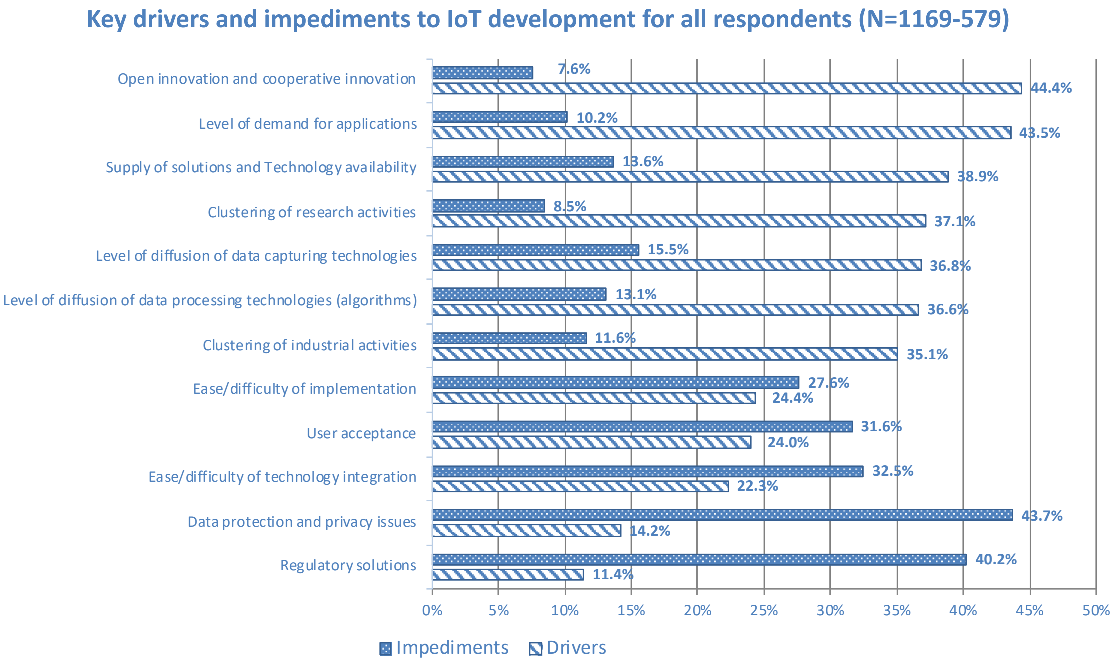

Figure 5-2: Key Drivers and impediments for IoT development – all respondents (N=1169). Source: JIIP consortium

The most important impediments indicated by survey participants are:

- Regulatory solutions for IoT;
- Data protection and privacy issues;
- Ease/difficulty of technology integration;
- User acceptance.

As already mentioned, these data, based on a representative sample of IoT actors is clearly a characterisation of the IoT landscape. The actual analysis of these facts allows to draw up recommendations and conclusions in Section 7.

5.2.1 Drivers

This section the report directly builds on the information displayed in the previous Figure 5-1 and Figure 5-2 and has the purpose to discuss the different drivers and impediments, providing a specification for each of them, explaining their meaning and impact and possibly pointing at possible measures.

Open and cooperative innovation for IoT

Cluster members should be helped and incentivised to cooperate openly and share information, creating trust and interaction. Openness and sharing are prerequisites for cluster cooperation, the generation of critical mass and the foundation of new, open value chains.

One key challenge is the correct balancing of cooperation and competition, since the unwillingness to share and an individualistic approach to the market is considered disruptive for cluster development. Fostering open innovation is principally related to awareness, dissemination, culture and education.

Demand for IoT applications

Demand is the economic pre-requisite for joint work and cooperation. A steadily developing demand for products, solutions and services is necessary to keep players' cooperation going. In this respect, clusters also have the responsibility to join forces to look for demand and to share resources to identify it and provide solutions.

Economic and social policies are at the basis of the development of society and affect the overall performance of society. The specific link to IoT development may be feeble, but it exists.

Supply of IoT solutions and technology availability

The appropriate technological and service solutions need to be available, as well as the skills. Failing to meet the needs of demand will disrupt cluster work, albeit clusters have the possibility to join forces either to develop solutions together or to jointly scout for solutions outside the consolidated group of co-operators.

This aspect is closely related to innovation and directly related to research and innovation and to application development, and therefore with the relevant support measures to tackle market failures.

Diffusion of data capturing technologies for IoT solutions

Data capturing technologies are a very specific and critical element of IoT application development. Clusters can generate the necessary critical mass to achieve this.

This is a specific technology areas, which according to IoT actors needs development. It both related to availability and to diffusion, i.e. the availability of data to run IoT-enabled applications.

Clustering of IoT research activities

Creating a critical mass of research activities and avoiding duplication and the associated inefficiencies is one of the key aspects of IoT development. Clusters and IoT actors call for aggregation and streamlining.

Specific measures, for example smart specialisation already point in this direction.

Clustering of industrial activities

This last driver mentioned by IoT players concerns the creation, enlargement and development of new value chains.

A very complex and critical aspect, targeted by scholars, such as Moretti, Duranton and others, who have pointed the issues related to clustering attempts: there have been policy attempts to replicate successful experiences, but their real effects are the subject of discussion.

5.2.2 Impediments

Here we discuss the impediments assessed through the surveys.

Data protection and privacy issues

A major obstacles for intermediate and final user acceptance of the data-intensive IoT activity. Users need to trust IoT systems. Policy-making is very dynamic in this domain.

The most useful action would be related to dissemination and awareness raising, since the regulatory is already in place and has already been updated recently.

Regulatory solutions

A level playing field, harmonised standards and interoperable solutions for the seamless interaction of devices and applications.

Policy action to identify necessary standardisation activities.

Technology integration

Technology integration encompasses skills and competencies to develop integrated products and services, which are the pre-requisite to produce effective and user-oriented solutions.

Vocational training and professional training is per se non the direct responsibility of EU policies, but guidelines, needs assessment and development of good practices would be an excellent contribution.

User acceptance

A key aspect, related to a correct understanding of IoT, of its characteristics and approaches, of the way value chains are integrated and how the rules protect the different stages of operation, as well as the data processed and the devices that process them.

User acceptance is mainly based on communication, dissemination and awareness raising.

Ease/difficulty of implementation

A relatively new technology domain requires additional effort and possibly support to acquire the necessary knowledge critical mass required for implementation processes.

An issue mostly related to technology development and innovation.

5.3 Success factors related to the economic and societal framework and ecosystem

Framework and ecosystem factors are those related to the general economic and sectoral trends. The dynamics of demand are significantly influenced by these factors. If the economy grows, the IoT-related factors will grow as well, pulling all the factors such as investment, increase of productions, supply of applications. These factors were synthesised from the case study report[73]

The table relates the different factors affecting the economic and social system, provides a brief description and then the specific impacts to be expected on IoT clusters.

The framework and ecosystem factors were discussed in the case studies and include:

Table 5-1: Framework and ecosystem factors and their impact on IoT clusters. Source: JIIP consortium

Factor	Specification	Impact on IoT Clusters
The general societal framework, economic dynamics, endogenous and exogenous shocks	Overall economic performance, in terms of demand, supply, inflation	Operation, performance and sustainability of IoT
	Rules and policies	Operation and performance, user acceptance

[73] The IoT cluster case studies report. (June 2018)

Factor	Specification	Impact on IoT Clusters
	Taxes	public budgets available for public research, development and innovation
Supply	The availability of solutions and technology, and more in general the dynamics of the innovation pipeline[74].	Response to demand, quality and effectiveness of solutions
Demand	level and critical mass of user demand, which depends on the above framework factors as well as from the understanding, innovative attitude and absorptive capacity of IoT users	Output, innovation, sustainability
Quality of the ecosystem	The level of IT sector development and on the combination of different ICT components	Quality of supply
Policy support at national or regional level	Legal, regulatory and industrial policy framework and support	Operation and performance, user acceptance
Ability of cities to work with open data	major issue with data, which can be heterogenous or lacking	IoT applications for Smart Cities and Smart Environment

5.4 Cluster-specific success factors

As mentioned, success factors are those that allow clusters to add value to their stakeholders and to be able to develop and be sustainable over time. Success factors are related to a number of areas, which were synthesised from the analysis of case studies[75]. The success factors have been classified and described in this section.

The main success factors emerging from the discussion with case study participants are: Financing, funding and economic balance; Strategic best practices; Operational and management best practices; Technology and application-related best practices.

It should be noted that the case studies report experiences, which need to be considered in the specific context and ecosystem. Therefore, case studies may provide facts that may appear contradictory, while in fact they are only peculiar to the specific situation and system focused. The conclusions of the case studies should therefore be considered as explanatory and not be given any statistical meaning.

The following paragraphs discuss the factors and the associated sub-factors.

5.4.1 Success factor: Financing and funding

Cluster managers and members confirm in the case studies that IoT clusters sustainability is a central theme. This impacts on the continuity of services, the strategic perspective and the actual ability to sustained development of the cluster itself, and of the sector or geographical

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[74] The innovation pipeline is the conceptual sequence which links knowledge creation with market application and sales. The sequence is not linear and has all the necessary iterations to ensure the appropriate linking of all the stages with the knowledge transfer process.

[75] The IoT cluster case studies report. (June 2018)

area in which it operates. In many cases, the current cluster funding hampers a long-term strategic planning, since it does not allow to secure long-term stability and decrease fluctuation.

According to interviewees, lack of long-term security in financing makes it difficult to plan ahead and acts as a big hindering factor.

Initial funding endowment provided by cluster founders

Depending on the context and ecosystem the case studies have shown that the initial endowment by cluster founders may be sufficient for the cluster start-up phase, after which fees and other financial resources have become available and, thus ensuring the sustainability of the undertaking.

Yearly contribution by EU, national, regional or local administration

Public bodies supporting or participating in an IoT cluster often provide a yearly contribution and cluster management sees this contribution as strategic towards its mid-term sustainability.

Membership fees

They are considered as very important, since they are one of the key mid-term sustainability factors. Many clusters differentiate fees according to member type (SMEs, LSEs, R&D or Academia). Membership fees by businesses are closely related to the performance and value added offered by the IoT clusters, since enterprises are very careful about the level and quality of benefits they get. The regular availability of public and private funds significantly influences the perspective and sustainability.

Some clusters recognise that they will never be able to collect all the funding from industry subscriptions, simply because the local industry base is too small. Clusters need a robust industrial ecosystem to be sustainable.

Membership fees of industry-driven clusters

There are exclusively privately driven, which may be industry-driven or developing around an open source project or platform. These clusters are self-sustainable and confirm their independence from public funding (FIWARE, ECLIPSE).

Contributions by universities and research organisations

University and research organisations are necessary as partners, but there have been issues related to the stability of their resources and contributions over time.

Funded project work

Several clusters engage in project work to sustain themselves. Project work is challenging: on the one hand it creates an independent source of funding, on the other is creates a potential mis-alignment of project objectives and cluster core business objectives. Clusters confirm that the time scope of cluster strategies is often not aligned with project funding.

In addition, project work may require co-funding, which challenges availability of additional resources. Clusters confirm that if project funding becomes dominating, the economic risk level of the cluster organization increases.

For these reasons, some clusters have made a clear decision not to build on external funding, but rather to sustain the activity just through the subscription fees.

5.4.2 Success factor: Strategic and operational best practices

The most successful clusters have moved from a member-driven push approach to large “clubs” mainly focus on sustained and sustainable networking, which means that the benefits and win-win relationships are acquired.

Some clusters, such as the Eclipse foundation, are completely self-sustained and sustainable and have expressed no specific need for cluster-related policies, they have fully-fledged procedures and processes in place, as well as common resource repositories.

Strategically, several clusters are becoming part of wider national and international networks, while still developing the connections to the local industry. Internationalisation is often a high priority, but in some cases international economic activities are limited, due to the limited internationalisation of the cluster's enterprises (low export).

Regular revision and renewal of the cluster strategy

The most successful clusters engage and engage their members in the regular revision, adjustment and relaunch of the cluster strategy and economic and operational positioning. This is actually a commonly adopted strategic and operational management approach, which allows the cluster to check and measure the changes and instances of the external systems. This is combined with the Monitoring of the entire surrounding ecosystem affecting the cluster, which includes the observation, monitoring, the identification and assessment of external qualitative and quantitative strong and weak signals are key activities for the cluster's strategic monitoring. Successful clusters set up an appropriate toolbox and processes to support the monitoring.

Formalisation of cluster processes

Some clusters see a significant benefit in the establishment of processes with the involvement of cluster members. Processes need to be agreed and optimised to fit the needs of the cluster, those of the members, including SMEs, and not to constraint operations and innovation creativity. Processes should in particular take care of the delicate balance of SMEs, taking account of the benefits they receive.

Technological assessment of the developments affecting clusters

The technological assessment focuses on the technical aspects of cluster strategies and operations. They include the definition of the main short-term and long-term technological developments and assessment of the cluster's positioning in terms of offering, role, skills and competencies, networking.

The results are the identification of gaps and the timely adoption of measures. Clusters base this, again, on a toolbox and on structured and communicated processes.

More than on enabling technologies, IoT clusters focus on concrete, close-to-the-market applications.

Cluster case study participants confirm that they do not deal with technology policy as such, they tend to focus on business issues and innovation initiatives. Even if IoT clusters clearly target technology strategy with their members, this in almost no case translates into an engagement in policy, for example standardisation and patenting.

Assessment of external factors related to regulations and policies affecting the IoT cluster's activity and that of their members.

Case study participants confirm that insecurity is still very high in certain situations, related to regulatory issues, data security issues and the legal framework. Regulations and the legal and policy framework heavily affect cluster operations and changes need to be recognised and lead to the necessary changes. The regulatory and policy framework affects IoT-related activities and the attitude of users. Clusters take care of these issues through specific services related to user acceptance.

5.4.3 Technology and application-related best practices

Clusters have identified a set of key issues related to the deployment of IoT applications, which have been discussed in the case studies. These issues are related to various themes such as

data silos, data formats and ontologies. Other key areas concern data capture and processing and output, as well the relevant non-technical implications.

Data silos, i.e. data is rarely shared among different verticals or even same domain.

The best practices IoT clusters put in place concern information and awareness raising of their members, the work towards networking and creation of a critical mass of potential IoT applications, thus facilitating the work of their members when they interact with data owners.

The cross-cluster networking and cooperation is one of the key approaches IoT clusters can facilitate to generate critical mass and awareness of applications potentials and of the associated rules to protect data, owners and stakeholders.

Homogenising data formats and semantics and data ontologies.

IoT clusters include this issue in their internal technological activities with their members. Since clusters do not deal with technology policy, as mentioned, policy-makers shall decide whether they need to involve IoT clusters.

Management of trust and data sovereignty

Clusters, as in the case of data formats, semantics and ontologies, deal with this issue in their internal technological activities with their members. Wider awareness raising and coordination activities, also with other IoT clusters, depend on the core mission and the availability of resources.

Technologies to process digital content

It is still considered a big challenge to extrapolate data and integrate them into virtual reality systems. The navigation through digital content still remains cumbersome and while firms are dedicated to making this process easier it remains costly.

According to cluster managers, another important impediment is the lack of technological maturity due to the limitations created by regulations and the lack of agility to target and implement the new technology. In other terms, regulations and their applications hamper innovation according to IoT clusters.

IoT risk assessment and management

As part of the IoT user acceptance, clusters demand a coordinate action on IoT security risk assessment. This is necessary to be aware of the potential threats to individual fundamental rights, to the level of risks and the necessary measures. It is also the basis to shape support to technological research and innovation and to put in the appropriate implementation rules.

Individual and organisational competencies, skills and expertise

There is a huge need for IT know-how: about 70000 additional skilled people are needed in the next years, posing a major challenge for the companies and clusters.

In economic and sector cycle phases of intense market activity clusters compete with the ecosystems in which they operate.

5.5 Summary of section

The interaction with direct survey participant and with IoT case study participants has allowed to identify the main challenges a cluster faces, what the key drivers and impediments are, which affect IoT take up as well as cluster sustainability and success.

The challenges are related to size of members and cluster critical mass, the commitment of strategic players and the rigidity of large enterprises. It is necessary to balance the individualistic tendency of some players as well as the competition with the mainstream activity of LSEs.

Clusters need to reach a pace of implementation sufficient to meet the needs of the internal members and most of all of external stakeholders, at the same time weighing out transaction costs.

Cluster's management also needs to make sure the commitment of members to appropriate strategic and operational processes. In other words, without establishing a hierarchy, the cluster management needs jointly with the members to establish acceptable procedures and processes to run the cluster operations.

The main obstacles to IoT uptake and development are, according to stakeholders, data protection and privacy issues, user acceptance and the level of demand for applications.

IoT innovation clusters are industry and market-related bodies. Their sustainability and success are dependent on the factors, which affect the success and sustainability of enterprises, such as the general societal framework, economic dynamics, endogenous and exogenous shocks, supply and demand; the general quality of the ecosystem and of infrastructures, as well as policy support at national or regional level.

Smart cities and communities are particularly sensitive to the ability of cities and urban areas to work with open data.

The success factors closely related to cluster operations are financing, funding and economic balance, strategic best practices and operational and management best practices.

6. The EU Policy Framework

In this section the report provides a brief background on the EU policy framework and a limited overview of IoT relevant policies of the Union. A comprehensive overview of all policy areas in which the European Commission is available in the Treaty on the Functioning of the European Union (TFEU)[76], in particular Title I which specifies the categories and areas of Union competence and specifically addressing the institutional setup and operations of the European Commission.

A more extensive narrative with the whole host of official policy documents is available on the European Commission's website[77], where all the relevant official policy documents are available, including those concerning the Internet of Things.

In this policy-related section we fundamentally aim to present the inputs received by IoT actors on specific policy intervention areas. These inputs were collected through the direct surveys in first instance and in addition through the case study interviews.

The analysis of responses has allowed to identify those priority measures, which should be implemented.

6.1 Internet of Things, IoT innovation clusters and the EU policy framework

The European Union has a comprehensive and integrated policy framework[78] targeting a wide host of societal and economic areas such as Jobs, growth and investment; Energy union and climate; Internal market and the specific digital single market[79]. Other policy areas, which are less relevant to IoT innovation clusters, include the monetary union, a balanced and progressive trade policy, Justice and fundamental rights, Migration, the EU as a stronger global actor and Democratic change.

Jobs, growth and investment, the digital single market[80] and more in general the Research and Innovation policy framework[81] and the relevant measures[82] are the most relevant domains which link to the role and support to IoT innovation clusters.

The Internet of Things is considered a key enabler and horizontal technology domain which has the potential to advance

- Industrial innovation, playing a key role in digitising European Industry, using smart systems, cyber physical systems, etc.
- Management of complex systems in the most comprehensive notion: from smart cities and smart mobility to environmental systems.
- Individual systems, such as smart living, wearables and individual devices.

As highlighted by the Commission Staff Working Document "Advancing the Internet of Things in Europe"[83], The Internet of Things (IoT) is considered the next Internet-enabled next major

[76] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A12012E%2FTXT

[77] https://ec.europa.eu/commission/index

[78] https://ec.europa.eu/commission/index

[79] The European Commission has set as a main goal to remove regulatory walls and moving from 28 national digital markets to a single one, removing existing online barriers and allowing citizens to benefit from goods and services and opening up the horizons of players in the digital markets, enabling businesses and governments to fully benefit from digital tools. This has the potential to generate a significant impact on the economy and create "hundreds of thousands of new jobs".

[80] https://ec.europa.eu/digital-single-market/en

[81] https://ec.europa.eu/growth/industry/innovation/policy_en

[82] https://ec.europa.eu/info/research-and-innovation_en

[83] SWD(2016) 110 final. Brussels, 19.4.2016.

economic and societal innovation, as further elaborated in Section 2 of this report. IoT allows the interconnection of any physical and virtual object with other objects and to the Internet and generating new smart environments, which sense, analyse, generate feedback loops and trigger actions, and support automated and human-led decisions.

In the European Commission's view, IoT innovation clusters may constitute one of the key enabling factors for this technology and its applications and it is therefore necessary to understand the key characteristics, modes of operation, success and sustainability factors of is necessary to understand which role these clusters play in supporting the development of this technology and how the EU can best support them.

Policy issues were addressed and assessed in the direct surveys and widely discussed in the IoT cluster case studies.

6.2 IoT actors' opinions on EU Policy measures for IoT development

In the direct survey questionnaires design the study team identified a number of policy measures and actions and asked survey participants for their assessment, which took two sides: on the one hand it inquired about their awareness of the availability to them of these measures. On the other hand, it requested the assessment of the relevance of these measures to IoT.

Figure 6-1 graphically presents the opinions of the 1169 survey participants on the availability of a set of IoT-related policy measures proposed to them.

Again, the graphic patterns helps reading the chart: the solid bars indicate the percentage of survey respondents who point out that the specific policy measure is not generally available, the bars with the striped pattern indicate the percentage of IoT actors who attest that the measure is available.

The measures are

- EU governance of IoT, which targets a common set of harmonised rules agreed with EU member states to enable the cross-border deployment of IoT applications in the Union.
- Identification of emerging IoT risks associated with IoT, i.e. making joint investigations at EU level on risks and countermeasures and develop an agreed harmonised framework to address this issue.
- Standards mandates: the European Commission shall analyse, in cooperation with technical bodies and member states, which are the requirements for standardisation to enable a smooth cross-border development of the IoT sector in Europe. This needs to involve standardisation bodies (CEN).
- Counselling on IP law and data ownership addresses the issue of cross-border handling of data, which is highly sensitive in the case of certain IoT applications. It also concerns the concrete application of the GDPR to this field.
- Creation of/support to labs, testing or technological facilities, which is based on the requirement of common technological development infrastructures for IoT. The EU is already engaged in this field, for example with the regional smart specialisation strategy in European Structural and Investment funds.
- Monitoring of the privacy and personal data protection issues, an activity under the current GDPR, which requires a generalised cooperation with EU member states.
- Technology transfer services, which concern support activities to facilitate the connections and networking of IoT actors for the purpose of sharing knowledge, technological, implementation, organisational and market solutions, as well as good practices.
- Public-Private Partnerships promotion, to develop IoT-enabled applications. This measures is certainly consistent with the case study results, which shows that most clusters targeting regional or local development need to involve public institutions.

However, there are serious doubts about the public institutions being able to solve cluster sustainability issues.

- Development of platforms cutting across sectors and industries is a measure that targets concrete connecting and networking infrastructures to enable IoT development in the EU digital single market.
- Promoting the international dialogue developing measures which favour EU-wide cooperation and international cooperation. A specific line of the Open Innovation, Open Science, Open to the World strategy of the European Union[84].
- Funding of IoT-related research and development, which is the target of Internet-of-Things related funds provided by the EU Framework Programme for Research and Innovation.
- Innovation and pilot projects with IoT applications, to support the development of new concepts and new solutions for businesses and society.

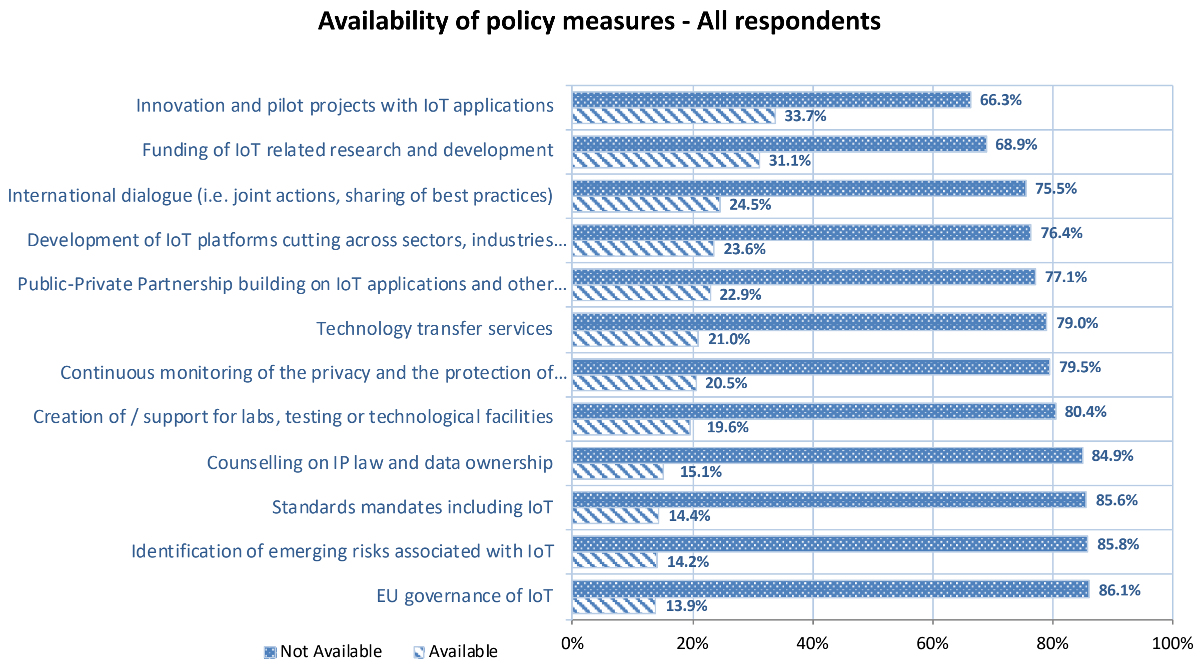

Figure 6-1: Availability of policy measures – all respondents (N=424). Source: JIIP, direct IoT survey.

In general, the majority of survey respondents, in all cases over 65%, declare that these suggested policy measures are not available for the IoT sector. The most important gaps are EU governance of IoT, as indicated by 85% of survey participants, the identification of emerging risks associated to IoT (86%), standards mandated concerning IoT (86%), counselling on IP law and data ownership (85%), support for labs, testing or technological facilities (80%).

Similarly, Figure 6-2 shows the opinions of survey respondents on the relevance of the same set of measures. Again, the patterns enable the reading of the percentages of respondents: the striped pattern indicates high relevance, the blue dotted pattern somewhat relevant patters and the solid pattern the somewhat not relevant measures.

Notably, IoT actors participating in the survey assign a high level of relevance to EU governance of IoT (over 40% of survey respondents), to Standards mandates including IoT (37%), Counselling on IP law and data ownership (37%), Identification of emerging risks

[84] https://ec.europa.eu/digital-single-market/en/news/open-innovation-open-science-open-world-vision-europe

associated with IoT, Technology transfer services, Monitoring of privacy and personal data protection (all around 36%). As the chart shows, all other measures are considered less relevant, with higher shares of survey participants selecting the "somewhat relevant" and "somewhat not relevant" options.

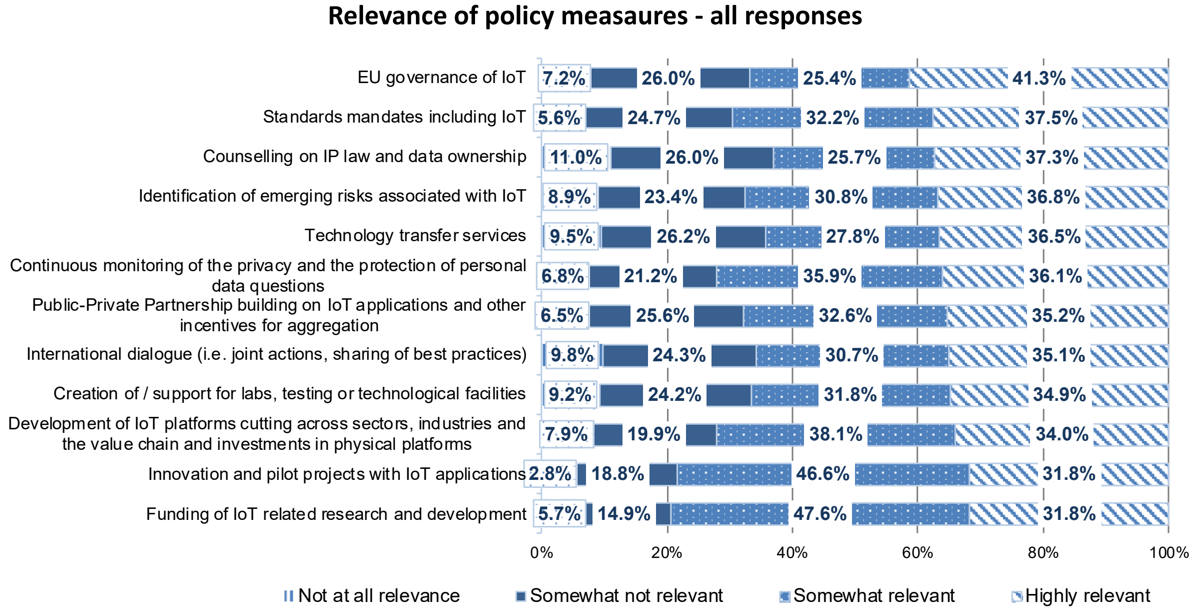

Figure 6-2: Relevance of policy measures – all respondents (N=403). Source: JIIP, direct IoT survey.

Table 6-1 below is based on the combination of the gaps in policy measures indicated by survey participants, i.e. the availability of measures, with the relevance of measures. In other terms this table presents the measures that are most "missing" and at the same time are considered most relevant by the 1169 survey respondents.

Table 6-1: IoT policy measures, their availability, relevance ranking and action priority. Source: JIIP consortium

IoT Policy Measure	Availability	Relevance ranking	Needed policy action
EU-level governance	Very low	1	Very high
Standardisation and mandates	Very low	2	Very high
Privacy and data protection monitoring	Low	3	High
Support to innovation and pilot projects	Medium	4	Low
Support to PPPs	Low	5	High
IoT-specific risk assessment	Very low	6	Very high
Technology transfer services	Low	7	High
Intellectual Property Rights regulations and management	Very low	8	Very high
Development of cross sector, cross-industry platforms	Low	9	High
Funding of IoT R&D	Medium	10	Low

IoT Policy Measure	Availability	Relevance ranking	Needed policy action
Support to labs and testing facilities	Very low	11	Very high
Support to the international dialogue	Low	12	High

The first column exhibits the policy measures, the second the assessment of their availability by IoT actors, the third displays the relevance, again as declared by survey participants. The fourth column features the combination of the former two results in terms of “very high” need for policy action in case of very low availability and high relevance ranking, “high” need combining low availability and medium ranking of importance, “low” need in case of medium availability and medium-low ranking.

According to the direct survey responses[85] and our analysis, the measures with the highest priority are

- EU-level governance of IoT.
- Standardisation and mandates related to IoT.
- IoT-specific risk assessment.
- Support to labs and testing facilities.

The next questions we have tried to answer, concerned the key drivers and impediments for IoT development. Table 6-2 below is on the one hand based on the responses to the second wave direct surveying and on the other on the other on the different policy domains within which the EU has the mandate to operate, as derived from the TFEU[86] and from the specifications derived from the European Commission's priorities[87].

Table 6-2: Map of the survey’s key drivers and impediments and the EU main policy lines. Source: JIIP consortium elaboration.

Key Drivers and Impediments	Driver	Impediment	EU policy themes								
			Internal market	Sector regulations	Technology regulations	Market supervision	Industrial policy (SMEs)	R&D policy	Innovation policy	Justice and Fundamental Rights	Internationalisation
Open and cooperative innovation	❍						X	X	X		X
Demand for applications	❍		X	X		X					X
Supply of solutions and technology availability	❍						X	X	X		
Clustering of research activities	❍							X	X		
Development of data capturing technologies	❍		X					X	X		
Data processing technologies	❍		X					X	X		
Clustering of industrial activities	❍			X			X	X	X		
Implementation approaches		❍					X	X	X		

[85] The first direct survey wave report. (June 2018)
The second direct survey wave report. (June 2018)

[86] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A12012E%2FTXT

[87] https://ec.europa.eu/commission/index_en

Key Drivers and Impediments	Driver	Impediment	EU policy themes								
			Internal market	Sector regulations	Technology regulations	Market supervision	Industrial policy (SMEs)	R&D policy	Innovation policy	Justice and Fundamental Rights	Internationalisation
User acceptance		❍	X	X	X	X	X	X	X	X	
Technology integration		❍			X						
Data protection and privacy issues		❍			X					X	
Regulatory solutions		❍			X					X	

The table should be read considering each key driver and impediment, as discussed in Section 5.2 of this report and indicated by survey participants[88] and are mentioned in the rows of the column. The reader can check the strategic EU policy lines relevant to the specific driver and impediment to identify the institutional link.

Table 6-3 shall be used to associate the priority policy measures as identified in Table 6-1 with the relevant EU policy lines previously identified.

For example, governance of IoT concerns all nine policy areas of the EU, while the standardisation issue is related to internal market policies, sector regulation policies and technology regulation policies. IoT risks are covered by sector regulations, technology regulations, industrial policy, R&D policy, innovation policy and justice and fundamental rights related policies.

Table 6-3: Map of the priority policy measures and the EU main policy lines. Source: JIIP consortium.

Policy measures	Need for policy action	EU policy lines								
		Internal market	Sector regulations	Technology regulations	Market supervision	Industrial policy (SMEs)	R&D policy	Innovation policy	Justice and Fundamental Rights	Internationalisation
Governance of IoT	Very High	X	X	X	X	X	X	X	X	X
Standards	Very High	X	X	X						
IoT risks	Very High		X	X		X	X	X	X	
IP counselling	Very High	X	X	X				X		X
Support for labs and infrastructures	Very High					X	X	X		
Privacy monitoring	High			X		X	X		X	
PPPs	High					X	X	X		
TT services	High					X	X	X		
Cross-sector IoT platforms	High					X	X	X		

[88] The first direct survey wave report. (June 2018)
The second direct survey wave report. (June 2018)

Policy measures		EU policy lines								
	Need for policy action	Internal market	Sector regulations	Technology regulations	Market supervision	Industrial policy (SMEs)	R&D policy	Innovation policy	Justice and Fundamental Rights	Internationalisation
International dialogue	High	X								X
IoT pilot projects	Low					X	X	X		
Funding IoT R&D	Low						X	X		X

6.3 Summary of section

The analysis of survey results confirms that policy priorities for IoT stakeholders are: EU governance of IoT, requiring the European Commission to take up its subsidiary role and coordinate IoT development policies and regulations at EU level, both ensuring harmonisation and a level playing field for IoT actors.

Furthermore, the EU shall undertake specific actions to support risk identification and assessment, which also imply some level of coordination of policy communication. Another task for the EU would be IoT-specific mandates to ensure interoperability and interconnection, IP law counselling support and the creation of infrastructures.

The priority measures proposed, and the policy actions can all be associated with the array of policy fields for which the European Union is mandated by the Member States.

7. Recommendations for EU action

The extensive desk and field analysis allows us to derive a number of recommendations based on the results, the evidence and the inputs provided by IoT actors and stakeholders. These recommendations are based on the analysis of the evidence collected in the course of the study and presented in the previous sections.

The comprehensive set of policy themes, which are the priority[89] of the European Commission, i.e. jobs, growth and investment; Digital Single Market; Energy Union and climate; Internal Market; Justice and Fundamental Rights; a Stronger Global Actor provides a very consistent framework to support IoT – and possibly ICT – clusters for the achievement of the Union's goals.

All the recommendations hereafter are relevant to the EU policy themes as presented on the European Commission website and on main documents[90].

The recommendations have been ranked to move from more general aspects to the more specific ones, i.e. system-level recommendations initially and then the more detailed issues related to the technological, market and regulatory development of Internet of Things innovation clusters. The relevant paragraphs contain the references to the previous sections of the report where relevant evidence is analysed.

7.1 The EU socioeconomic ecosystem

7.1.1 Improve the development of the European socioeconomic ecosystem[91]

The direct effect on the economic dimensions of Europe, determining demand, trends and economic dynamics may be limited, but the Union has the possibility to work on the framework conditions and on the rules, which allow the appropriate and fair implementation and use of technologies and the positive orientation of market forces. This includes knowledge, the awareness of rights, which influences supply, demand and acceptance of IoT applications.

IoT stakeholders and clusters suggest the assessment of the impacts on the balance of job creation and job destruction related to the introduction of technology.

7.1.2 Who should act?

The European Commission may act upon the mandate to coordinate the cross-border dimension of the European Digital Single Market, overcoming barriers, creating a level playing field and working together with the EU Member States to create the necessary framework and regulatory conditions.

The EU Member States have the possibility to cooperate with the Commission to work at national levels and to create actions which integrate the EU level with the national levels, making sure that there are no national rules, which in any way prove to be inconsistent with the EU level.

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[89] https://ec.europa.eu/commission/index_en

[90] *ibidem*

[91] This recommendation is embedded in the evidence and analysis in the following intermediate reports and in the sections of this document:

- 5.2: Key drivers and impediments for IoT development. Demand
- 5.3: Success factors related to the economic and societal framework
- The IoT cluster case studies report. (June 2018)

7.2 Public Private Partnerships for IoT clusters

7.2.1 Support the establishment of IoT cluster Public Private Partnerships[92]

IoT actors (Table 6-1) are in favour of the establishment of Public Private Partnerships. As the study has shown, many of the clusters analysed stem from PPPs. IoT actors are in favour of the consolidation of a cross-border approach to IoT cluster development, also aiming to create a critical mass of cluster activities and their specialisation.

The development of IoT clusters could be embedded in the programmes supporting regional development and smart specialisation, as part of the European Structural and Investment funds (ESIF).

IoT cluster case studies underline that Governments around the world realise that IoT adoption will define the competitiveness of their cities, provinces, countries, or regions. Governments at various levels have a number of key roles to play as regulators of IoT development, as agenda setters and as adopters.

7.2.2 Who should act?

The EU may use a number of instruments in the Framework Programme and in Structural and Investment funds. There is a process of achieving synergies between research and innovation instruments and structural funds, which may fruitfully combine upstream and downstream joint activities.

Member States, Regions and local community have the very important chance to ensure the integration of measures and their correspondence with local needs. They are also in the position to create cross-border and interregional systems to support IoT.

7.3 EU-level IoT governance[93]

7.3.1 Establish IoT governance mechanisms in Europe

According to the results presented in Table 6-1, IoT actors support the establishment of a EU-level IoT governance, which should be naturally entrusted to the European Commission. EU-level IoT governance would be fully in line with the three pillars of IoT development mentioned in Section 6.1 of this document:

1. A single market for the IoT, allowing devices and services to connect seamlessly and on a plug-and-play basis, scaling up across borders.
2. A prospering IoT ecosystem taking advantage of open platforms allowing to develop across vertical silos, identifying selected priority lead markets.
3. A human-centred IoT, respecting European values, empowering people along with machines and businesses, thanks to high standards for the protection of personal data and security.

The main measures include a level playing field, fair competition, seamless interconnection, performant infrastructures, knowledge sharing, cross-border value chains, personal data

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[92] This recommendation is embedded in the evidence and analysis in the following intermediate reports and in the sections of this document:

- 4.3: why are innovation clusters established. Public Private Partnerships.
- 5.4.1: Success factor. Financing and funding.
- 6.2: Actor's opinions on EU policy measures for IoT development.
- The IoT cluster case studies report. (June 2018)

[93] This recommendation is embedded in the evidence and analysis in the following intermediate reports and in the sections of this document:

- 6.1: Internet of Things, IoT innovation clusters and the EU policy framework. The digital single market.
- 6.2: IoT actor's opinions on EU of Policy measures for IoT development
- The second direct survey wave report. (June 2018)

protection, standardisation and user awareness and acceptance. The policy action on IoT-related standardisation (work with harmonised standards and standardisation bodies) should focus not only on technology integration issues, but also the security, safety and personal protection of users and their data.

7.3.2 Who should act?

The European Commission has the mandate to deal with cross-border governance issues and the power to propose policies and regulatory measures, including soft law, in particular within the framework of the digital single market.

Member States have the possibility to propose the instances to adapt the rules and policy framework to their specific needs and to put in place and adopt EU rules.

7.4 Improve awareness, user acceptance and user involvement[94]

7.4.1 Improve awareness, user acceptance and user involvement

The Union is deeply concerned with human rights and the individual in respect to technology and at the same time wants to support the deployment of technology for the benefits of individuals and society. There is room to undertake specific risk assessment activities and to put in place appropriate policy communication measures to ensure correct and evidence-based user information.

IoT stakeholders support this priority (Table 6-1) confirming a high priority for IoT-specific risk assessment, which could be addressed by IoT-specific European Commission-supported methodological and implementation studies.

One of the top priorities indicated by survey participants is privacy protection and data protection monitoring (Table 6-1): EU data protection law is very advanced and strengthened by the recent introduction of the General Data Protection Regulation. It is now important, according to stakeholders, that it is applied in such a way to build up confidence of EU IoT users.

The Commission has created a “trusted label” for the IoT to promote security, liability, privacy and data protection in the IoT, run by ENISA. The Network Information Security (“NIS”) Directive[95] requires operators in critical sectors to take proportionate technical and organisational measures to manage the risks posed to the security of networks and information systems they use in their operations. In the staff working document[96], the Commission suggests that operators using the IoT should adopt the Trusted IoT label.

7.4.2 Who should act?

The European Commission may act within its mandate and opportunity to identify and assess the key issues related to acceptance and usability of IoT to be communicated to citizens,

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[94] This recommendation is embedded in the evidence and analysis in the following intermediate reports and in the sections of this document:

- 4.5: The actors and roles in the IoT clusters of the study
- 5.2: Key drivers and impediments for IoT development
- 6.2: IoT actors’ opinions on EU policy measures for IoT development
- The first direct survey wave report. (June 2018)
- The second direct survey wave report. (June 2018)
- The IoT cluster case studies report. (June 2018)

[95] https://ec.europa.eu/digital-single-market/en/network-and-information-security-nis-directive

[96] SWD(2016) 110 final

businesses and IoT users and to develop appropriate good practices and other user-oriented measures.

EU Member States can put in place their own measures and as opportune integrate them with EU level actions.

7.5 Promote IoT and IoT policy communication and the international industry and innovation dialogue[97]

7.5.1 Policy communication and industry and innovation dialogues

The IoT-specific governance measures should be complemented with Public communication about IoT technologies about their potential and impacts on society. Policy makers may want to convey the message that IoT is not a cure-all, but has specific practical benefits, if it is correspondingly regulated. There should be cluster-related policy communication about their characteristics and benefits.

Furthermore, IoT stakeholders are in favour of the international industry and innovation dialogue. In the context of the EU level IoT governance, the European Commission can assume the role of the promotion of IoT clusters internationally.

7.5.2 Who should act?

The European Commission may identify and put in place the most appropriate good practices for communication and coordinate and undertake a EU-level communication activity.

EU Member States can put in place analogous measures at national level and act as a user and amplifier of EU-level measures.

7.6 Promote critical mass of IoT innovation cluster activities[98]

7.6.1 Measures to favour the critical mass of IoT innovation clusters

IoT case study stakeholders have pointed out the importance of an appropriate size of critical mass to ensure productivity, sustainability and impact of IoT clusters. There are some activities, which would fit well into cross-cluster value chains. This means that IoT solutions and systems are not only built through in-cluster value chains, but may build on distributed, specialised IoT clusters, connected through flexible, ad-hoc value chains.

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[97] This recommendation is embedded in the evidence and analysis in the following intermediate reports and in the sections of this document:

- 5.3: Key drivers and impediments for IoT development. User acceptance.
- The second direct survey wave report. (June 2018)
- In addition, there are indirect signals on the need to foster policy communication on the field of IoT: the survey participants call for increased monitoring of the privacy and personal data protection. The Union places significant focus on this subject matter and the fact that stakeholders emphasise its important is most likely a hint at the need to foster policy communication (Section 6.2).

[98] This recommendation is embedded in the evidence and analysis in the following intermediate reports and in the sections of this document:

- 4.5: The actors and roles in the IoT clusters of the study. Critical mass.
- 4.6: The start-up landscape in IoT clusters
- 5.1: Cluster challenges. Cluster critical mass.
- 5.2: Key drivers and impediments for IoT development.
- 5.3: Success factors related to the economic and societal framework and ecosystem.
- 5.4: Cluster-specific success factors.
- The IoT cluster case studies report. (June 2018)

IoT cluster members support this approach and a more comprehensive cluster policy at EU level to avoid activity overlapping and duplication, favouring the cluster smart specialisation of research and innovation activities of clusters and of the internationalisation initiatives, through policy instruments like the EU Framework Programme, which can create synergies for example with European Structural and Investment Funds – ESIF.

Likewise, the European Union can address the issue of IoT infrastructures and their performance – which has been pointed out by the cluster case studies as being critical for the uptake of IoT systems – by connecting clusters and their facilities, labs, incubators, etc. Certainly, well-functioning and performant infrastructures, in particular telecommunication infrastructures, are very important to IoT players. At the same time, the Commission should support to the development of cross-sector, cross-industry platforms (Table 6-1).

7.6.2 Who should act?

Critical mass is essentially achieved through monetary incentives, facilitating aggregations, associations and the creation of value chains, also cross border. The European Commission may act under the mandate to manage funding programmes, which aim to create critical mass in IoT-related and clustering activities.

EU Member States have the opportunity to use national instruments and programmes, also at regional level, to support the formation of critical mass in IoT cluster activities.

7.7 Develop best practice and provide support to core cluster strategic services[99]

7.7.1 Develop and disseminate best practices for core cluster strategic service.

The European Commission operates at cross-border level according to the subsidiarity principle and has the possibility to engage in coordination, best practice development and sharing.

The EU may, in the context of its overall innovation, technology and economic development policies, launch support actions, which make available solutions and best practices to clusters, for example through Coordination and Support Actions (CSAs) in the Framework Programme.

Taking this approach, the European Commission can disseminate best practices in the areas of innovation, management, value chain construction, connection of clusters and IoT actors. The best practices may concern technology management, technology assessment and marketing, value chain construction and sustainability, communication, sales management, finance, etc.

According to the principle of subsidiarity, the European Union can play a key role in supporting the internationalisation of cluster activities and in promoting the development of international IoT value chains facilitating cluster interaction.

7.7.2 Who should act?

The European Commission and the Member States of the Union may cooperate to define good practice development projects and through the dissemination of such practices towards IoT communities.

[99] This recommendation is embedded in the evidence and analysis in the following intermediate reports and in the sections of this document:

- 5.4.2: Success factor: Strategic and operational best practices
- 5.4.3: Technology and application-related best practices
- The IoT cluster case studies report. (June 2018)

7.8 Increase focus on IoT start-ups in clusters[100]

7.8.1 Increase focus on IoT start-ups in clusters

With a specific reference to IoT start-ups and their role in driving innovation, the Start-up Europe initiative can specifically consider the embedding of start-ups in IoT ecosystems and put in place measures and best practices to facilitate their flexible integration in value chains. The Start-up Europe initiative is already well structured and is providing training (summer academies); venture capital funding through H2020; pitching sessions with investors; conferences and networking events; the European Digital City index already maps cities across Europe that support digital entrepreneurs as part of the European Digital Forum, with the ultimate aim to support digital entrepreneurship across Europe. The index is providing information about the strengths and weaknesses of local ecosystems to start-ups and scaleups.

7.8.2 Who should act?

The European Commission has the possibility to deploy its measures in place to support start-ups and to develop financial services, such as venture capital, to support their development.

Likewise, the EU Member States can use their industrial policy measures to support start-ups directly and their funding.

7.9 Financing and funding[101]

7.9.1 Financing and funding

Since IoT clusters are essentially service structures, they face funding issues, which impact on their strategies and the timeframes of the strategies.

Certainly, the Union can use structural and investment funds to help the launch of clusters, however the sustainability issue is a major one. It is important that the EU is aware of the different impacts different funding sources have on clusters and their operations.

The EUROPEAN COMMISSION may provide methodological and experience support and best practice advice to improve efficiency and effectiveness of output. Considering how clusters consider project-based funding in relation to their operations, it is probably not advisable that the EU directly funds project activities. This is also confirmed by survey respondents, who assign a low priority (Table 6-1) to:

- Support to innovation and pilot projects in IoT.
- Direct funding of IoT research and development.

[100] This recommendation is embedded in the evidence and analysis in the following intermediate reports and in the sections of this document:

- 3.5.3: Discussion of the taxonomy. Types of organisations relevant for the IoT empowerment
- 4.5: The actors and roles in the IoT clusters of the study
- 4.6: The start-up landscape in IoT clusters: thematic weights
- The IoT cluster case studies report. (June 2018)

[101] This recommendation is embedded in the evidence and analysis in the following intermediate reports and in the sections of this document:

- 4.5.4: Start-ups in IoT clusters
- 5.4.1: Success factor: financing and funding
- 6.2: IoT actors' opinions on EU policy measures for IoT development
- The second direct survey wave report. (June 2018)
- The IoT cluster case studies report. (June 2018)

The EU shall therefore focus on providing resources enabling the creation, critical mass, efficient and effective operation of IoT clusters, more that offering specific financial support to their operations.

Certainly, one of the services provided by clusters are assistance and support to public grant acquisition and management. However, this type of support does not seem to belong to one of the top priorities of IoT actors and their clusters.

7.9.2 Who should act?

The European Commission, through the different funding agencies and funding programmes.

The Member States and the regions, through their instruments and programmes.

8. Annexes

8.1 The clusters from the desk research

Cap Digital	765	75	6	364
LSEC - Leaders in Security	750	250		63
Aerospace Valley	510	25		10
Digital Catapult	390	103		53
Minalogic	305	42		13
MEDICEN PARIS REGION	297	27		27
Systematic Paris-Region	290	106	5	72
Flanders' FOOD, FF	210	100	1	37
Photonics cluster OPTITEC	148	5		51
Automotive Cluster @Business Upper Austria - OÖ Wirtschaftsagentur	143	109		17
OPTICS VALLEY	134	17		17
FIIF	133	43		6
Pôle MecaTech	125	44		95
Images & Réseaux	104	31	7	12
CenSec	94	10	1	5
Cluster Lumiere	92	17		17
Swedish Smart Grid Cluster	87	22		
DSP Valley	86	3		21
S2E2 competitiveness cluster - Smart Electricity Cluster	85	33		43
INFOPOLE Cluster TIC	84	15	1	11
Lifetech.brussels	80	10		4
Human.technology Styria GmbH	76	14		15
Silicon Alps Cluster GmbH	60	20	1	16

Estonian ICT Cluster	57	13		
AIOTI Alliance	50	48	8	24
Arctic Design Cluster	50	9		64
Groen Licht Vlaandere	50	10	1	7
Estonian Connected Health Cluster	41	9		6
Hungarian Mobility and Multimedia Cluster	32	2		
GERMAN INDUSTRY 4.0	30	14		1
IoT Security Foundation	30	12		8
Cool Silicon e.V.	26	6		
Flanders Make	25	57		6
Smart Grid service cluster	21	3		
IoF	21	24		9
IoF	21	24		9
Smart Grid Service Cluster	21	3		
PrintoCent	14	6		
Danish Smart Cities	11	7		1
Silesian ICT & Multimedia Cluster	11			
Copenhagen Cleantech Cluster	10	6		
Hudiksvalls Hydraulikkluster	10	2		
MONICA	10	4		6
bIoTope	8		1	4
Electric mobility NO	8	4		
CREATE IoT	8	3		4
VICINITY	7	3		3
Synchronicity	7	5		7
Activage	6	7		11

inter-iot	5	1	1	4
TagItSmart	5	4		3
AGILE	4	4	1	3
symbIOTe	4	2		6
Unify IoT	4	1		2
IOTFORUM	4	3	3	7
Cluster Microelectronics and Embedded Systems	4	1		4
Norwegian Smartgrid Centre (Borad)	3	5		
BIG Iot	2	5		4
BE-IOT	1		1	1
CCC	1			
ERTICO-ITS	1	2		7
Produktion2030	1	7		3
Smartgridgotland	1	2		
Autopilot	1	9		10
ICT Cluster	1		3	4
Super IoT	1	1		6
Know-Center GmbH	1	9	3	12
Protik Innovation Center	1	3	1	
IoT Smart Santander Living Lab	1			
C2C-CC		1		11
UNIFY-IOT			1	3
BrainsBusiness ICT North Denmark		3		3
DIH IoT				1
Finnish Industrial Internet Forum		3		5
Innovation Network RoboCluster			1	4

Innovation Network for Smart Energy (Inno-SE)				4
One Sea - Autonomous Maritime Ecosystem		5	1	
5G Test Network Finland (5GTNF)				
Copenhagen Fintech				4
Danish Technological Institute, Robot Technology, DTI Robotics				
MADE - Manufacturing Academy of Denmark		5	1	18
Accelerating Photonics innovation for SME's (ACTPHAST 4.0)				17
Centre de recherche en aéronautique ASBL, Cenaero		1	3	1
Helsinki Living Lab - Forum Virium Helsinki		3		1
Future Classroom Lab		6		
Virtual Services and Open Innovation				6
WIRELESSINFO – Czech Living Labs				1
Smart City Lab (SCL)		1		1

8.2 Cluster challenges

Cluster challenges	
Size of cluster members	Members may be too small to allow the efficient integration of activities
Cluster critical mass	Cluster may not succeed to join forces and together achieve sufficient critical mass to compete efficiently
Commitment of strategic players	Some cluster members still may be cautious when it comes to participating in clusters and/or sharing internal knowledge
Rigidity of large enterprises	Large enterprises may not have the flexibility to adapt to common cluster processes and to cooperate with SMEs efficiently.
Pace of implementation and development	Start-ups may perceive cluster dynamics and processes as very slow, which may threaten their economic sustainability
Transaction costs	Networking may fail because of exceedingly high costs to make them work
Individualistic approaches in clusters	Members may still pursue individual competition paths.
Mainstream activity of LSEs	May not be compatible with the promotion of the participation of local SMEs and with need of local industrial development.

Cluster challenges	
Technological and communication infrastructures	The performance of infrastructures is a key success factor for IoT. Insufficient level of service is a strong hampering factor.
Appropriate strategic and operational processes	IoT cluster management and members consider it as essential that the successful cluster has shared processes in place, which allow to assess direction and performance continuously.

8.3 Cluster key drivers and impediments

8.3.1 Drivers

Drivers	Specification
Open and cooperative innovation for IoT	Cluster members should be helped and incentivised to cooperate openly and share information, creating trust and interaction. Openness and sharing are prerequisites for cluster cooperation, the generation of critical mass and the foundation of new, open value chains. One key challenge is the correct balancing of cooperation and competition, since the unwillingness to share and an individualistic approach to the market is considered disruptive for cluster development.
Demand for IoT applications	Demand is the economic pre-requisite for joint work and cooperation. A steadily developing demand for products, solutions and services is necessary to keep players' cooperation going. In this respect, clusters also have the responsibility to join forces to look for demand and to share resources to identify it and provide solutions.
Supply of IoT solutions and technology availability	The appropriate technological and service solutions need to be available, as well as the skills. Failing to meet the needs of demand will disrupt cluster work, albeit clusters have the possibility to join forces either to develop solutions together or to jointly scout for solutions outside the consolidated group of co-operators.
Diffusion of data capturing technologies for IoT solutions	Data capturing technologies are a very specific and critical element of IoT application development. Clusters can generate the necessary critical mass to achieve this.
Clustering of IoT research activities	Creating a critical mass of research activities and avoiding duplication and the associated inefficiencies is one of the key aspects of IoT development. Clusters and IoT actors call for aggregation and streamlining.
Clustering of industrial activities	This last driver mentioned by IoT players concerns the creation, enlargement and development of new value chains.

8.3.2 Impediments

Impediments	Specification
Data protection and privacy issues	A major obstacles for intermediate and final user acceptance of the data-intensive IoT activity. Users need to trust IoT systems.
Regulatory solutions	A level playing field, harmonised standards and interoperable solutions for the seamless interaction of devices and applications.

Impediments	Specification
Technology integration	Skills and competencies to develop integrated products and services, which are the pre-requisite to produce effective and user-oriented solutions.
User acceptance	A key aspect, related to a correct understanding of IoT, of its characteristics and approaches, of the way value chains are integrated and how the rules protect the different stages of operation, as well as the data processed and the devices that process them.
Ease/difficulty of implementation	A relatively new technology domain requires additional effort and possibly support to acquire the necessary knowledge critical mass required for implementation processes.

8.4 Success factors related to the societal framework and ecosystem

Factor	Specification	Impact on IoT Clusters
The general societal framework, economic dynamics, endogenous and exogenous shocks	Overall economic performance	Operation, performance and sustainability of IoT
	Rules and policies	Operation and performance, user acceptance
	Taxes	public budgets available for public research, development and innovation
Supply	The availability of solutions and technology, and more in general the dynamics of the innovation pipeline[102].	Response to demand, quality and effectiveness of solutions
Demand	level and critical mass of user demand, which depends on the above framework factors as well as from the understanding, innovative attitude and absorptive capacity of IoT users	Output, innovation, sustainability
quality of the ecosystem	The level of IT sector development and on the combination of different ICT components	Quality of supply
Policy support at national or regional level	Legal, regulatory and industrial policy framework and support	Operation and performance, user acceptance
Ability of cities to work with open data	major issue with data, which can be heterogenous or lacking	IoT applications for Smart Cities and Smart Environment

[102] The innovation pipeline is the conceptual sequence which links knowledge creation with market application and sales. The sequence is not linear and has all the necessary iterations to ensure the appropriate linking of all the stages with the knowledge transfer process.

8.5 Cluster-specific success factors

8.5.1 Financing and funding

Financing and funding issue	Specification
Initial funding endowment provided by cluster founders	Many clusters confirm that is has been sufficient to launch the study and to secure the start-up phase, when fees and other financial resources became available.
Yearly contribution by EU, national, regional or local administration	Many clusters that are participated by a public institution have a yearly contribution. Cluster management see this contribution as strategic towards its mid-term sustainability.
Membership fees	They are considered as very important, since they are one of the key mid-term sustainability factors. Many clusters differentiate fees according to member type (SMEs, LSEs, R&D or Academia). Membership fees by businesses are closely related to the performance and value added offered by the IoT clusters, since enterprises are very careful about the level and quality of benefits they get. The regular availability of public and private funds significantly influences the perspective and sustainability. Some clusters recognise that they will never be able to collect all the funding from industry subscriptions, simply because the local industry base is too small. Clusters need a robust industrial ecosystem to be sustainable.
Membership fees of clusters merely industry-driven	There are exclusively privately driven, which may be industry-driven or developing around an open source project or platform. These clusters are self-sustainable and confirm their independence from public funding (FIWARE, ECLIPSE)
Contributions by universities and research organisations	University and research organisations are necessary as partners, but there have been issues related to the stability of the resources over time.
Funded project work	Several clusters engage in project work to sustain themselves. Project work is challenging: on the one hand it creates an independent source of funding, on the other is creates a potential mis-alignment of project objectives and cluster core business objectives. Clusters confirm that the time scope of cluster strategies is often not aligned with project funding. In addition, project work may require co-funding, which challenges availability of additional resources. Clusters confirm that if project funding becomes dominating, the economic risk level of the cluster organization increases. For these reasons, some clusters have made a clear decision not to build on external funding, but rather to sustain the activity just through the subscription fees.

8.5.2 Strategic and operational best practices

Strategic and operational issue	Specification
Regular revision and renewal of the cluster strategy	The most successful clusters engage and engage their members in the regular revision, adjustment and relaunch of the cluster strategy and economic and operational positioning.
Formalisation of cluster processes	Agreement, definition and formalisation of processes of the cluster and involvement of cluster members. Processes need to be agreed and optimised to fit the needs of the cluster, those of the members, including SMEs, and not to constraint operations and innovation creativity. In particular taking care of the delicate balance of SMEs.
Monitoring of the entire surrounding ecosystem affecting the cluster	Observation, monitoring, the identification and assessment of external qualitative and quantitative strong and weak signals are key activities for the cluster's strategic monitoring. Clusters set up an appropriate toolbox and processes to support the monitoring.
Technological assessment of the developments affecting clusters	Definition of the main short-term and long-term technological developments and assessment of the cluster's positioning in terms of offering, role, skills and competencies, networking. The results are the identification of gaps and the timely adoption of measures. Clusters base this, again, on a toolbox and on structured and communicated processes. More than on enabling technologies, IoT clusters focus on concrete, close-to-the-market applications. Cluster case study participants confirm that they do not deal with technology policy as such, they tend to focus on business issues and innovation initiatives. Even if IoT clusters clearly target technology strategy with their members, this in almost no case translates into an engagement in policy, for example standardisation and patenting.
Assessment of external factors related to regulations and policies affecting the IoT cluster's activity and that of their members.	Case study participants confirm that insecurity is still very high in certain situations, related to regulatory issues, data security issues and the legal framework. This affects IoT-related activities and the attitude of users. Clusters take care of these issues through specific services related to user acceptance.

8.5.3 Technology and application-related best practices

Technology and application-related issue	Specification
Data silos, i.e. data is rarely shared among different verticals or even same domain.	The best practices IoT clusters put in place concern information and awareness raising of their members, the work towards networking and creation of a critical mass of potential IoT applications, thus facilitating the work of their members when they interact with data owners. The cross-cluster networking and cooperation is one of the key approaches IoT clusters can facilitate to generate critical mass and awareness of applications potentials and of the associated rules to protect data, owners and stakeholders.
Homogenising data formats and semantics and data ontologies.	IoT clusters include this issue in their internal technological activities with their members. Since clusters do not deal with technology policy, as mentioned, policy-makers shall decide whether they need to involve IoT clusters.

Technology and application-related issue	Specification
Management of trust and data sovereignty	Clusters, as in the case of data formats, semantics and ontologies, deal with this issue in their internal technological activities with their members. Wider awareness raising and coordination activities, also with other IoT clusters, depend on the core mission and the availability of resources.
Technologies to process digital content	It is still considered a big challenge to extrapolate data and integrate them into virtual reality systems. The navigation through digital content still remains cumbersome and while firms are dedicated to making this process easier it remains costly. According to cluster managers, another important impediment is the lack of technological maturity due to the limitations created by regulations and the lack of agility to target and implement the new technology. In other terms, regulations and their applications hamper innovation according to IoT clusters.
IoT risk assessment and management	As part of the IoT user acceptance, clusters demand a coordinate action on IoT security risk assessment. This is necessary to be aware of the potential threats to individual fundamental rights, to the level of risks and the necessary measures. It is also the basis to shape support to technological research and innovation and to put in the appropriate implementation rules.
Individual and organisational competencies, skills and expertise	There is a huge need for IT know-how: about 70 000 additional skilled people are needed in the next years, posing a major challenge for the companies and clusters. In economic and sector cycle phases of intense market activity clusters compete with the ecosystems in which they operate.

8.6 Survey process

The survey process comprised two waves in course of the project.

1. The first survey wave was run from the 1st of August 2017 to the 15th of September 2017 with several follow-up contacts to promote the return, and aimed at IoT clusters, companies, RTOs and HEIs alike. The survey was sent out to targets with a personalised link.
2. The second survey wave was run from the 22nd of March until the 19th of April. The survey was sent out on the one hand to targets with a personalised link, on the other hand a generic link was send out to national contact points, multipliers and spread via twitter and LinkedIn.

Table 8-1: Number of distributed surveys in the two waves

Survey	Targets	Number of distributed surveys
1st wave	Clusters	130
	Companies	2157
	HEIs	589
	RTOs	

2nd wave	Companies	1797
	HEIs	501
	RTOs	

Table 8-1 presents the number of surveys with a personalised link that has been distributed in the two survey waves. No such numbers can be shown for the generic link to the survey in the second wave, as the absolute number of surveys that has been spread via social media is unknown to the project team.

Table 8-2: Number and type of respondents. Source: JIIP consortium.

Type of organisation	Number of respondents	Survey
Cluster	35	1st wave
Companies	271	1st wave
	326	2nd wave
HEIs	41	1st wave
	93	2nd wave
RTOs	30	1st wave
	123	2nd wave
Type of organisation not available	114	1st and 2nd wave
Other	113	1st and 2nd wave
Total All respondents	1169	1st and 2nd wave

Clusters have been addressed sufficiently in the first survey wave and have returned in total 35 completed surveys. Companies were targeted in both survey waves with 271 returned survey in the first wave and 326 in the second wave. HEIs returned in the first wave 41 surveys and 92 in the second. 30 RTOs responded in the first survey wave while 123 did so in the second wave. 114 respondents did not respond to the question asking for the type of organisation to which they belong; 113 respondents indicated to other categories of organisations as were offered as menu of choice in the survey in both waves.

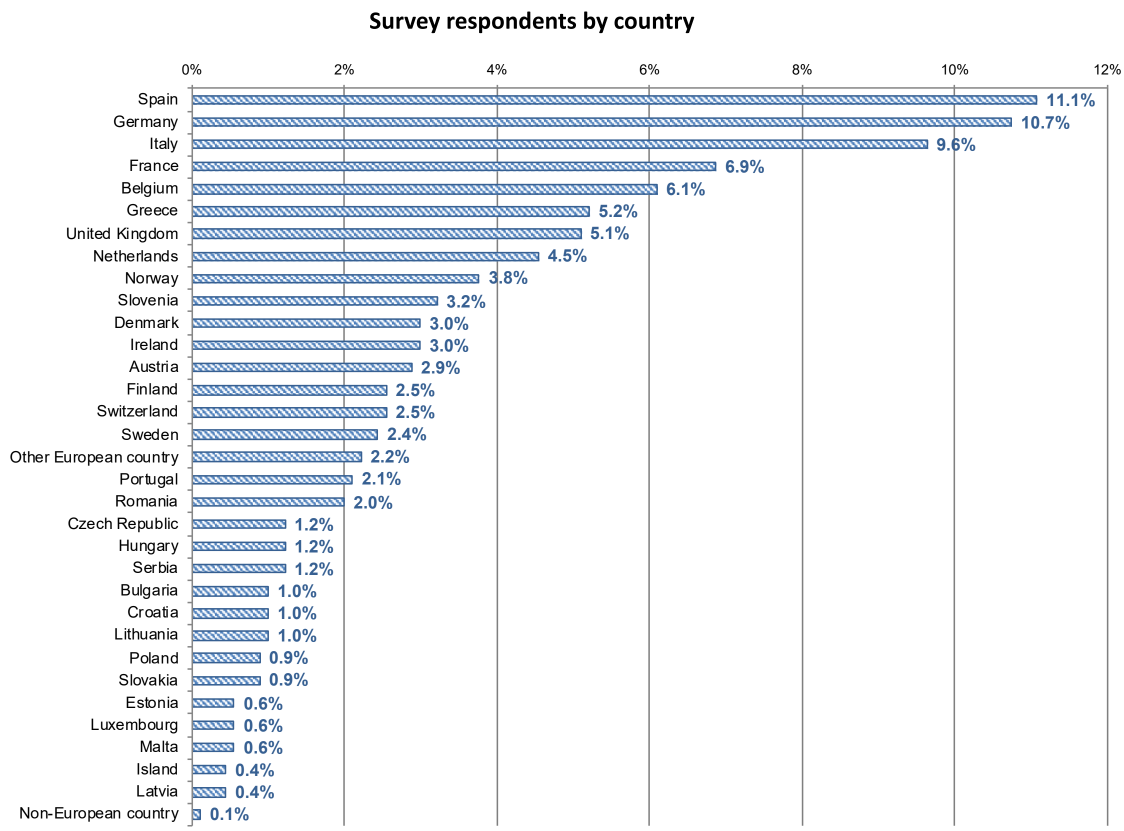

Figure 8-1 Geographical location of respondents. Source: JIIP consortium.

Figure 8-1 shows the percentages and the frequencies of respondents by country. Most responses come from Spain, Germany, Italy, France, Belgium followed by Greece and the United Kingdom.

8.7 Case study process

8.7.1 The cluster case studies

To meet the challenge of a comprehensive understanding of the EU innovation cluster landscape the survey and analysis requires the integration of quantitative sources with the analysis of qualitative information, which is capable of providing supplementary information on the IoT innovation cluster landscape.

The integration of quantitative information and the qualitative judgments is the key to provide a clear understanding of the dynamics (factors of emergences, key drivers, common characteristics, experiences, success factors, needs) that have led to the creation of and characterise the existing IoT innovation clusters landscape in the European Union.

The case studies presented in this report will help determining how the EU can best support the deployment of IoT solutions, in order to enhance their acceptability and adoption by end-users and citizens and foster new market opportunities for EU suppliers.

The case studies are not presented individually, but rather by topic addressed:

- A brief overview of the key cluster characteristics, their origin and the main drivers and objectives. This section helps providing an overview and identifying the key typologies of clusters according to their initial setup and development.
- General highlights on cluster composition and the roles of the different players.
- Drivers and obstacles of cluster development and operation. The relevant section focuses on systemic and structural factors, also related to the functioning of the ecosystem as well as on funding and sustainability issues, as well as the associated performance indicators.
- The catalogue of key activities and services provided by IoT and ICT clusters, separately considering infrastructures.
- Cluster and IoT policy needs. These were kept separate, since clusters, in general, can be considered as territorial or thematic platforms engaged in networking and support of technological or entrepreneurial ecosystems. The overall range of setups and activities are quite homogenous, but depending on the needs, interests, weights, structural and context characteristics. The specific IoT needs pertain to the technology, its take-up and acceptance and is dealt with separately.
- The last section proposes conclusions and lessons learnt from the case studies, pointing at common and distinguishing features and conclusions.

The case studies identified a number of clusters, following the principle of geographic coverage but also considering different typologies and setups. The case studies involved the cluster management and key cluster participants from enterprises, academia and research. Not all clusters were ready and available to take part in our case study work and in some cases, we could interview the cluster management but not obtain many additional interviews due to unavailability. In these cases, we preferred to keep the cluster and accept a more limited set of additional interviews.

The following table presents the interviewees by cluster and country, in case of virtual clusters the same cluster had interviewees from different EU Member States.

It should be noted that the interviews were setup under the customary condition that inputs and opinions expressed would never be presented in conjunction with the identity of the interviewee. The positions therefore were presented as originated by the cluster as a whole.

The conclusions are mainly resulting of the analysis of the study team.

Table 8-3: List of cluster case studies and interviewees

Name of interviewee	Organisation and role	Cluster	Country
László Hencz	Alliance Cluster Management Ltd. , Managing Director	Alliance Cluster	Hungary
Bátorfi Péter	Intelliport Solutions Kft.	Alliance Cluster	Hungary
Varga Csaba	Stratégiakutató Intézet Nonprofit Kft. -	Alliance Cluster	Hungary
Dr. Kapás Ferenc	NOS Kft.	Alliance Cluster	Hungary
Minárovits Márton	Albacomp RI Kft.	Alliance Cluster	Hungary
Dr. Kiss Àkos	University of Szeged- Faculty of Engineering	Alliance Cluster	Hungary
Sascha Stöppelkamp	Cluster Manager, BICCnet	BICCnet	Germany
Prof. Dr. Andreas Herkersdorf	TU München, Chair for integrated systems	BICCnet	Germany
Prof. Dr. Manfred Broy	Cluster speaker and founding president of CDB	BICCnet	Germany
Peter Möhring	Giesecke+Devrient	BICCnet	Germany
Uffe Koch	CEO of Pre.do and Det Gode Firma	BrainsBusiness	Denmark
Jakob Norgaard Mortensen	Adm. direktør & partner (CEO) of Combine	BrainsBusiness	Denmark
Birgit Pia Nøhr	Co-Cluster Manager BrainsBusiness	BrainsBusiness - ICT North Denmark	Denmark
Keld Arenholt Christensen	Industry 4.0 Consultant Aalborg University	BrainsBusiness - ICT North Denmark	Denmark
Ralph Mueller	Eclipse Foundation Europe GmbH - Managing Director	ECLIPSE Foundation Europe	Germany
Riikka Virkkunen	VTT, coordinator in cluster	FIIF	Finland
Iiro Salkari	Vaisala (former VTT) Initiator of the cluster	FIIF	Finland
Ulrich Ahle	FIWARE Foundation - Chief Executive Officer	FIWARE Foundation	Germany
Cruz Enrique Borges Hernandez	DeustoTech - Deusto Institute of Technology - Research Associate	FIWARE Foundation	Spain
Inge Arents	Cluster manager	Flanders Food	Belgium
Stefan Griess	Senior Manager Digital Transformation, Asseco Solutions AG	Forschungs- und Anwendungszentrum Industrie 4.0 (Potsdam)	Germany
Hanna Theuer	Division Manager, Anwendungszentrum Industrie 4.0 and post-doc research associate, the University of Potsdam	Forschungs- und Anwendungszentrum Industrie 4.0 (Potsdam)	Germany
Dr. Sander Lass	Technical Manager, Anwendungszentrum Industrie 4.0 and post-doc	Forschungs- und Anwendungszentrum Industrie 4.0 (Potsdam)	Germany

Name of interviewee	Organisation and role	Cluster	Country
	research associate, University of Potsdam		
Jose Ignacio del Rio	IBERMÁTICA – Director i3B Instituto Ibermática de Innovación	GAIA	Spain
Xabier Garcia de Kortzar	VICOMTECH – Transferencia Tecnológica	GAIA	Spain
Tomas Idiondo	GAIA – Director del Cluster	GAIA	Spain
Mario Ricco	General Director, MEDIS DIH	MEDISDIH Apulian Mechatronic Technological Cluster and Digital Innovation Hub	Italy
Cristina Tanese	Technologist, MEDIS DIH	MEDISDIH Apulian Mechatronic Technological Cluster and Digital Innovation Hub	Italy
Felice Vitulano	Innovation Officer at ICT Company Exprivia	MEDISDIH Apulian Mechatronic Technological Cluster and Digital Innovation Hub	Italy
Ola Svedin	CEO	Mobile Heights	Sweden
Aline Studemund	Project Manager Innovation & Communication	Mobile Heights	Sweden
John Lindström	CEO	ProcessIT Innovations R&D Centre	Sweden
Frank Bösenberg	Silicon Saxony Management GmbH: Managing Director	Silicon Saxony	Germany
Christoph Kögler	Leiter Fokusgruppe IoT beim Silicon Saxony e. V.	Silicon Saxony	Germany
1 interview partner	iSAX GmbH & Co. KG	Silicon Saxony	Germany
Ralf Rabätje	Vr-on	Silicon Saxony	Germany
1 interview partner	Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration (IZM) - Center ASSID	Silicon Saxony	Germany
Giulio Maternini	Professor, University of Brescia	Smart Cities, Smart Communities Lombardy	Italy
Luca Ferraris	Head of Strategy, Italtel Cluster Manager	Smart Cities, Smart Communities Lombardy	Italy
Roberta Gianfreda	Manager, R&D department, TerrAria s.r.l.	Smart Cities, Smart Communities Lombardy	Italy
Vittorio Casella	Professor, University of Pavia	Smart Cities, Smart Communities Lombardy	Italy
Riccardo Roggeri	CEO, Techinnova	Smart Cities, Smart Communities Lombardy	Italy
Arturo Medela	TST Sistemas – Research and Innovation Responsible	Smart Santander	Spain
Luis Muñoz Gutiérrez	Universidad de Cantabria - Professor	Smart Santander	Spain
Juan Becerro	TTI Norte - Managing Director	Smart Santander	Spain
Francesca Spagnoli	Senior researcher at imec - SMIT - Vrije Universiteit Brussel	SynchroniCity	Belgium (Denmark)

Name of interviewee	Organisation and role	Cluster	Country
Dr. Christoph Runde	VDC (Managing Director)	VDC	Germany
Manfred Dangelmayer	Fraunhofer ISI	VDC	Germany
3 interview partners	Festo AG & Co. KG	VDC	Germany
Milan Šolaja	Vojvodina ICT Cluster Novi Sad (Managing Director of VOICT)	Vojvodina ICT Cluster	Serbia
Katić Vladimir	Faculty of Technical Sciences, University of Novi Sad	Vojvodina ICT Cluster	Serbia
Monika Konya	Software Innovation Pole Cluster Szeged (as project partner of VOICT)	Vojvodina ICT Cluster	Serbia

8.7.2 The cluster case study interview guideline

Interview Guide for Case Studies on behalf of the European Commission:

SMART 2015/0012 - Study on Mapping Internet of Things Innovation Clusters in Europe

1. **Personal Information:**

1.1 Organisation/enterprise and function in your organisation/enterprise

1.2 Forms of personal participation/collaboration at BrainsBusiness

2. **Areas of Interest:**

2.1 Cluster History

What were the main factors that led to the establishment and location of the cluster? What were the main factors for the participation of your organization within the cluster?

2.2 Cluster Development

What were main drivers and obstacles for the development of the cluster? What is success for the cluster and where is it successful in particular?

2.3 Cluster's Composition

What are the different roles of the cluster's actors in developing the cluster? How are different goals and attitudes overcome for a sustainable cooperation?

2.4 Main Services and Infrastructures within the Cluster

What are the main developments of services and new solutions within the cluster? What are the main infrastructural needs (e.g. funding issues)?

2.5 Main fostering and hampering Factors to IoT Development

What are the main fostering and hampering factors in the IoT sector for innovation cooperation and the development of market solutions? What are approaches within the cluster to leverage fostering and hampering factors?

2.6 Cluster's Policy Needs

Which main policy measures does your cluster use and what impact do they generate? Which additional measures would be helpful?

2.7 IoT Policy Needs:

Which main IoT-related policy measures does your cluster use and what impact do they generate? Which additional measures would be helpful?

8.8 Preferred functions of the online platform

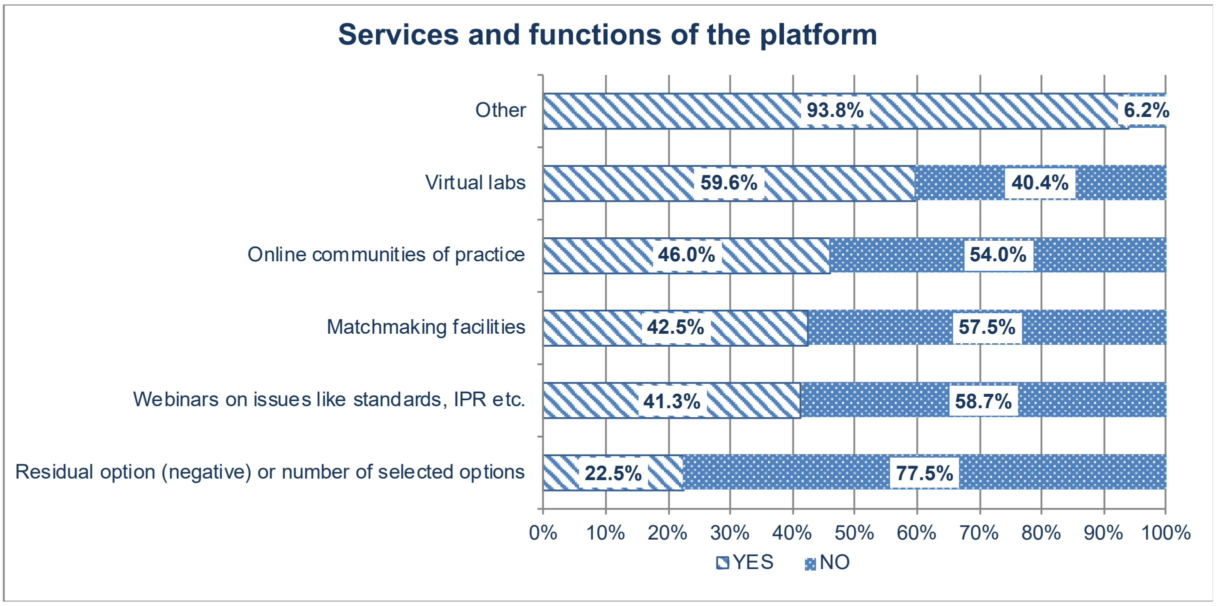

Figure 8-2: Preferences on functions and services offered - all respondents (N=1169)

Free text responses

The respondents indicated the main additional services the platform should provide. These are

- Savings Loyalty System Based on Micro-Contributions from Retailers
- Financing alternatives
- networking
- Incubator
- Consulting
- strong links to political entities, EP and national governments
- end user involvement functions.

9. GLOSSARY

AI	Artificial Intelligence
COM	Commission-issued documents with a focus on legislative documents: documents with references including COM, C et SEC and other types, including agendas and minutes of Commission meetings
CORDIS	Community Research and Development Information Service (of the European Union)
CSV	Comma-separated value file. a delimited text file that uses a comma to separate values to store tabular data in plain text. It used to export and import data records from databased and spreadsheets.
DSM	Digital Single Market
EC	European Commission
eCORDA	The EU Framework Programme participants' database (reserved)
EU	European Union
HEI	Higher Education Institution
ICT	Information and Communications Technologies
IoT	Internet of Things
IP	Intellectual Property
LSE	Large Scale Enterprises
MNC	Multinational Corporations
OECD	Organisation for Economic Cooperation and Development
PPP	Public Private Partnership
R&D	Research and Development
R&I	Research and Innovation
RTO	Research and Technology Organisation
SME	Small and Medium-Sized Enterprises
SWD	Staff Working Document
TT	Technology Transfer
VAT number	Value-added tax number. A unique tax identifier for EU corporates and professionals.

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