Manufacturing Made Smarter Innovation Hubs

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About CSTI

Supporting the evidence needs of industrial innovation policy

Research conducted by the Centre for Science, Technology & Innovation Policy (CSTI) explores what makes national innovation systems effective at translating new science and engineering ideas into novel technologies and emerging industries.

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Executive summary

The digital revolution is underway, and it has the potential to positively affect the UK's economy and productivity. Innovation Hubs have become an increasingly prevalent innovation policy tool for the roll out of industrial digitalisation. In this context, this report was produced to help navigate the complexity of the Innovation Hubs' landscape by examining their different dimensions and international examples. We explore the scope and governance models of Innovation Hubs through the review of the international Industrial Digital Technologies testbed and living lab facilities and their functions. This will contribute to the identification of potential design principles, 'business models', and lessons learned, which might inform the development of UK MMS Innovation Hubs.

Key findings

Organisational aspects

- *Form.* More than 60% of the Digital Innovation Hubs (DIHs) are a partnership, part of an existing organisation (RTOs, universities, or firms) or an informal network organisation. Foundations (12%) and public-private partnerships (9%) are also somewhat prevalent, whereas more formal arrangements such as government agencies (2%) and joint ventures (3%) are much less common. Often the different hubs have close links to one another, and, in some cases, even have the same people as members of their governing boards.
- *Size*. Most of the DIHs are either large (22.4 % have > 5 million turnover) or relatively small (34.1% have < 250,000 turnover). However, in terms of employees, they are prevalently small with 65% of them having less than 25 workers.
- *Governance models*. A lot of variance exists in governance models. Some hubs have bigger and more formalised governance structures drawing experts from academia, industry, and government, while others have just a few people on their management boards.
- *Funding sources*. The sources of funding are quite varied, leveraging funding opportunities at the European, national, and regional levels, as well as private and members' contribution.
- *Customer base*. Most DIHs work with more than 50 customers (56%), and only 5% with up to five customers. The prevailing type of customers is SMEs (96%) and start-ups (80%), although large companies (61%) are also very common, and other RTOs are slightly less (44%). This shows that DIHs are open to engaging with many and different types of actors.
- *Partnerships*. Many hubs function on a membership basis, and most have hundreds of industry partners (large and small), and a close connection with universities, other RTOs, and governments. SMEs are considered to be the most common type of partners. However, large enterprises, other RTOs and universities also appear as important partners of DIHs.

Functions and services

- The most common services offered by the hubs are services that are directed at validating existing and new ideas, such as technology testing and demonstration, concept validation and prototyping. This often involves factory, lab, or company visits.
- In this regard, we have identified Living Labs as an interesting innovation policy tool that enables iterative testing processes under realistic use conditions involving (end) users as co-creators.
- Equally common are services for connecting and qualifying the different actors of the innovation process (e.g., workforce training, collaborative research, ecosystem building and networking, conferences and workshops, and incubator/accelerator support).
- This is normally accompanied by consultancy services of various types (technical, investment, networking, policy/funding, regulatory) and other technical services (licensing, inspection, certification).
- Services related to the end of the innovation process (e.g., commercialisation, marketing, and customer-related services) are the least common.

Competences

- The most common technological competences of DIHs are in recent digital technologies with cross-sectoral applications, such as IoT (80%), AI and cognitive systems (68%), data analytics (63%), and robotics and autonomous systems (62%).

Industrial sectors served

- The most recurring industries served by DIHs are manufacturing of advanced equipment, services of a public utility, such as education and health, and areas more traditionally associated with lower technological intensity, such as agriculture, hunting and forestry.
- Two models of DIH seem to exist: some focus on a single industry and specialise, while others are more open and serve multiple industries.
- Some clustering of activity also occurs, with one group specialising in manufacturing industries, another in services, such as health, education, hospitality and financial intermediation, and a third one specialising in natural resource industries.
- While almost half of the DIHs cover a wide range of TRLs, we have found compelling evidence that, across sectors, DIHs focus on the middle stages of innovation (TRL 5-7). This shows that they are indeed bridging the innovation gap between ideas and commercialisation.

Further details about this exploratory work are provided in each section.

I. Background

The digital revolution offers opportunities for small and large companies across Europe. Taking advantage of industrial digitalisation has the potential to positively affect the UK's economy and productivity, which has become stagnant. Over the next decade, industrial digitalisation could boost UK manufacturing by £455bn, achieving sector growth of up to 3% per year, and generating a net gain of 175,000 jobs whilst lowering CO2 emissions by 4.5%[1]. Despite the benefits of digitisation, many companies, especially SMEs, still struggle to adapt and risk falling out of touch with their markets[2]. According to the European Commission[3], *"around 60% of large industries and more than 90% of SMEs lag behind in digital innovation"*. The consequences can be severe for individual companies, as well as for regions and entire countries.

As the economic crisis related to the outbreak of Covid-19 has shown, supply chains have become increasingly globally interconnected and can face disruption due to political, economic, social, technological, environmental and legal factors, with potentially unexpected and dramatic impacts. An agile, data-driven supply chain ecosystem can absorb, react and mitigate such impacts. For this purpose, supply chains must become more flexible and responsive whilst incorporating increased resilience and traceability. Digital technology and innovation will be the enablers for delivering such transformation. The Made Smarter report also highlighted the importance of industrial digitalisation technologies (IDT) as a means to improve the resilience of supply chains.

Against this backdrop, Innovate UK is designing a new support mechanism within the Manufacturing Made Smarter (MMS) ISCF challenge initiative: Innovation Hubs. The intention is to fund two MMS innovation hubs related to the following themes: the 'Smart Flexible Factory'; and the 'Digital Supply Chain'. Each of the Innovation Hubs will have its own national network of test beds, living labs or other facilities to develop, demonstrate and test new solutions for digitising these manufacturing functions. It is expected that the Hubs will reuse or build onto existing facilities wherever available, will identify and enable the use of capabilities and expertise developed in universities and other organisations, and will fund projects by UK manufacturers and tech providers using these facilities and capabilities.

Innovate UK is engaging with stakeholders to determine the scope and specifications for the MMS Innovation Hubs. The expectation is that Innovation Hubs will enhance the productivity and resilience of the UK's manufacturing base and supply chains by achieving the following: providing a national facility to show the state of the art of technology; developing test beds and living labs for industrial digitalisation technologies to develop and demonstrate the potential of such technologies; providing support to multiple industry sectors by curating and disseminating effective practices and lessons learned from IDT 'use cases'; and providing support to UK firms to access demonstration and testbed facilities, tools and know-how.

[1] Made Smarter (2017) *Made Smarter Review*

[2] WEF (2020) *Companies need help to overcome rising data inequality*

[3] European Commission (2021) *Digital Innovation Hubs in Europe*

1.1 PROJECT AIMS

The overall objective of the project is to help navigate the complexity of the Innovation Hubs' landscape by examining different dimensions and international examples. The report aims to inform the development of Innovation Hubs and develop the scope and governance model through the review of an international IDT testbed and living lab facilities and their functions.

In particular, Innovate UK is interested in strengthening the existing evidence base through the following:

- **Section II:** Examining governance models used by Innovation Hubs and R&D Centres, investigating the different international organisations that focus on digital manufacturing and identifying their missions, funding sources, governance structures, functions and services.
- **Section III:** Systematically reviewing the international IDT testbed, living lab and other test and demonstration environments, their areas of application, objectives, functions and outcomes with a view to extracting potential design principles, and their 'business models', and lessons learned, which might inform the development of the UK MMS Innovation Hubs.
- **Section IV:** "Light touch" reviewing and mapping of the current capabilities and resources of UK competence centres, IDT testbed and living lab facilities. Understanding the UK landscape provides basis for accessing existing facilities and resources the by UK MMS Innovation Hubs.

1.2 GLOSSARY

Innovation Hub (IH)

Innovation Hubs are multi-partner coordinators that help companies expand their use of digital technologies to improve business and production processes, products, and services and to increase overall competitiveness. Digital IHs share advanced knowledge and expertise with their customers and provide them with access to the latest technologies. They also guide customers in exploring and piloting digital innovations, and, when required, they offer business and financing support to customers to allow them to implement these innovations across the value chain. IHs act as a first regional point of contact, a doorway, and strengthen the innovation ecosystem [4] Having different origins and serving different purposes, IHs are diverse in nature. However, their focus is largely on TRL 4-6.[5]

Smart Flexible Factory

A Smart Flexible Factory is a fully connected and flexible system that relies on a constant stream of data from connected operations and production systems in order to learn and adapt to new demands.

Digital Supply Chain

Built on Web-enabled capabilities, a digital supply chain capitalises on connectivity, system integration and the information-producing capabilities of "smart" components to derive insights for increased efficiencies, waste reduction and facilitating greater profits.

[4] European Commission (2018) *Digital Innovation Hubs in Europe*

[5] Focus areas of IHs are different to other initiatives such as The Made Smarter North West Pilot (regional focus, working specifically with SMEs, manufacturing advisory services, plug & play solutions), ISCF Manufacturing Made Smarter Research Centres (lower TRLs), and EPSRC National Research Facilities (lower TRLs; access to capabilities and facilities).

II. Governance structures and business models

Overview of this section

In this section, we analyse 13 international organisations that contain innovation hub-like functions. The analysis highlights their missions, funding sources, governance structures, functions and services. The key findings are presented below.

Mission

- Two main objectives stand-out: 1. developing high-value digital manufacturing technologies by linking different actors to bridge the gap between ideas and innovation (the so-called 'valley of death'); and 2. diffusing these technologies to new or existing industries to improve their competitiveness.
- Common technology areas include sensors, industrial internet of things (IIoT), data analytics, robotics, automation, digital twins, and artificial intelligence.

Funding sources

- Funding available for the hubs generally ranges from $15 to $80 million per year, with significant variance.
- The most common funding model is public-private partnerships. Even when the hubs are funded through public funds initially, they are expected to raise funds from other sources in the future.

Governance structures

- Innovation Hubs are generally organised as networks of not-for-profit organisations. Often the different hubs have close links to one another, and, in some cases, even having the same people as members of their governing boards.
- Significant variation exists, however, in their governance models. Some hubs have bigger and more formalised governance structures drawing experts from academia, industry, and government, while others have just a few people on their management boards.
- Many hubs function on a membership basis, and most have hundreds of industry partners (large and small), and close connection with universities, other RTOs, and governments.

Functions and Services

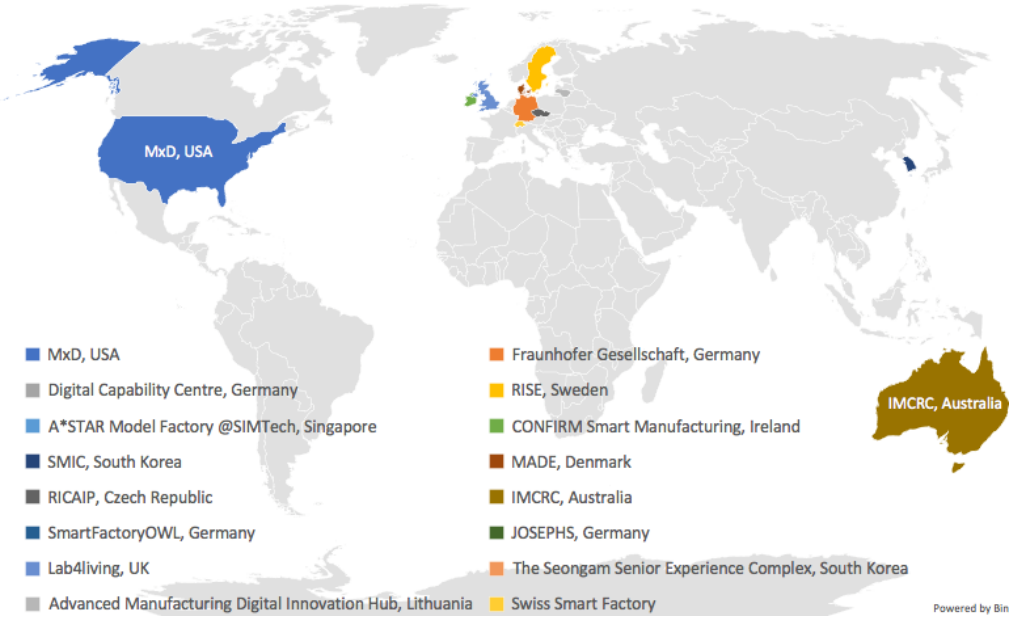
- The most common services done by the hubs are technology demonstration, testbeds and living labs, which sometimes includes factory, lab, or company visits.
- This is normally accompanied by consultancy services of various types (technical, investment, networking, regulatory) and other technical services (licensing, inspection, certification).
- Workforce training, capability building, and conferences and workshops are also central services of the hubs under study.
- We have identified Living Labs as an interesting innovation policy tool that enables iterative testing processes under realistic use conditions involving (end) users as co-creators.

Outliers

- In many senses MxD and Fraunhofer IPA are outliers. They both command considerably higher resources than most of the other hubs.
- MxD also boasts a significantly larger facility area of 22,000m², and has the peculiarity of focusing mainly on national defence technologies.
- Fraunhofer IPA distinguishes itself for being much older than the rest. It was founded in 1959, while the other hubs were launched from 2014 onwards.

We have analysed 13 international organisations that have Innovation Hub functions. They represent different international organisations that focus on digital manufacturing (among other areas), covering four continents: North America, Europe, Asia and Australia (see Figure 1). Appendix 1 offers profiles of each organisation in relation to its mission, sector, governance, funding, institutional structure and context as well as its functions and services. The examples covered include innovation hubs and research centres in the USA, Germany, Sweden, Singapore, Ireland, South Korea, Denmark, Australia, Czech Republic, Lithuania, and Switzerland.

FIGURE 1 INTERNATIONAL INNOVATION HUBS



This section also provides a brief introduction to Living Labs and the opportunity to test and validate products and services involving users as co-creators. Appendix 2 offers examples of non-manufacturing related living labs to highlight the diverse areas of application and their focus on realistic use conditions.

Limitations

- This section provides a snapshot of the international organisations that focus on digital manufacturing (among other areas). When appropriate, the umbrella organisation has been studied in order to showcase their governance model and the variety of functions that guide its operations. Due to the varying levels of analysis and differing governance models, caution is needed when interpreting the findings.
- Efforts have been made to present diverse cases; however, due to the availability and access to publicly available information in English, these cases are presented at different levels of detail.
- While a variety of international organisations with multi million pound funding have been included in this review, it is important to note that the list of cases is not exhaustive.

2.1 INTERNATIONAL INNOVATION HUBS

An overview of 13 different organisations and their mission, focus areas, governance and institutional structures, and functions and services is presented in Table 1. This report acknowledges that the analysed organisations perform innovation hub functions, while not only being innovation hubs. For simplicity, this report refers to these organisations as innovation hubs.

TABLE 1 INTERNATIONAL INNOVATION HUBS AND THEIR MISSIONS, FUNCTIONS AND GOVERNANCE STRUCTURES

Organisation	Mission[A]	Focus Area	Governance	Funding[b]	Institutional Structure and Context	Functions and Services[c]
MxD: Manufacturing x Digital (Chicago, USA)	To equip US factories with digital tools and services	Future factory, cybersecurity, supply chain, digital engineering, workforce development, defence collaborations	61 multi-tier management roles including a 10-member executive council drawn from industry	Initial $80 million seed funding in 2014 by US Department of Defence (DoD). In 2019, $60 million five-year contract by DoD. Most projects require a 1:1 cost share match by industry.	>270 members; large companies, non-profits, SMEs, solution providers, academic, government	Demonstration facilities open to partners for experimentation (12,000 visitors/year), workforce training (MxD Learn) focused on cybersecurity and digital engineering skill development, R&D projects (so far, approx. $100 million invested in more than 60 projects), public workshops
Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) (Stuttgart, Germany)	To conduct applied research for economic production of sustainable and personalised products	Battery production, bio intelligence, digital transformation, frugal manufacturing systems, AI for production, resilient value creation, supply chain	Two institute directors with dual professorial appointments at University of Stuttgart, and strong presence on industrial boards	€76 million (annual budget 2019). Generally, Fraunhofer Gesellschaft receives funding both from the public sector (approximately 30%) and through contract research earnings	593 staff; 15 specialist departments; six business units; hosted by University of Stuttgart; industrial & academic networks	Demonstration facilities for testing and feasibility studies. Development projects (innovation workshops, technology scouting, feasibility studies, prototype development, etc.), optimisation projects (potential analysis, exploring project, production planning and optimisation), specific project formats (systems engineering projects, consortia and partnerships). Joint research, venture partnerships, transfer

Organisation	Mission[A]	Focus Area	Governance	Funding[b]	Institutional Structure and Context	Functions and Services[c]
				(approximately 70%).		workshops, training, patents database, licensing
Digital Capability Centre (DCC) (Aachen, Germany)	Explore – Try – Apply	Digital manufacturing, digital supply chain and technology ecosystem	McKinsey & Company employees provide leadership and expertise	Exact figure N/A*[d]; McKinsey & Company and RWTH Aachen University	Small team of experts; hosted by RWTH Aachen University; DCC global network	Capability building programs, workshops, testbeds, trials, consultancy, trainings, factory tours
RISE – DigiCORE (Västerås, Sweden)	To strengthen organisations in the digital transformation	Artificial intelligence, cyber security, data science, design, digitalisation, Internet of Things, climate neutral industry, mobility, service innovation	RISE Group; Board of Directors; Council	RISE group: 3,568 million SEK (Net sales in 2019)* Exact figure for DigiCORE N/A.	Limited company, wholly owned by the Swedish State	Demonstration and testing facilities (hardware and software), workshops, lab tours, borrowing/renting equipment, networking, business development
A*STAR's Model Factory @SIMTech (Singapore)	To develop targeted high-value manufacturing technologies and human capital to enhance Singapore's competitiveness	Robotics & automation, digital manufacturing, additive manufacturing, and advanced materials	9-member management; directors represent research, knowledge transfer and other divisions	Exact figures N/A*[e]	SIMTech is a research institute of the Singapore Agency for Science, Technology and Research (A*STAR).	Demonstrators for shop floor, resource management, enterprise, supply chain & logistics, and nerve centre. Collaborative projects, consortia, and sharing of research facilities. Workforce trainings, conferences, lectures, seminars, workshops and courses. Technology licensing, open innovation, and risk sharing in commercialisation. Capability building via manpower sharing. Model factory visits.

Organisation	Mission[A]	Focus Area	Governance	Funding[b]	Institutional Structure and Context	Functions and Services[c]
CONFIRM Smart Manufacturing (Limerick, Ireland)	To transform industry to become leaders in Smart Manufacturing	Data analytics, product & process control, enterprise modelling & simulation, software systems, network systems & IoT, sensors, robotics & controls, materials processing	Executive (with professorial director), industrial and scientific advisory committees, operations team, 39 investigators	€45 million Science Foundation Ireland (SFI)	A national strategic initiative supported by SFI; hosted by University of Limerick; 100 industry partners	Testbed and prototype facilities, collaborative R&D, networking, workforce training, workshops.
Smart Manufacturing Innovation Centre (SMIC) (Ansan, South Korea)	To build advanced smart factory, which can connect 'virtual production' to 'actual production'	IIoT, cloud computing, VR/AR, big data, CPS/digital twin, AI, 5G wireless, mart machine, 3D printing	It is supported by Ministry of Trade, South Korean Government.	Exact figures N/A*[f] 50% Government, 50% Industry	Runs a membership model for industry for testing new technologies for smart factories	Smart Factory insights and support to SMEs, consulting, demonstration factory/visualisations of CPS/digital twin and 5G concepts, proof of concept by industry, product certification, networking, global conferences, global exhibitions, trainings, factory hackathons
MADE – Manufacturing Academy of Denmark (Copenhagen, Denmark)	To apply research, drive innovation and strengthen education to improve the competitiveness of Danish manufacturing	Advanced manufacturing and Industry 4.0 solutions in the Danish manufacturing sector. Machining, electronic measurement systems, ICT trust, cybersecurity and network security, advanced manufacturing systems, digital industrial, mobility technologies	13-member team consists of a managing director, a secretariat head, consultants, coordinators and student assistants	DKK 380 million ($60 million) (2014-2019) via industry (48%), Innovation Fund Denmark (38%), universities (9%), private funds and associations (6%)	MADE is an independent association with 170 members: industrial partners large and small, universities, RTOs, and sponsors	Open labs, company visits, conferences, demonstration & cluster projects for SMEs; technology development (via research projects) and network building, supporting education
RICAIP (Prague, Czech Republic)	To create a collaborative ecosystem for application-oriented research in the	Industry 4.0, industrial production, artificial intelligence , virtual and augmented reality, remote industrial production control, rapid adaptation	Steering Committee; Executive and International Advisory Boards drawing from industry, academia	€14.986 million (2019-2026) via EU's Horizon 2020 programme	Four founding partners (in Germany and Czech Republic): DFKI, ZeMA, CIIRC CTU and CEITEC BUT	Testbed facilities (RICAIP will connect testbeds in Prague, Brno and Saarbrucken); Very high variability set of machines and transportation tools fully integrated and operated in multi-site dimension, evaluation

Organisation	Mission[A]	Focus Area	Governance	Funding[b]	Institutional Structure and Context	Functions and Services[c]
	advanced production area		and Czech Government			and feasibility studies of new processes and technologies at testbed, implementation support of solutions in shop-floor.
IMCRC (Carlton, Victoria, Australia)	To help Australian companies in research-led innovations in manufacturing business models, products, processes, and services	Advanced manufacturing technology utilisation: additive manufacturing, automated and assistive robotics, advanced materials, sensors and data analytics, augmented and virtual reality, and high value product development. Industrial Transformation Program (ITP): digital technology platforms, business model innovations, digital and data-driven manufacturing.	The board of directors represents a broad range of industry, research and government expertise	$30 million to co-fund industry-led research projects on a 1:1 basis until mid-2022	Partners include industry, research organisations, government & industry associations and collaborators	Industry education, public advocacy; Co-funds projects on a dollar-for-dollar basis, broad, multidisciplinary and industry-led research projects
SmartFactoryOWL (Ostwestfalen-Lippe, Germany)	To be an Industry 4.0 innovation platform and "transmitter" between research institutes and external partners to co-create technologies for future factories	Digital manufacturing, industrial automation, ICT, robotics / human machine interaction, high performance computing / cloud-based simulation services, additive manufacturing, high-performance production (flexibility, productivity, precision and zero defect), intelligent/ sensor-based equipment	5-member management committee drawn from the participating organisations, predominantly from Fraunhofer IOSB-INA	€5 million (2020) via Fraunhofer IOSB-INA and OWL University of Applied Sciences and Arts	Research institutes, Fraunhofer IOSB-INA, OWL University of Applied Sciences and Arts, and external partners: industrial, scientists, students, start-ups, society and politics.	TRL5-7; demonstration: A real laboratory and certified test environment for Industry 4.0; pilot production and prototype development for SMEs; technology services for SMEs: lab tours, excursion, demonstration of Industry 4.0 concepts, networks; AI living lab; trainings
Advanced Manufacturing	To boost the competitiveness	Digital manufacturing, services promoting	LINPRA Board (or Presidium) consists	Exact figures N/A*	AM-DIH is hosted by Engineering Industries	Awareness creation, ecosystem building, scouting, brokerage,

Organisation	Mission[A]	Focus Area	Governance	Funding[b]	Institutional Structure and Context	Functions and Services[c]
Digital Innovation Hub (AM-DIH) (Vilnius, Lithuania)	of Lithuanian companies by bringing together Lithuanian ecosystem members	digitisation, standardisation and legal regulation, human resources and cyber security. The Lithuanian national initiative for digitising industry, Pramonė 4.0.	of representatives of leading Lithuanian engineering industry companies, science and education institutions	Public and private sources: Horizon 2020, European Social Fund, COSME, national basic research funding, private funding, partner resources, memberships	Association of Lithuania (LINPRA), and is led by non-profit public organisation created to support the AM-DIH - Intechcentras.	networking, collaborative research, concept validation and prototyping, testing and validation, pre-competitive series production, commercial infrastructure, incubator/accelerator support, education and skills development
Swiss Smart Factory (Biel, Switzerland)	To become Switzerland's leading, internationally recognised competence centre for Industry 4.0	Smart sensors & actuators; smart networking & automation; AR/VR; AI & smart data; cloud- & edge computing; autonomous robots & cobots	Swiss Smart Factory is one of the SIPBB's four Competence Centres. Switzerland Innovation Foundation coordinates the five locations like SIPBB.	Public and private funding. Approx. CHF 70 million for SIPBB (federal loan guarantees) 2018 revenue: 68% public funds (KTI, Innosuisse, EU-Projects) and 32% industrial sales and R&D projects	A private Swiss non-profit organisation, SIP Biel/Bienne(SIPBB) works with its operating company Switzerland Innovation Park Biel/Bienne Ltd. 40 members from industry and research.	Test and demonstration platform, research and innovation projects, training and further education, incubator/accelerator. Allocated premises, technology services and R&D competencies to be utilised in both Swiss and foreign innovation projects; IoT-based pilot production facility

Notes: N/A = Not available; *Funding/budget are not fully comparable with other hubs. a) Information provided in this column does not include the official mission statement but offers a summary; b) Funding may not be limited to innovation hub functions but may also include other areas of the organisation; c) Functions and services are not limited to innovation hub-like functions and may also include other aspects relevant to the hosting organisation; d) A similar DCC in Singapore was built at a cost of $15 million' e) Funding comes from Singapore's RIE2020 plan with a budget of USD 2.3 billion (2016-2020); f) SMIC is also part of the South Korean Government's plan that will provide financing of up to KRW 2 trillion ($1.7 billion) for establishing the advanced manufacturing infrastructure using 5G networks and creating a KRW 300 billion fund for companies pushing to build smart factories.

DFKI = German Research Centre for Artificial Intelligence, Germany (non-profit public-private partnership); ZeMA = Centre for Mechatronics and Automation Technology GmbH, Saarbrücken, Germany.; CIIRC CTU = Czech Institute of Informatics, Robotics and Cybernetics, Czech Technical University, Prague; CEITEC BUT = Central European Institute of Technology, Brno University of Technology, Czech Republic; ICT Information & Communication Technologies; LINPRA = Engineering Industries Association of Lithuania.

There are some common themes across the innovation hubs. In their **missions,** we can perceive two intertwined objectives. First, there is the development of high-value digital manufacturing technologies that are linking different actors to bridge the gap between ideas and innovation. In that sense, just like the Fraunhofer IPA's mission of using applied research to transform ideas into innovations, DCC Aachen's mission is to apply their Explore-Try-Apply approach with companies. Second, there is the diffusion of these technologies to new or existing industries to improve their competitiveness. As such, MxD's mission is to equip U.S. factories with the digital tools and expertise, and make every part better than the last. SIMTech synthetises these two goals by aiming to develop targeted high-value manufacturing technologies and human capital to enhance Singapore's competitiveness. A word cloud of the missions of selected hubs in this review is presented in Figure 2. The visualisation of the mission statements draws attention to important and reoccurring themes such as Manufacturing, Digital and Innovation. These themes further highlight the relevance of the selected cases to inform the development of the 'Smart Flexible Factory' and 'Digital Supply Chain' MMS Innovation Hubs.

FIGURE 2 WORD CLOUD OF ALL MISSIONS IN THIS REVIEW

The **scope of technologies** of selected hubs in this review includes sensors, industrial internet of things (IIOT) and data analytics to robotics and automation, on the one hand, while, on the other, it includes recent advancements of Industry 4.0 technologies, e.g. digital twins and artificial intelligence. The digital supply chain is also an important theme in the scope of technologies and services offered by the hubs, particularly for MxD, DCC Aachen, and A*STAR Model Factory.

In line with the hubs such as MxD and CONFIRM, most projects bridge the gap in the innovation *"valley of death"*, so named because of the high number of innovative concepts and ideas that fail when crossing over from public sector research to private sector commercialisation. They do so by working on **technology readiness levels** (TRLs) 4-7. **Demonstrators of Industry 4.0 technologies** are common across hubs, e.g. in A*STAR Model Factory where these are available under five categories: shop floor, resource management, enterprise, supply chain & logistics, and nerve centre. Likewise, SmartFactoryOWL offers companies the opportunity to test and further develop their products and technological solutions in ideal and real test conditions using practice-oriented demonstrators on a

production area of approx. 2,000m². RISE Group has 126 testbeds - DigiCORE is one of them, and is specialised in digital production technologies.

Public-private partnerships are common **funding models**. For example, MADE is financed by mixed public-private sector funds amounting to DKK 380 million ($60 million) (2014-2019) with mixed funding from industry (48%), Innovation Fund Denmark (38%), universities (9%), and private funds (6%). Similarly, in its first five years, MxD has invested more than $90 million of public (mostly US Department of Defence) and private funds in 63 research and development projects across 35 states. Where the hubs are funded through public funds initially, those are expected to fundraise from other sources, in addition to public funds, to sustain themselves in the future. In terms of the order of magnitude, it is interesting to observe that the funding available for these hubs generally ranges from $15 million to $80 million per year, although with significant variance between them.

Operating on an international scale, or being part of a national **network,** is also a common feature of the analysed hubs. For example, DCC has grown its network of global centres to nine since DCC Aachen was opened in 2017. Interestingly, many of these hubs are linked to each other one way or another. MxD has partnered with McKinsey & Company to setup DCC in Chicago as part of their global network of DCCs, which relates to the A*STAR Model Factory, as common people sit on the governing boards of DCC Singapore and A*STAR. Moreover, many hubs function on a membership basis, and most have hundreds of industry partners (large and small), and close connection with universities, other RTOs, and governments.

The most common **services** offered by the hubs are technology demonstration, testbeds and living labs, which sometimes includes factory, lab, or company visits. These are normally accompanied by consultancy services of various types (technical, investment, networking, regulatory) and other technical services (licensing, inspection, certification). Workforce training, capability building, and conferences and workshops are also central services of the hubs under study.

Although the hubs share some common characteristics, several differences also exist. The first difference is related to **governance models**. For example, MxD, Fraunhofer IPA and RISE have more formalised and bigger governance structures including experts from academia, industry and policy making. In contrast, RICAIP and MADE have only a few people on their immediate management boards. The second difference is the **factory size.** For example, CONFIRM has 1,619m^2 area while MxD has 22,000m^2. This is also dependant on a third difference, which is the availability of (initial) **funding**. SmartFactoryOWL was set-up with €5 million and can be compared to MxD which was started with $90 million, or to Fraunhofer IPA, which has an annual budget of €76 million. A fourth difference is the organisation's *age*. Fraunhofer IPA is quite well established and was launched in 1959. In contrast, the other hubs are quite young, and were launched from 2014-onwards. This may suggest that these hubs could be looking for more stable or alternative income sources over the longer term.

Although some overlaps exist in terms of manufacturing applications, a fifth difference is related to the **application areas** that the analysed hubs are focussing on. For example, there is a heavy focus on the national defence sector in MxD. Each DCC factory is aimed at a specific sector and/or a product, e.g., DCC Aachen has a textile learning factory.

The **number of partners or members of the networks** represents another difference. For example, MxD, Fraunhofer IPA, and MADE have a staggering number of partners. In contrast, Swiss Smart Factory, RICAIP and others have a smaller number of partners. This may also be linked to the hub launch time, funding and other factors. Finally, most hubs operate as not-for-profit organisations; RISE is an exception to this being a for-profit hub.

In conclusion, the analysis of communalities and differences across several aspects related to the hubs' missions, governance structures and business models offers important considerations that have the potential to inform the set-up and management of future innovation hubs.

2.2 LIVING LABS

Innovation hubs have a variety of functions and services, as highlighted in the previous section of this report. One common function relates to the provision of an environment and supportive services and infrastructure that enables R&D activities to take place. To do so, organisations, such as Fraunhofer Center for Applied Research for Supply Chain Services (SCS), established their own living lab.

Living Labs represent an environment and an innovation approach that receives growing attention among practitioners, policy makers and innovation scholars[6] [7]. They provide a collaborative platform for private and public sector innovation. Living labs are initiated and funded by policy makers with regional or national policy goals in mind. As platforms that are providing shared resources and bringing together a variety of private and public stakeholders, Living Labs help gather, create, communicate, and deliver new knowledge, validate existing products, services and processes, facilitate professional development, and social impact in real-life contexts. More specifically, Living Labs enable the co-creation process between universities, large organisations, SMEs, start-ups and users.

The nature and landscape of Living Labs is diverse. They can be found in a variety of sectors. For example, the Living Lab approach is observed in relation to ICT, smart cities and digital cities, health care, agriculture and many other areas. Regardless of the sector, however, all stakeholders are actively involved throughout the innovation process. In the traditional laboratory context, which is more common in industrial environments, the knowledge gained is limited to a few stakeholders, namely the owners of the laboratory[8]. Some laboratories (e.g. IBM Solution Delivery Services Centre) have offered their services to suppliers helping them fulfil RFID mandates from influential customers. In such a case, adopters are not involved in the process of co-creating the solution but are offered a package solution. This approach certainly accelerates the technology adoption but it is not really different from normal business activities where companies rely on consulting experience for solutions. The German Research Centre for Artificial Intelligence's 'Smart Factory' is an example of an organisation that is focusing on innovative industrial automation and information technologies which are developed and tested in a realistic industrial production environment before being transferred to industry.

An example of an organisation that directly, as well as through its active members, provides co-creation, user engagement, test and experimentation facilities targeting innovation in many different domains such as energy, media, mobility, healthcare, agrifood, is The European Network of Living Labs (ENoLL). ENoLL acts as a *"platform for best practice exchange, learning and support, and Living Lab international project development".* It is the international federation of benchmarked Living Labs in Europe and worldwide and counts for over 150+ active Living Labs members worldwide (440+ historically recognised over 14 years) covering five continents in addition to Europe. Evident through the variety of living labs belonging to ENoLL, it is apparent that living labs differ with regard to their set-up, objectives, functions and governance.

The on-going transformation from 'for the user' towards being 'with the user' and 'by the user' is an innovation trend that is reflected in both living labs and Smart Factories. Scholars[9] suggest that users

[6] Greve, K., Leminen, S., De Vita, R., Westerlund, M., (2020b) Unveiling the diversity of scholarly debate on living labs: A bibliometric approach. Int. J. Innov. Manag.

[7] Westerlund, M., Leminen, S., Rajahonka, M., (2018) A Topic Modelling Analysis of Living Labs Research. Technol. Innov. Manag. Rev. 8, 40–51.

[8] Bendavid, Y., Cassivi, L., (2012) A "living laboratory" environment for exploring innovative RFID-enabled supply chain management models. Int. J. Prod. Dev. 17, 94.

[9] Leminen, S., Nyström, A.G. and Westerlund, M., (2015) A typology of creative consumers in living labs. *Journal of Engineering and Technology Management*, *37*, pp.6-20.

"drive the innovation activity or play an increasingly significant role in the innovation process" (p. 14). Similar to living labs, a key feature of Smart Factories is the involvement and interaction of different stakeholders. Furthermore, the real-life context in which innovation takes place in living labs is a defining characteristic of Smart Factories. Therefore, living labs may serve as a useful example to reflect on iterative testing processes under realistic use conditions involving (end) users as co-creators. Table 2 provides examples of non-manufacturing related living labs and is used to highlight the diverse areas of application and the realistic use conditions that they offer in order to test, develop and validate products, services, technologies and processes.

TABLE 2 LIVING LAB EXAMPLES

Living lab	JOSEPHS®	The City of the Future Living Lab	Lab4living	Seongnam Senior Experience Complex
Location	Nuremberg, Germany	Milan, Italy	Sheffield, UK	Seongnam, South Korea
Type	• Physical space • Open to the public • Every 3 months themes change • Companies present prototypes	• Virtual as well as real research environment and community • Hospital context	• Physical space • Healthcare context • Participant recruitment	• Physical space • Open to the public • Combination of facilities (e.g. health centre, test and demon. spaces)
Focus	Users interacting with prototypes from different companies	Users interacting with a number of services within a real city environment	Users interacting with their environment, often integrating creative arts, design with healthcare approaches	Users actively involved in the development of products, services and technologies for seniors

Note: please see Appendix 2 for detailed information on Living Labs case studies

2.3 TESTBEDS

Digital innovation hubs host a variety of demonstration and co-innovation environments, including pilot lines, living labs and testbeds. The terminology related to such demonstration facilities is not always used consistently and there are variations in how the terms are employed between different countries, sectors and technology domains. This section however, specifically focuses on 'testbeds' (or 'test beds') which is a term that can refer to any platform carrying out transparent and replicable testing of novel tools, technologies, systems and even theories. Yet, for some the term 'testbed' is the overarching label for any platform for demonstration, testing and co-innovation (and, in this usage, includes other environments or facilities such as living labs).

In the context of manufacturing and digital innovation, however, industrial 'testbeds' are typically leveraged to explore how digitalised tools, components and subsystems (often from different suppliers and vendors) interoperate and perform and whether they function together as anticipated. In utilising these specialised and controlled environments, the aim is to reduce the risks of a new technology, before employing it in the actual production process or product. The outcomes from testbed activities provide important feedback and 'use cases' for the innovation community, informing technical innovation strategies (on issues of interoperability, system architecture, standards development, etc.), but also business models and sector strategies. By contrast, 'living labs' (discussed in section 2.2) can be seen as platforms for the demonstration and co-innovation of digital manufacturing innovations. A key distinguishing characteristic is the emphasis on exploring the 'living' experience of users interacting with the novel technologies, systems or services. Indeed, the realistic and authentic use conditions under which a product, service or process is tested, together with its collaborative nature fostering co-creation among different stakeholders represent essential living lab components.

A variety of testbed examples exist, varying in their area of application but also in terms of the environment in which they are embedded and how they are defined and used. For example, testbeds are a major focus and activity of the Industrial Internet Consortium (IIC)[10]. The Industrial Internet Consortium describe testbeds as *"platforms to think through innovations and test new applications, processes, products, services and business models to ascertain their usefulness and viability before taking them to market. They uncover the technologies, techniques and opportunities essential to solving these and other important problems that benefit businesses and society*". The IIC collects testbed ideas from member companies and hosts a valuable online resource of testbed results, resources and white papers reflecting on best practices and use cases.

Produktion2030 represents a Swedish strategic innovation programme facilitating advanced manufacturing (funded by Vinnova, the Swedish Energy Agency and Formas). The programme supports 12 national testbeds for smart production[11]. The programme defines their testbeds as *"specialised and controlled environments where experiments can be repeated and the risks of a new technology reduced, before using it in the actual production process or product. Testbeds should be open environments, where businesses and researchers can work together and uncover new opportunities."* The Produktion2030 testbeds are designed to create a forum in which industry, universities and research institutes can pool resources, providing innovation environments to perform tests that would be impossible in the parties' own facilities. Produktion2030 testbeds explore topics such as: Smart digitalisation for sustainable human-centred automation in production; logistic operations in productions; digitalization of supply chain in Swedish additive manufacturing; and smart maintenance.

RISE provide testbeds and demonstration environments for industrialisation and verification. The approximately 100 testbeds and demonstration environments are available to businesses, academia and the public sector. Their website provides an opportunity to explore and select from their list of testbeds and demonstration environments by using filters.[12] They distinguish between Isolated testbeds (IT), Laboratory testbeds (LT), Testbeds in real life (TR) and Virtual testbeds (VT). The results can also be filtered and selected by industry, region, content type, sustainability goals and strategic innovation programme.

Interpretations and applications of testbeds reach beyond the testing of a digitalised subsystem or process and can also refer to manufacturing system testbeds. Kim et al.(2020)[13] describe a number of large scale smart factory testbed facilities. For example, they introduce a distributed reconfigurable factory testbed which was initiated by the Engineering Research Center for Reconfigurable Manufacturing Systems at the University of Michigan. The testbed includes both real and virtual machines, and demonstrates a software architecture to control the machines over a communication network. On the other hand, the German Research Center for Artificial Intelligence has created a smart factory testbed together with several renowned industrial partners, including Siemens and Harting, to demonstrate the capability to manufacture highly customized products using different industrial standard solutions and ICT platforms. The Institute for Advanced Manufacturing at the University of Nottingham proposed a software architecture for Evolvable Assembly Systems (EAS). It comprises five main components: reconfiguration, monitoring, agent environment, translation, and definition. The components are controlled through a unified user interface, and every device is linked with intelligent resources. The developed software offers a training environment for manufacturing automation and includes a basic tool box for implementing evolutionary learning algorithms for the reconfiguration of

[10] Industrial Internet Consortium (2021) Testbeds

[11] Produktion2030 (2021) Testbeds for smart production

[1212] RI.SE website

[13] Kim, DY., Park, JW., Baek, S. et al. (2020). *A modular factory testbed for the rapid reconfiguration of manufacturing systems*. J, Intell, Manuf., 31, pp. 661–680

manufacturing systems. Kim et al.(2020) [14] provide an overview of different smart factory testbeds for research, demonstration, and educational purposes, including: SMART Testbed (University of Michigan), Smart manufacturing systems Testbed (NIST), SmartFactoryKL (DFKI, Kaiserslautern), Smart factory web (Industrial Internet Consortium), and iFactory (IMS Center, University of Windsor, Canada). Table 3 offers an overview of some illustrative examples which reflect the breath of international testbeds, their application field and host organisation.

TABLE 3: SELECTED TESTBEDS

Testbed host	MxD	Stena industry innovation lab Testbed (SII Lab)	Smart production systems research group	CONFIRM Smart Manufacturing
Location	Chicago, USA	Chalmers UT, Sweden	HTW Dresden, Germany	Limerick, Ireland
Testbed types	• Process manufacturing • Discrete manufacturing	• Learning factory • Collaborative robots • VR & AR for training • In-house logistics	• Industrial IoT Testbed	• Future wireless innovation testbed
More information: MXD Factory Floor website Digitalization of Supply Chain in Swedish Additive Manufacturing (DiSAM) website HTW Dresden website Cofirm website				

[14] Ibid.

III. Systematic Review of International IDT Facilities

Overview of this section

In this section, more than 600 Digital Innovation Hubs (DIHs) were analysed using several types of quantitative methods. Here are our key findings:

Sectors of application

- The most recurring industries served by DIHs are manufacturers of advanced equipment and services of public utilities, such as education and health, and areas that are more traditionally associated with lower technological intensity, such as agriculture, hunting and forestry.
- Two models of DIH seem to exist: some focus on a single industry and specialise, while others are more open and serve multiple industries.
- Some clustering of activity also occurs, with one group specialising in manufacturing industries, another in services such as health, education, hospitality and financial intermediation, and a third one specialising in natural resource industries.

Technological readiness levels (TRLs)

- While almost half of the DIHs cover a wide range of TRLs, we have found compelling evidence that, across sectors, DIHs focus on the middle stages of innovation (TRL 5-7). This shows that they are indeed bridging the innovation gap between ideas and commercialisation.

Services

- Consistently, services related to the end of the innovation process (e.g. commercialisation, marketing, and customer-related services) are the least common, while the most common ones relate to connecting and qualifying the different actors in the innovation process (e.g. education and skills development, collaborative research, ecosystem building and networking) and validating existing ideas (e.g. concept validation and prototyping, testing and validation, incubator/accelerator support).

Competences

- The most common technological competences of DIHs are in recent digital technologies with cross-sectoral applications, such as IoT (80%), AI and cognitive systems (68%), data analytics (63%), and robotics and autonomous systems (62%).

Organisational aspects

- *Organisational form.* More than 60% of DIHs are a partnership or part of existing organisations (RTOs, universities, or firms) or an informal network organisation. Foundations (12%) and public-private partnerships (9%) are also somewhat prevalent, whereas more formal arrangements such as government agencies (2%) or joint ventures (3%) are much less common.
- *Size*. Most of DIHs are either large (22.4 % have > 5 million turnover) or relatively small (34.1% have < 250,000 turnover). However, in terms of employees they are prevalently small with 65% of them having less than 25 workers.
- *Funding sources*. The sources of funding are quite varied, leveraging funding opportunities at the European, national, and regional levels, as well as private and members' contribution.
- *Customer base*. Most DIHs work with more than 50 customers (56%), and only 5% with up to five customers. The prevailing type of customers is SMEs (96%) and start-ups (80%), although large companies (61%) are also very common and other RTOs are slightly less (44%). This shows that DIHs are open to engaging with many and different types of actors.
- *Partnerships*. SMEs are also considered the most common type of partners. However, here large enterprises, other RTOs and universities, also appear as important partners of DIHs.

The following sections provide an overview of the IDT testbed, living lab facilities and other test demonstration environments. Different to the previous section of the report, which focuses mainly on governance structures, missions and business models of 13 selected organisations with Innovation Hub functions, this section is systematically analysing the data gathered through the tool of a "Digital Innovation Hub" that is available through the European Commission (EC) website and is representing 658 Digital Innovation Hubs[15] (DIHs). Specifically, the review will be focusing on their prevailing areas of application and the services provided, and their functions and objectives. Furthermore, prevailing organisational models and choices will be explored. Such a review can inform future intervention in the UK, specifically identifying the potential synergies to be exploited by creating a central innovation hub to coordinate the national innovation ecosystem. The database includes different types of innovation hubs and is not limited to manufacturing-related ones. The diverse nature of these hubs further highlights the capacity of different organisations to provide innovation hub functions. This report also analyses non-manufacturing related DIHs, as they offer valuable insights for the development of the UK MMS Innovation Hubs.

While self-reported data can present limitations in terms of their consistency, this approach is particularly suitable in the context of this report. Firstly, the database summarises information in a structured manner and is containing a rich set of international experiences of different environments. The size of the database (658 self-declared DIHs at the moment of data collection) ensures, on the one hand, that information can be obtained about the different models needed to support a DIH, and, on the other, by analysing a large amount of data, significant patterns can be identified. Secondly, self-reported[16] data is valuable when studying demonstration environments, due to the absence of an agreed definition and categorisation in the academic literature and in practice. Using an approach that is based on self-declared data, including in this case those organisations that identify themselves as DIHs rather than just using a rigid definition, is, therefore more appropriate. Indeed, the database includes facilities such as the Bar-Ilan Center for Smart Cities which uses the term living lab to describe itself. On the other hand, Stena Industry Innovation Hub at Chalmers call themselves a testbed for acceleration of industrial digitalisation. These and other test and demonstration environments are included in the DIH database. Finally, the database includes DIHs which possess technological competences in key IDT areas including but not limited to artificial intelligence, machine learning and data analytics, additive manufacturing, robotics and automation, virtual reality and augmented reality, the Industrial Internet of Things (IIoT) and connectivity.

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[15] "Digital Innovation Hub" database is available through the European Commission (EC) website: https://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-tool. The database also comprises organisations which are not only DIHs, but perform some of their functions. Notwithstanding this fact and consistently with the terminology used in the database, throughout this chapter and the next one the expression DIHs will be used to describe the organisation included in the EC website. The following paragraphs provide evidence of the rich diversity of organisations captured in the database.

[16] The EC website is a "yellow pages" of Digital Innovation Hubs. The information provided about each entry is based on self-declaration. The European Commission currently verifies all the entries in the catalogue (based on the provided information) if they comply to the following 4 criteria:

1. They are part of a regional, national or European policy initiative to digitise the industry.
2. They are a non-profit organisation.
3. They have a physical presence in the region and present an updated website clearly explaining the DIHs' activities and services that are provided related to the digital transformation of SMEs/Midcaps or industrial sectors that are currently insufficiently taking up digital technologies
4. They have at least 3 examples of how the DIH has helped a company with their digital transformation, referring to publicly available information, identifying for each the following:
    - Client profile
    - Client need
    - Provided solution to meet the needs

The purpose of the catalogue is to support the networking of Digital Innovation Hubs and to provide an overview of the landscape of Digital Innovation Hubs in Europe, supported by Regional, National and European initiatives for the digitalisation of industry.

The European Commission defines these DIHs as actors or initiatives that are helping *"… companies in the region become more competitive by improving their business/production processes as well as products (and services) by means of digital technology."* DIHs are initiatives that are set-up to support the digital transformation of existing industry. Having different origins and serving different purposes, they are a new concept that builds upon previous experiences and organisations. For this reason, the configuration and governance of DIHs is heterogeneous. The European Commission suggests that *"for the long-term sustainability and success of these organisations, their differences need to be acknowledged and built-up on."*

To highlight the diverse nature of digital innovation hubs and their business models, functions and services, funding sources and links to partner organisations, Appendix 3 provides insights into four examples of international digital innovation hubs, as part of the EC DIH database. The cases have a range with regard to their turnover, organisational form, technology readiness level focus, and the market sectors they service. Moreover, the varying technological competencies and services that these hubs offer are presented together with a description of their activities, funding sources and partner organisations.

To complement and broaden the scope of the analysis on DIHs, a keyword clustering analysis on peer-reviewed academic literature, focusing on living labs, testbeds and pilot lines is provided in Appendix 4. Clustering is a process whereby the datapoints are divided into smaller groups based on similarity measures. We used the abstracts of the articles in numerical format to ensure it works with the K-means clustering and to ensure that the contextual information from each of the abstracts is intact, with a BERT classifier being used. This is a Natural Language Processing technique that reads through the sentence by a process called sentence embedding to extract the contextual meaning before classifying the datapoints into clusters. To run this algorithm, we relied on the keyword classifier provided by the articles' authors which was then used by the machine for "learning". This training dataset is used against all the abstracts of the papers before the dataset is being partitioned. Based on the analysis of 22701 articles through keyword clustering, the diverse nature and application of demonstration environments is apparent and represented through ten distinct clusters (Appendix 4).

3.1 INNOVATION FUNCTIONS

An overview of particular innovation functions related to knowledge generation, diffusion and application, together with examples of DIHs that possess relevant capabilities and services are shown in Table 4. More details with respect to the DIH and a particular service example are offered in Appendix 5.

TABLE 4 INNOVATION FUNCTIONS AND RESPECTIVE DIH EXAMPLES

Technology Development	
Knowledge Generation	
Function	**Example DIH**
Technology demonstration (TRL 4-6): • Demonstrators, prototypes…	**Centre for Applied Data Analytics and Machine Intelligence, CeADAR** (Ireland)
Manufacturing demonstration (MRL 4-6): • Pilot lines, model factories…	**bi-rex - Big Data Innovation & Research Excellence** (Italy)
Integrated system demonstration (SRL 2-4)[a]: • Integrated system testbeds…	**Smart production systems research group** **(**Germany)
User co-creation/utility demonstration: • Use case testbeds, • 'Living labs'…	**OuluHealth** (Finland)

Service innovation and design processes	**EOSC-DIH** (Netherlands)
Grant funding for knowledge generation	NA
Innovation System Development	
Knowledge Diffusion	
Function	**Example DIH**
Use cases • Use case libraries / repositories • Best practices databases…	**FIWARE Innova iHub** (Italy)
Network linkages • Brokerage service helping innovators connect to facilities/services • Factory visits, networking events • Consortium / R&D partnership support	**Urban ICT Arena** (Sweden)
System intelligence • Benchmarking, market analysis… • Roadmapping, foresight analysis…	**AFIL - Lombardy Intelligent Factory Association** (Italy)
'Institution' development • Standards working groups, advice… • 'Sandboxes', regulatory advice	**Healthday.si - Digital Innoation Hub in Healthcare and Biotech** (Slovenia)
Capability Development	
Knowledge Application	
Function	**Example DIH**
Workforce development • Training: Technician training • Executive education, lifelong learning • Workshops, seminars…	**Digital Innovation Hub for Smart Manufacturing Pomurje Technology Park** (Slovenia)
Consulting / business advisory services • Technology advisors / staff sharing • I4.0 assessment / advisory services • Signposting to additional funding	**Silesia Smart Systems** (Poland)
Access to expertise, facilities	**AddedValue** (Hungary)
Quality assurance • Certification, testing, inspection	**Baltic Maritime Digital Innovation Hub** (Lithuania)
Technology transfer • Technology licensing • Risk sharing in commercialisation • Patenting, IP portfolio support…	**Foundation for Research and Technology – Hellas (FORTH) / PRAXI Network** (Greece)

Note: a) System Readiness Level (SRL). More information: Sauser, B., Verma, D., Ramirez-Marquez, J. and Gove, R., (2006) "From TRL to SRL: The concept of systems readiness levels". In *Conference on Systems Engineering Research*, Los Angeles, CA (pp. 1-10).

See Appendix 5 for detailed information on selected DIHs and their innovation functions.

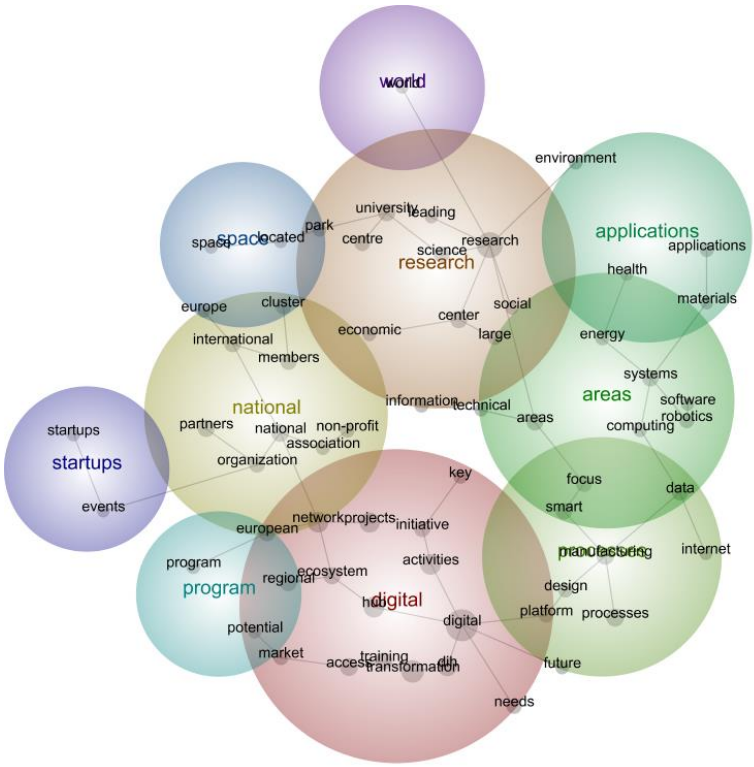
3.2 DIGITAL INNOVATION HUBS: MAPPING THE FIELD

The database, hosted by the European Commission, hosts qualitative, self-reported, information about each DIH. Normally, DIHs have reported information about their vision, mission, objectives and more specific information about the activities performed. These data are highly unstructured and often inconsistent. To mention a few examples, the length of the information provided oscillates between just one statement and others that are more than a thousand words. Furthermore, in some cases, the information was repeated multiple times and in different languages, or presented with typos, spelling mistakes or unclear translations. While a manual effort to clean the dataset has been performed, and given the size of this section of the database (583 respondents), it is possible that some noise in the data is still present. Nevertheless, such self-reported data are particularly interesting, as they offer an empirical perception of the DIHs about their own strategic priorities. Studying the "discourse" produced by DIHs themselves is a very important step in identifying the boundaries of the field under investigation.

A specific approach built on machine learning has been employed to analyse such data.

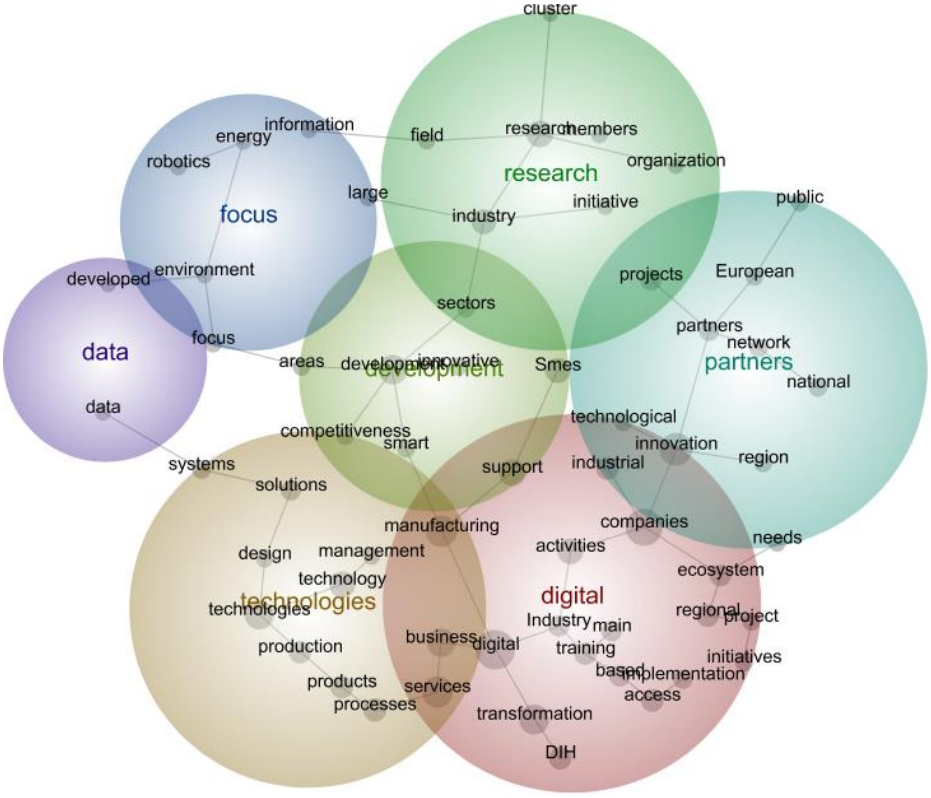
Figure 3 visually presents the outcome of such an analysis, which includes both a conceptual and relational text analysis. The figure shows, indeed, the most common concepts, and clusters them in thematic "bubbles"; furthermore, their connection and proximity are also visualised. The prominence of different themes is heat-mapped. The theme that is identified as "digital" is the most recurring one and is, indeed, characterising the activity of DIHs. Such a concept is discussed in relation to different activities (initiatives, projects, access), and, within the context of a digital transformation, it is creating new needs. Research is the second theme that is emerging, as DIHs aim to become the leading centre of excellence and are often associated with universities or other science parks. The theme 'national' seems to discuss the different partners and levels of intervention. In this cluster, indeed, words such as "national", "international", "Europe", "cluster" all appear, together with words such as "non-profit", "partners", "members" and "organisations". The right side of the figure, which includes three themes in different shades of green, seems to capture the application of DIH, by describing the phases of the innovation process and its components (e.g. "processes", "manufacturing", "design") as well as potential industries of relevance ("materials", "health", "robotics", "computing", "smart [cities]", "energy"). It is interesting to observe that a specific theme is identified comprising start-ups and events. These themes are explored with more focused statistics, or through narrower case studies in the following sections.

FIGURE 3 CONCEPT MAP – DIHS DESCRIPTION



The description provided by the DIHs was also used to identify those ones declaring to be contributing to the manufacturing sector. When limiting the analysis to only those DIHs using the word “manufactur*” within the text of their description, 187 organisations remain, generating the conceptual map presented in Figure *4*.

FIGURE 4 CONCEPT MAP – DIHS DESCRIPTION INCLUDING THE WORD MANUFACTUR*



The map reveals a higher relative importance, witnessed by the colour of the relevant bubble, of words such as “production”, “processes”, “design” or “technology”. An analysis of the word most commonly related with “manufacturing” in the map above would reveal “design”, “system”, “implementation” and “smart” as the most prominent words. At the same time, concepts identifying specific industries in the previous map no longer appear (e.g. “health”, “robotics”).

3.3 AREAS OF APPLICATION AND SERVICES

Areas of application of DIHs are analysed by looking at two main factors: the focus on specific industries and the intervention at different technology readiness levels (TRLs). Figure 5 summarises the focus of DIHs with respect to different industrial sectors. The figure highlights how DIHs are finding applications in many industries. Such industries differ in terms of their technological complexity, the nature of the organisations involved and the focus on products or services. The most recurring industries include, indeed, the manufacturing of advanced equipment, services of public utility, such as education and health, and the areas that are more traditionally associated with lower technological intensity, such as agriculture, hunting and forestry. Such heterogeneity in industry, where DIHs find their application, will also result in the need for DIHs to engage with a wide range of stakeholders, as the different industries involve, to a different extent, large and multinational companies, SMEs, research organisations and public institutions. Amongst the industries that are cited the least by the respondents, it is possible to identify mining and quarrying, fishing and the manufacture of coke, refined petroleum products and nuclear fuel. The percentage of DIHs identifying these industries, however, is at least 10%.

Figure 6 provides an initial visualisation and clustering of the different DIHs based on their industry focus. DIHs are presented as small ellipses and the intensity of their colouring identifies how many industries they serve. Immediately it is possible to see the different models that are emerging. While some (white) DIHs focus on a single industry and are, therefore, more specialist, others seem to be more open and are placed in the middle of the network. The choices of different DIHs also seem to lead to some industry clustering; for example, on the right side of the graph, it is possible to see services (Health and Social Work, Education, Hospitality, Financial Intermediation), on the left side there are manufacturing industries, while on the top of the graph there are industries associated with natural resources (Mining and Fishing).

FIGURE 5 INDUSTRIES SERVED BY DIHS (% CALCULATED ON 557 RESPONDENTS)

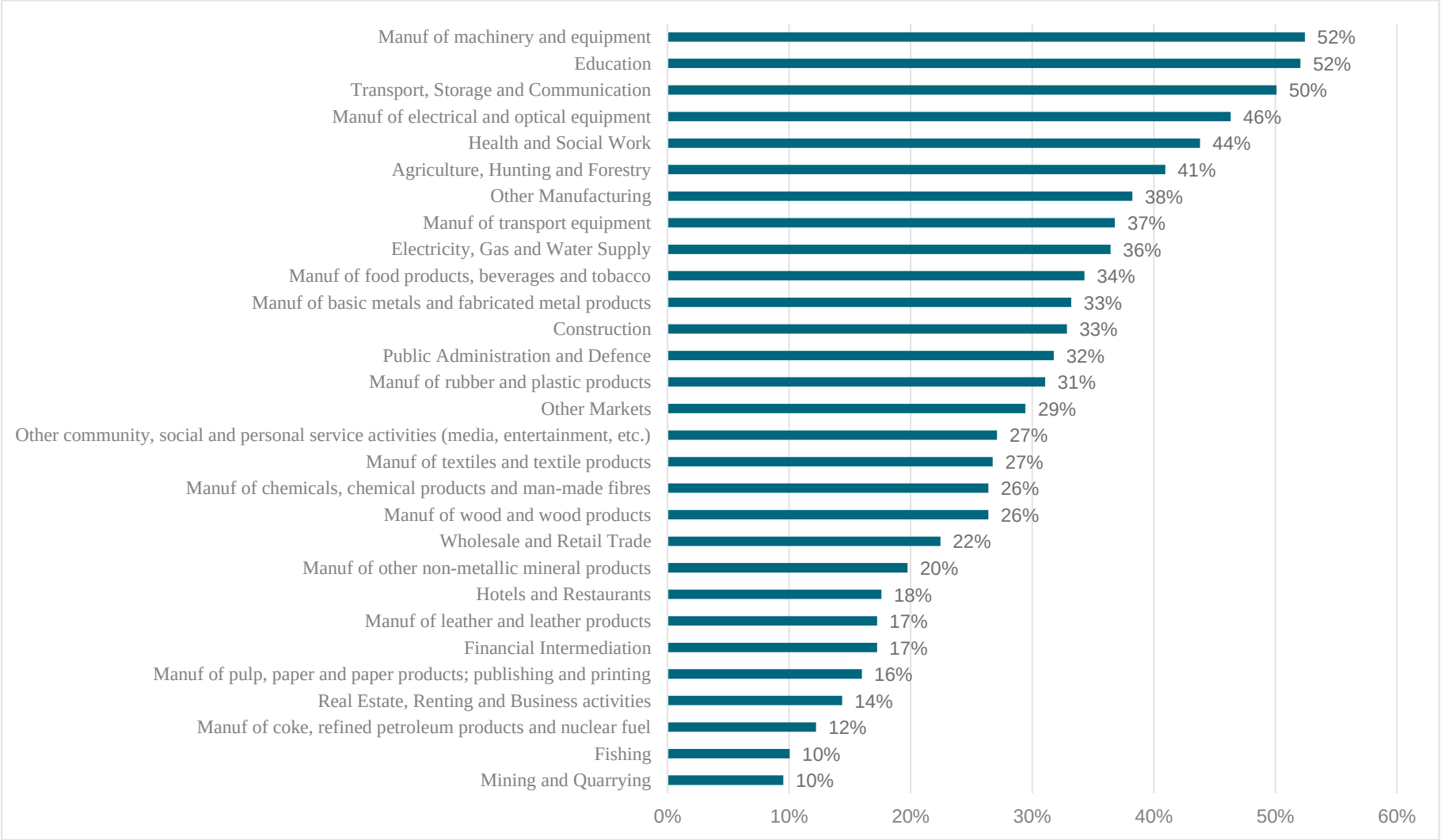
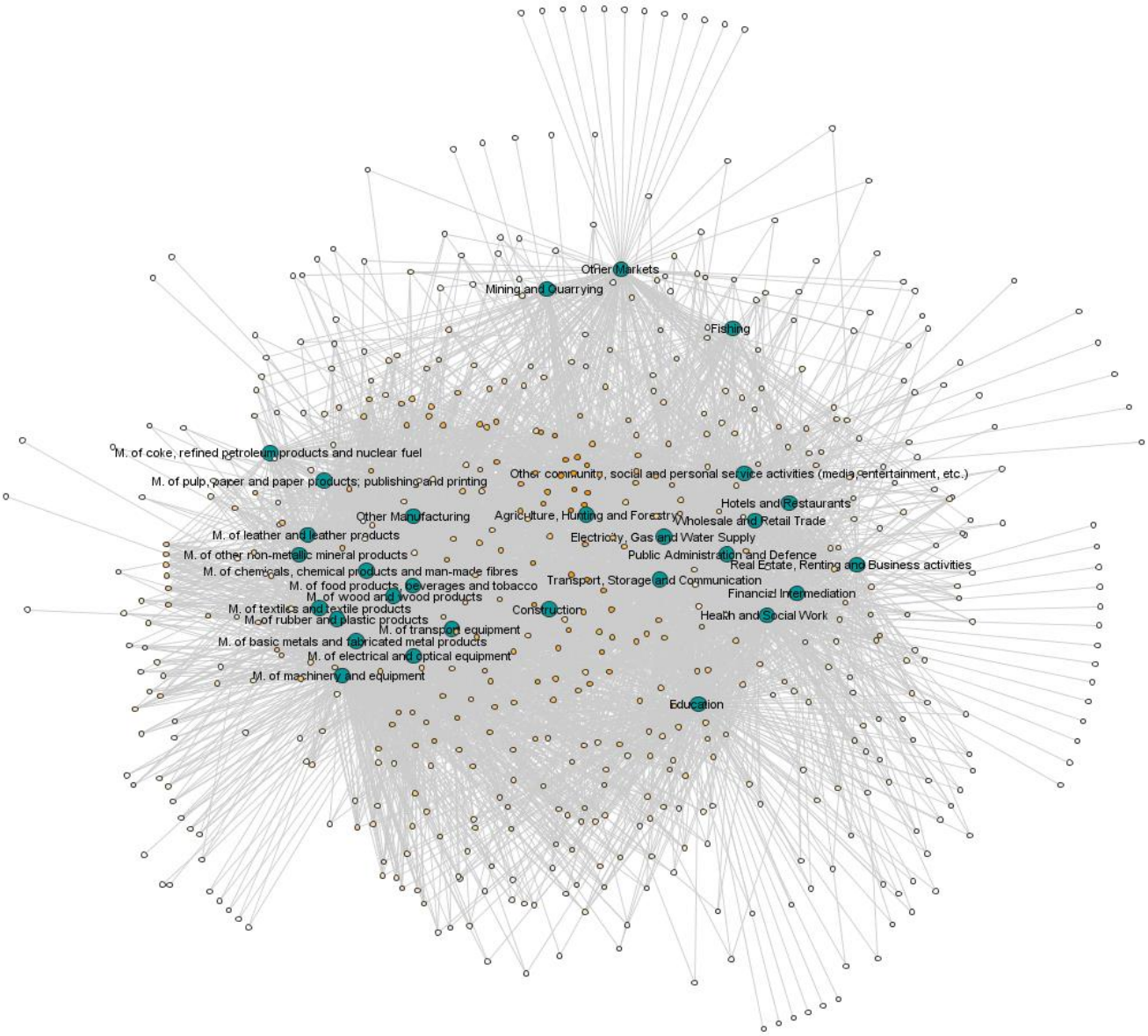
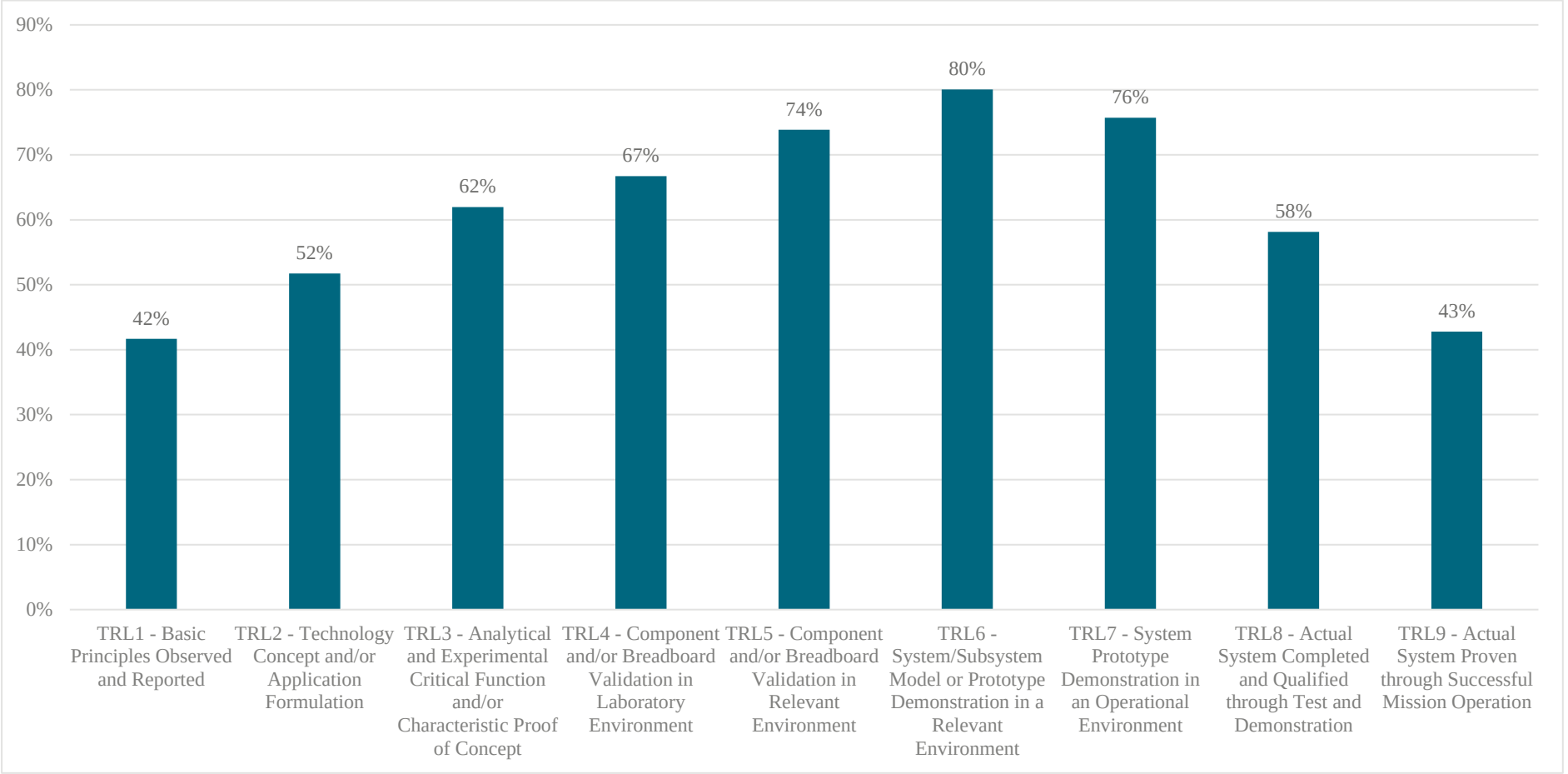


FIGURE 6 VISUALISATION OF DIHS AND THEIR INDUSTRY FOCUS



It is particularly insightful to observe the shape of the graph, presented in Figure 7, which describes the application of the DIH methodology to different levels of technological readiness. While DIHs declare to be focusing on all the different phases of the innovation journey, the inverted U-shape pattern suggests that their main potential lies in the intermediate steps of technological development. The lowest percentages are recorded for TRL1 (Basic Principles Observed and Reported) and TRL9 (Actual System Proven through Successful Mission Operation). As consistent with their nature, most of the DIHs focus on the validation and demonstration of a technological component or system in different environments. The graph suggests that DIHs cover a specific space in the innovation process, facilitating the middle steps of the promotion of an innovation and complementing the activities of those organisations that are more involved with basic research (e.g. universities) or commercialisation (e.g. market research agencies). In terms of the amount of TRLs covered by the different DIHs, the vast majority of DIHs employ an open strategy. Less than 20% associate themselves with 1-3 TRLs, while almost half of them (47%) cover between 5 and 7 levels.

FIGURE 7 DIHS' FOCUS: TRL (% CALCULATED ON 547 RESPONDENTS)



Note: One DIH can focus on more than one TRL level (and tend to do so)

FIGURE 8 THE MAPPING OF DIHS APPLICATIONS BY INDUSTRY AND LEVEL OF TECHNOLOGY READINESS

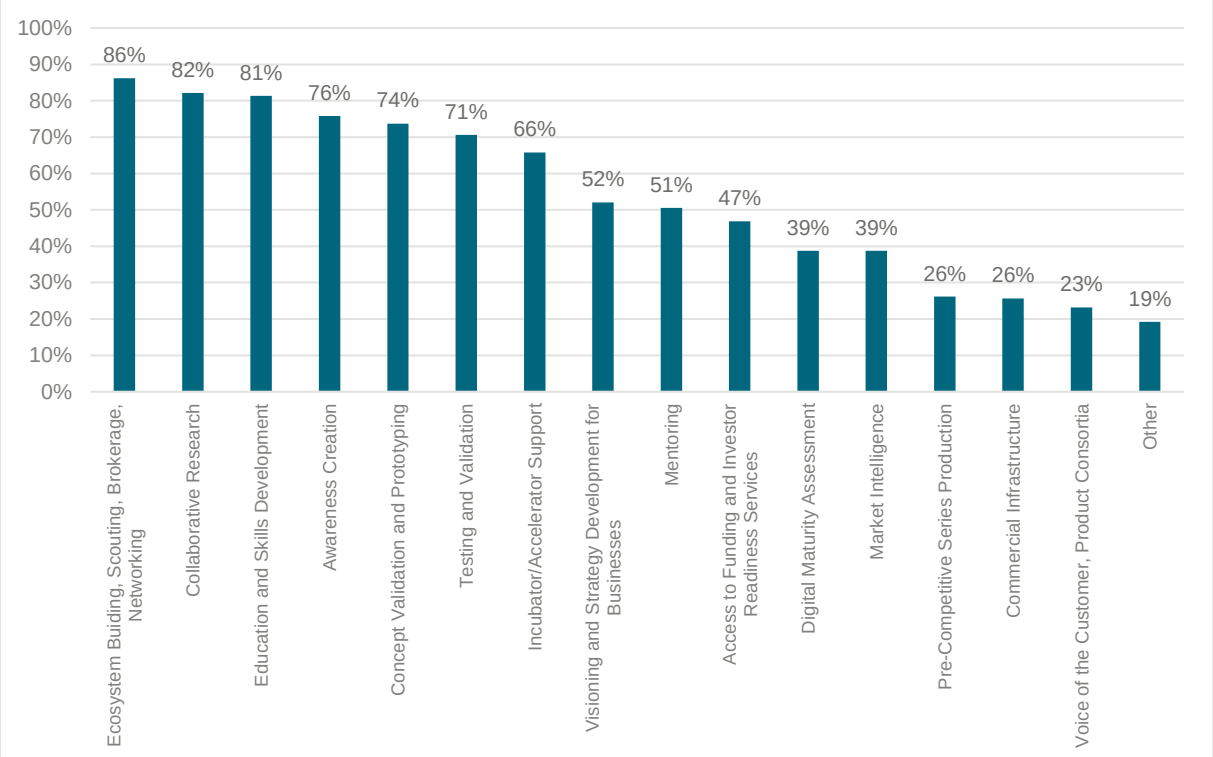
	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9
Agriculture, Hunting and Forestry	47%	59%	67%	69%	76%	82%	80%	63%	49%
Fishing	36%	49%	59%	67%	72%	83%	76%	61%	45%
Mining and Quarrying	36%	42%	56%	68%	76%	85%	80%	65%	50%
Electricity, Gas and Water Supply	36%	46%	56%	70%	76%	84%	77%	63%	47%
Construction	36%	46%	59%	69%	76%	84%	77%	61%	46%
Wholesale and Retail Trade	36%	43%	53%	66%	74%	81%	78%	64%	48%
Hotels and Restaurants	38%	40%	48%	62%	71%	82%	77%	68%	55%
Transport, Storage and Communication	39%	46%	54%	68%	74%	82%	77%	64%	49%
Financial Intermediation	39%	43%	53%	64%	73%	84%	78%	65%	52%
Real Estate, Renting and Business activities	47%	46%	51%	63%	72%	82%	76%	65%	56%
Public Administration and Defence	39%	45%	47%	63%	67%	80%	78%	63%	51%
Education	42%	50%	54%	66%	75%	82%	76%	64%	50%
Health and Social Work	40%	46%	52%	61%	71%	81%	76%	63%	54%
Other community, social and personal service	36%	46%	54%	68%	77%	83%	79%	67%	55%
Man. of food products, beverages and tobacco	37%	46%	54%	69%	76%	83%	79%	64%	50%
Man. of textiles and textile product	52%	60%	62%	60%	67%	72%	68%	58%	47%
Man. of leather and leather products	41%	54%	68%	75%	80%	84%	79%	60%	47%
Man. of wood and wood products	53%	61%	69%	71%	75%	81%	76%	57%	44%
Man. of pulp, paper and paper products	53%	60%	68%	74%	80%	84%	79%	63%	51%
Man. of coke, refined petroleum products	60%	60%	65%	65%	75%	76%	73%	66%	59%
Man.of chemicals, chemical products and fibres	58%	63%	65%	61%	70%	76%	73%	61%	53%
Man. of rubber and plastic products	47%	57%	66%	70%	74%	81%	74%	58%	44%
Man. of other non-metallic mineral products	53%	54%	60%	64%	76%	79%	74%	61%	48%
Man. of basic metals and fabricated products	49%	53%	57%	64%	72%	76%	72%	64%	60%
Man. of machinery and equipment	43%	49%	57%	73%	76%	85%	80%	64%	54%
Man. of electrical and optical equipment	49%	55%	67%	70%	77%	82%	77%	57%	44%
Man. of transport equipment	53%	55%	68%	77%	77%	81%	75%	57%	49%
Other Manufacturing	50%	59%	71%	75%	80%	86%	82%	66%	50%
Other Markets	42%	51%	64%	75%	80%	85%	78%	57%	41%

It is also possible to integrate these two perspectives in order to map the applications of DIHs across different industries and along different levels of technology readiness. Figure 8 summarises these results, showing in percentage how many DIHs with a specific industrial focus engage with different TRLs. Colour coding is used to identify the intensity of such an involvement. Overall, the figure follows the pattern identified in the previous graph, with a strong prevalence of DIHs applications for TRL5-7. There are, however, industries that have an earlier involvement with DIHs, such as textile and the manufacturing of wood, and others with a more even profile, like the manufacturing of coke and petroleum products. It is also interesting, even if it is probably not surprising, to observe the lower presence of DIHs in relation to TRL1 in several industries, including many services.

For completeness, it has to be acknowledged that while percentages are calculated on the total number of DIHs that are reported to be involved with a specific industry, not all of the DIHs have reported their engagement at different TRLs. The percentage reported in the figure might, therefore, underestimate the phenomena studied.

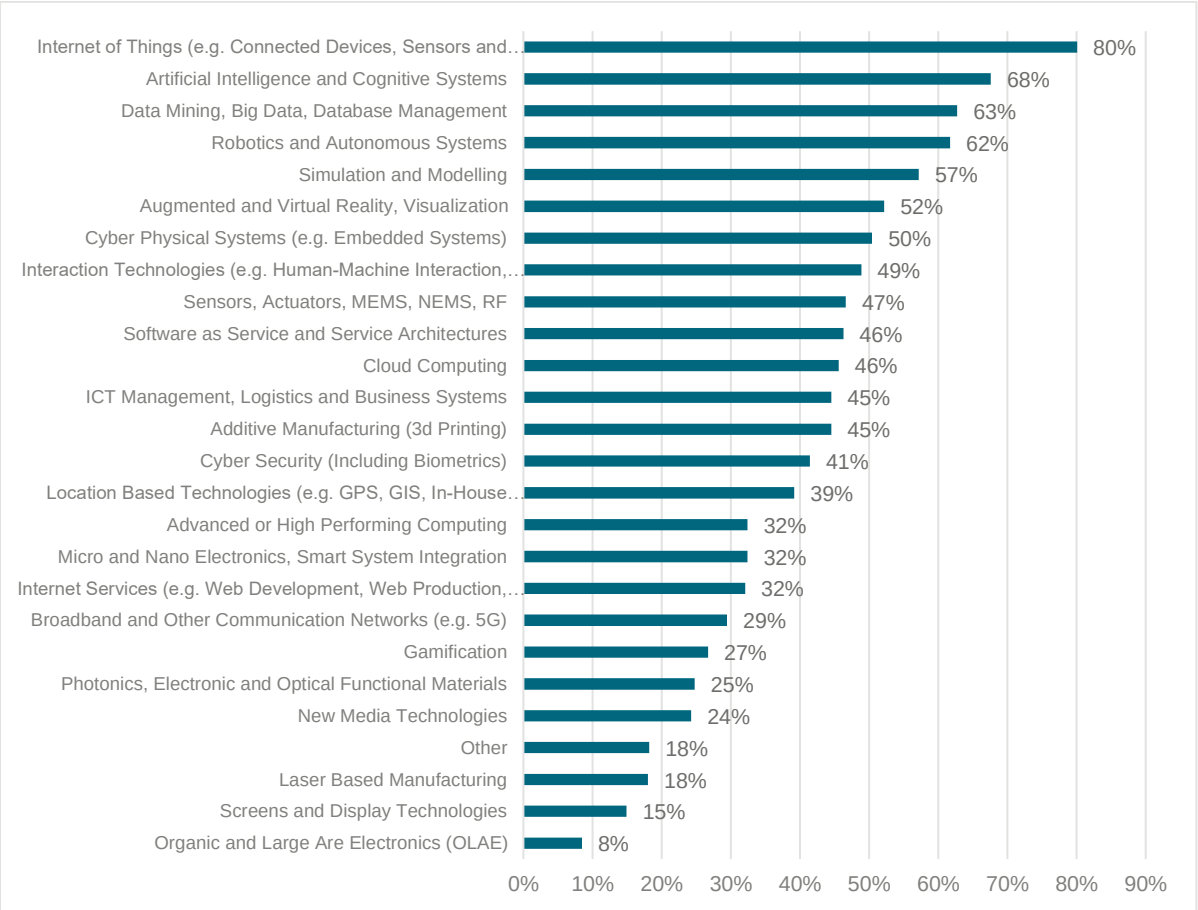
The nature of the services provided is also consistent with the discussion developed so far (Figure 9). The support given to the phases at the end of the innovation process and those that are closer to commercialisation are indeed the least common (e.g. commercial infrastructure, voice of the customer, market intelligence); instead, at the opposite extreme of the ranking, many DIHs declare that they offer education and skill development and a wide range of activities associated with networking (ecosystem building, collaborative research, incubation) and testing. Again the data suggests the important role of DIHs in connecting the different actors that are involved along the different phases of the innovation process, and that they have a specific role in it, which does not overlap with one of the other players for basic research or commercialisation.

FIGURE 9 THE SERVICES OFFERED BY THE DIHS (% CALCULATED ON 578 RESPONDENTS)



These services are provided by the DIHs thanks to the availability of a wide set of technological competences, as summarised in Figure 10. It is, of course, not surprising that an extensive coverage can be observed of the most recent technological developments in many fields; however, it is particularly meaningful to detect the importance of competences associated with "systems", or with interdisciplinary and cross-sectoral applications (e.g. big data, modelling). Again, the data confirms the interest and capacity of DIHs to work across and integrate with traditional industries. Competencies are traditionally more rooted in specific industries, and, indeed, appear as less prominent in the figure.

FIGURE 10 THE TECHNOLOGICAL COMPETENCES OF DIHS (% CALCULATED ON 578 RESPONDENTS)



In order to understand the combination of technological competences and services that DIHs offer, a clustering analysis[17] is carried out. The analysis is divided into two parts: a part dedicated to clustering "*Competences*", and another dedicated to clustering "*Services*". The clustering method that is applied in both cases is identical. We have used the *matrix dissimilarity* routine in Stata for detecting similarity patterns amongst the group of "*Competences*" and the group of "*Services*", using the Jaccard coefficient for binary data (since research hubs have indicated the presence/absence of a specific competence of

[17] First, when the DIHs (i.e. the observations of our dataset) did not provide information about their sets of "*Competences*" and "*Services*" (i.e. the variables of our dataset) we have replaced this missing data with zero. Second, we have dropped the category "Other" for both "*Competences*" and "*Services*". Third, since we are interested in determining patterns of similarities in the offer/presence of competences and services, we have transposed our dataset and exchanged observations with variables, to simplify the computational process by considering "*Competences*" and "*Services*" as observations.

service, without providing any additional information about it). The main idea behind this approach is the following: if we concentrate on "*Services*", then two "*Services*" can be considered to be similar if they are offered by the same group of research hubs. On the other hand, two "*Services*" are dissimilar if one is offered by a specific group of hubs, and the other is offered by a completely different group of hubs. Once we have estimated the dissimilarity scores for each pair of "*Competences*" and "*Services*", we run a *cluster analysis* imposing four clusters as a threshold and by using the average linkage method, i.e., the distance between clusters is related to the average distance between objects within each cluster.

Table 5 illustrates the results obtained for *Competences*. Based on the analysis of 658 DIHs[18], 25 technical competences were grouped in four clusters. Each cluster highlights the competences that DIHs tend to possess in combination with other competences. The number of technical competences per cluster range between three (cluster 4) and ten (cluster 1). Cluster 1 seems to group together competences that are associated with microelectronics/optoelectronics with a telecoms/ICT hardware focus, often related to sensors and infrastructure for industrial digitalisation. Cluster 2 can be read as a tracking/tracing/analysis cluster with a mix of location/security/logistics services and related infrastructures. While this is a possible interpretation, the creation of a separate cluster might artificially isolate security-related competences, which could, in principle, cut across most clusters. Cluster 3 seems to be a cyber-physical systems cluster, grouping together the competences that are linking real worlds and cyber worlds. Cluster 4 could represent a data analytics cluster, especially if IoT competences are used to gather big data (rather than building that kind of ICT infrastructure which is the focus of Cluster 1).

Similarly to the clustering of technical competences, also the DIHs' *Services* were analysed in relation to their common co-occurrence (see Table 6). Each cluster includes between one (cluster 2) and six services (cluster 1). The underlying commonality within each cluster seems to be the innovation development stage and associated business needs. The first cluster is largely concerned with services related to idea generation, testing and the provision of a supportive environment. The second cluster includes incubator and accelerator support which helps nurture start-ups at the beginning phases of their project and provides a tailored mentorship that supports the growth of these ventures. The third cluster includes services related to strategy development and funding. Finally, the fourth cluster is concerned with commercial aspects and marketing of the innovation. To conclude, the analysis highlights that DIHs tend to provide a number of services that focus on a particular innovation development stage and associated business needs.

[18] When the DIH did not indicate the presence (or absence) of a specific competence/service offered (i.e. missing data), we treat this competence/service as absent, in order to consider the entire population of DIHs in the analysis.

TABLE 5 TECHNICAL COMPETENCES CLUSTERS

	Competence 1	Competence 2	Competence 3	Competence 4	Competence 5	Competence 6	Competence 7	Competence 8	Competence 9	Competence 10
Cluster1	Organic and Large Area Electronics (OLAE)	Micro and Nano Electronics, Smart System Integration	Photonics, Electronic and Optical Functional Materials	Screens and Display Technologies	Broadband and Other Communication Networks (e.g. 5G)	Advanced or High Performing Computing	Gamification	Laser Based Manu-facturing	Internet Services (e.g. Web Dev., Web Prod., Design, Networking, & E-Commerce)	New Media Technologies
Cluster2	Location Based Technologies (e.g. GPS, GIS, In-House Localisation)	Cyber Security (Including Biometrics)	Software as Service and Service Architectures	Cloud Computing	ICT Management, Logistics and Business Systems					
Cluster3	Sensors, Actuators, MEMS, NEMS, RF	Cyber Physical Systems (e.g. Embedded Systems)	Robotics and Autonomous Systems	Interaction Technologies (e.g. Human-Machine Interaction, Motion Recognition and Language Tech-nologies)	Augmented and Virtual Reality, Visualisation	Simulation and Modelling	Additive Manu-facturing (3d Printing)			
Cluster4	Internet of Things (e.g. Connected Devices, Sensors and Actuators Networks)	Artificial Intelligence and Cognitive Systems	Data Mining, Big Data, Database Management							

TABLE 6 SERVICES CLUSTER

	Service 1	Service 2	Service 3	Service 4	Service 5	Service 6
Cluster 1	Awareness Creation	Ecosystem Building, Scouting, Brokerage, Networking	Collaborative Research	Concept Validation and Prototyping	Testing and Validation	Education and Skills Development
Cluster 2	Incubator/ Accelerator Support					
Cluster 3	Visioning and Strategy Development for Businesses	Digital Maturity Assessment	Access to Funding and Investor Readiness Services	Mentoring		
Cluster 4	Pre-Competitive Series Production	Commercial Infrastructure	Voice of the Customer, Product Consortia	Market Intelligence		

3.4 ORGANISATIONAL ASPECTS CHARACTERISING DIHS

In this section DIHs are analysed while considering a number of features that are characterising their organisation. Such information is useful to identify the principles behind their design and that are influencing their business model.

A first aspect to consider is the organisational form of DIHs (

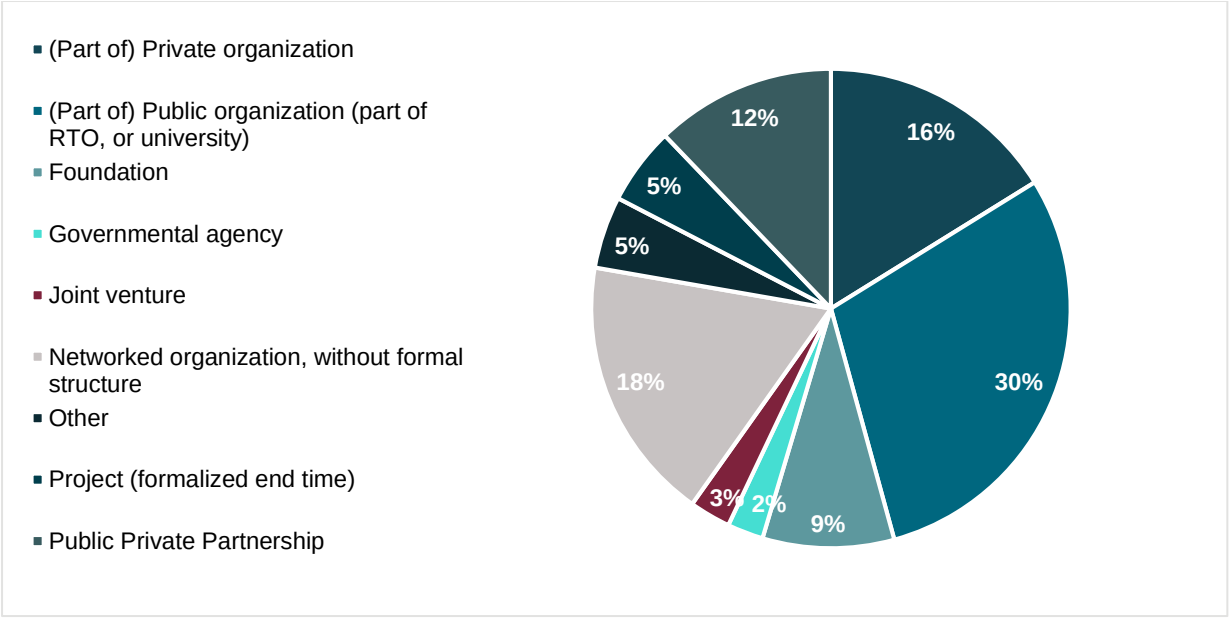
Figure 11). Consistently with the discussion developed so far, the prevailing organisational forms are network-based, with more than 60% of the DIHs being an informal network, a partnership or part of other existing organisations. More formal arrangements, such as a governmental agency or joint ventures, are much less common. It is also interesting to remark as temporary the organisational structures (projects) that are not commonly chosen, suggesting, potentially, a medium-term strategic horizon for the DIHs.

The size of the DIHs can be observed by considering their number of employees and their turnover (Table 7). While the distribution of turnover suggests the existence of either large or relatively small DIHs, with only 10% of the DIHs in the bracket of 500,000 to 1,000,000 Euros, the size of these organisations in terms of employees is relatively small, with almost 65% of them having less than 25 employees.

TABLE 7 NUMBER OF EMPLOYEES AND TURNOVER OF DIHS

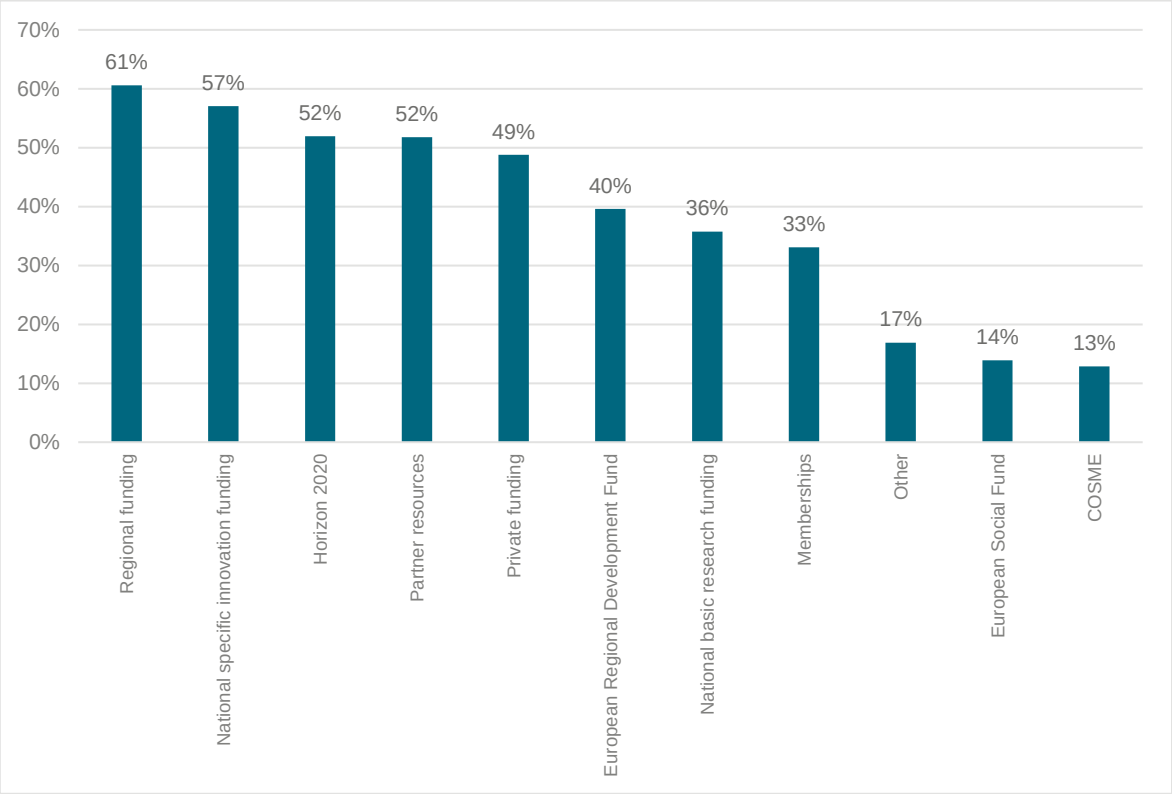
Turnover	N.	%	Employees	N.	%
0-250.000	174	34.1%	1-9	244	43.8%
250.000-500.000	58	11.4%	10-25	121	21.7%
500.000-1.000.000	52	10.2%	25-50	56	10.1%
1.000.000-5.000.000	112	22.0%	50-100	36	6.5%
>5.000.000	114	22.4%	>100	100	18.0%

FIGURE 11 THE ORGANISATIONAL FORM OF DIHS (% CALCULATED ON 575 RESPONDENTS)



To support their activities, DIHs leverage a wide range of funding opportunities, including external funding at the European, regional and national level, as well as a private and members' contribution. More targeted funding, such as the European Social Fund or the one associated with the Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME) scheme are less relevant than others (*Figure* **12**).

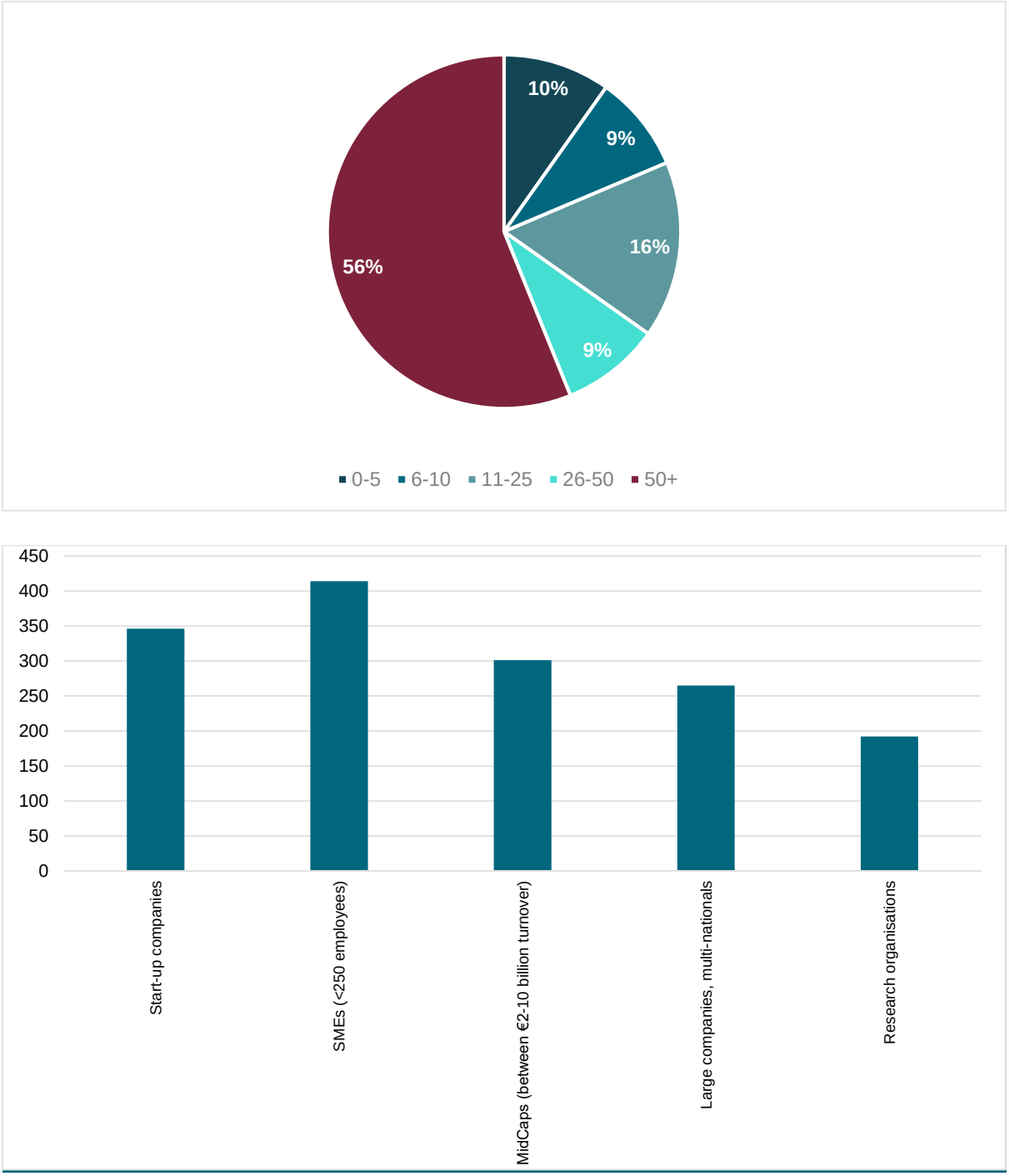
FIGURE 12 FUNDING SOURCES OF DIHS (% CALCULATED ON 568 RESPONDENTS)



When moving the analysis to the relationship of DIHs with the external environment, it is possible to consider the profile of their customers.

FIGURE 13 shows how the vast majority of DIHs have a large portfolio of customers, with only 10% (40) having less than 5 clients. The focus on the innovation of DIHs is clear when looking at the nature of their customers, with the prevailing category being SMEs and start-ups. Larger organisation are less frequently reported as being customers of DIHs, but still more than other research organisations – confirming the more applied nature of DIHs' activities. Other data available in the database, covering the geographical scope of the 582 DIHs included in the dataset, identifies their focus as being mainly regional (36%) or national (22%), with only 8% of DIHs describing their scope as "global".

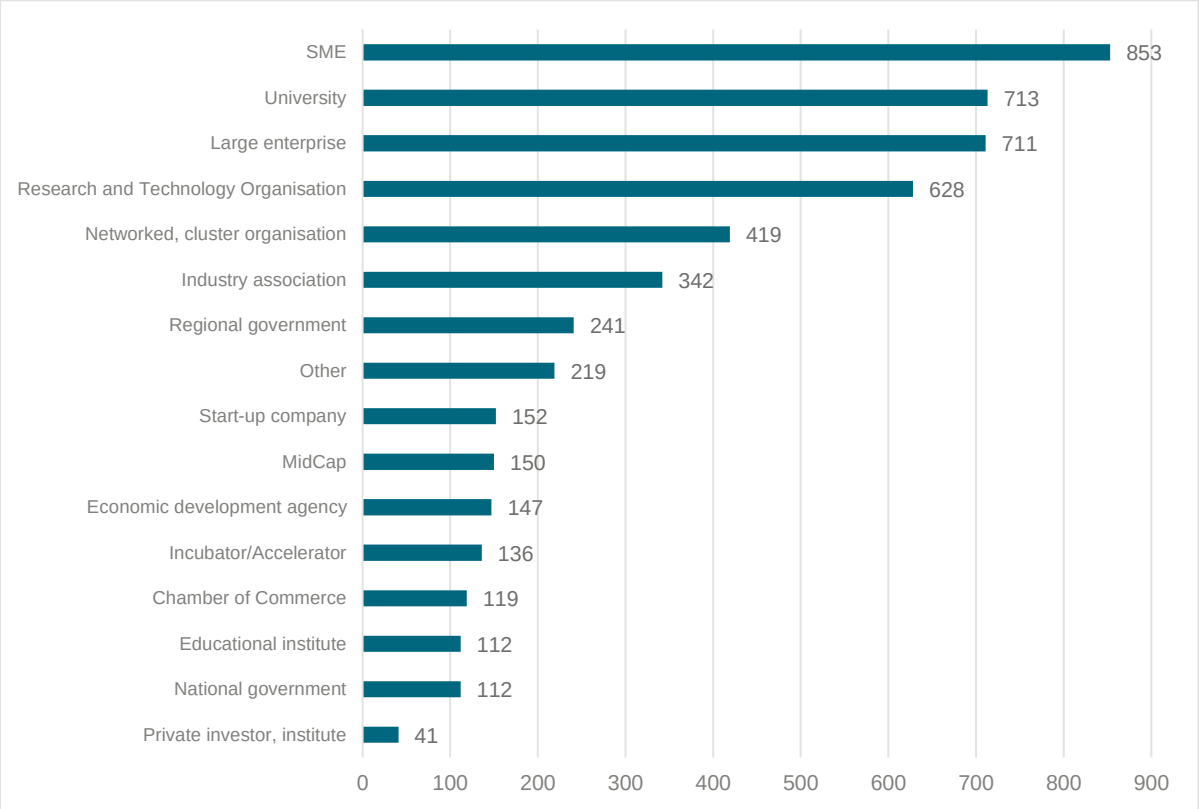
FIGURE 13 THE CUSTOMERS OF DIHS: NUMBER (408 RESPONDENTS) AND PROFILE (432 RESPONDENTS)



A final aspect when investigating the relationship between DIHs and their external environment is the reported partnerships. The notion of partnership is often subjective and somehow this is visible in the information provided in the dataset, characterised by a huge variation in terms of the number of partners identified by the DIHs. While such information is, therefore, less consistent than others, it is, nevertheless, interesting to observe the distribution of different types of partner organisations (Figure 14). It is particularly insightful to observe how SMEs, the prevailing type of customers, are also identified as the most common type of partners, somehow confirming the extremely open and collaborative

approach of DIHs. While large enterprises appeared less frequently as customers of DIHs when compared to start-ups, the opposite is true in the case of partnership; therefore, identifying an interesting dynamic that is associated with the interaction of DIHs with firms of different sizes. Similarly, while research organisations were identified as less important customers than other organisation types, RTOs and Universities are important partners of DIHs.

FIGURE 14 THE NATURE OF PARTNER ORGANISATIONS OF DIHS



The analysis highlights that DIHs support the digitisation agenda of many countries and they specifically help in developing the regional innovation ecosystem. It is clear that DIHs employ different business models and rely on a targeted funding mix plus a matrix of different funding instruments for the digital transformation of mainly SMEs. The collaborative nature of DIHs is evident through the number and types of partners they engage with.

IV. Capabilities and Resources in the UK

Overview of this section

In this section, Digital Innovation Hubs (DIH) in the UK were analysed using qualitative and quantitative methods. Here are our key findings.

Overview

- According to the European Commission Database, 24 DIHs are present in the UK, with a high geographical concentration in London and the South East area.

Competences

- In terms of competences, the UK landscape follows the same pattern emerging at the European level with a strong relevance of IoT and AI, but also with some variations, such as the higher relevance of gamification (47% vs. 27%) and screen and display technologies (41% vs. 15%) or the lower incidence of augmented and virtual reality and visualisation (41% vs. 52%).

Services

- Regarding services, the pattern is once again similar to the European one, but with UK DIHs being more involved with all the different services – that is, they are less focused on the middle ones. Peculiarities include a higher prevalence of collaborative research (94% vs. 82%) and visioning and strategy development for businesses (80% vs. 52%).

London Ecosystem Network

- Some specialisation in terms of an industry focus seems to occur in the London DIHs ecosystem with only two industries (Health and Social Work and Other Community Social and Personal Services Activities) being supported by two DIHs. This may lead to an overreliance of these industries on these hubs.
- Intersections exist between the London DIHs both in terms of services and competences, highlighting potential synergies and collaboration opportunities.

Qualitative analysis of selected UK DIHs

- The four cases analysed are similar in their organisational structure, as they are all not-for-profit organisations and, with the exception of TWI, they were all established with support of the UK government.
- They also converge in the range of services provided, with all of them carrying out collaborative research with public and private actors, consultancy of various types, and workforce training.
- Digital Catapult and HVM Catapult stand-out from the others as they provide demonstration and test facilities, whereas TWI is distinct in its focus on welding, joining, and other metal technologies and services. HSSMI's particularity, in turn, is its focus on supporting the implementation of circular economy concepts and other sustainable manufacturing technologies.

Following the presentation of the international landscape of DIHs, this section focuses on the UK. The data collected from the European Commission database will provide the context and be enriched by the qualitative data with respect to the four specific cases of interest.

4.1 DIHs IN THE UK

According to the European Commission database, at the moment of data collection, 24 DIHs are present in the UK (Table 8). This report acknowledges that the analysed organisations perform innovation hub functions, while not only being innovation hubs. For simplicity, this report refers to these organisations as innovation hubs. The table immediately makes visible the high geographical concentration of the DIHs, with a third of them being based in London and an additional four in the South East.

TABLE 8 DIHS PRESENT IN THE UK

Name	Region
Bristol Robotics Laboratory's RIF	South West
Compound Semiconductor Applications Catapult	Wales
CP Lab Newcastle	North East
CPI	North East
Cranfield University Digital Innovation Hub	East of England
Digital Catapult	London
Digital Health & Care Institute	Scotland
Digital Manufacturing Innovation Hub Wales (DMIW)	Wales
EPCC	Scotland
Future Cities Catapult	London
IDEAL (Innovation and Digital Enterprise Alliance London)	London
Imperial College of Science, Technology and Medicine	London
Manufacturing Technology Centre	West Midlands
NESTA	London
OptimiseHub - South Coast Digital Innovation Hub	South East
Satellite Applications Catapult	South East
SCALE-UP INSTITUTE	London
SMART TRANSPORTATION ALLIANCE	London
Sunderland Software City	North East
The AMRC's Factory 2050	Yorkshire and The Humber
The High Value Manufacturing Catapult	West Midlands
Transport Systems Catapult	South East
UK Digital Health Hub	London
Web Science Institute	South East

Figure 15 presents the technological competences possessed by the UK DIHs. While only being collected from a small number of respondents (17), the data seems to confirm the patterns emerging at the global level, with a strong relevance of IoT and AI, for example, but also some variations (e.g. the higher relevance of gamification and screen and display technologies or the lower incidence of augmented and virtual reality and visualisation).

FIGURE 15 TECHNOLOGICAL COMPETENCES POSSESSED BY DIHS (17 RESPONDENTS)

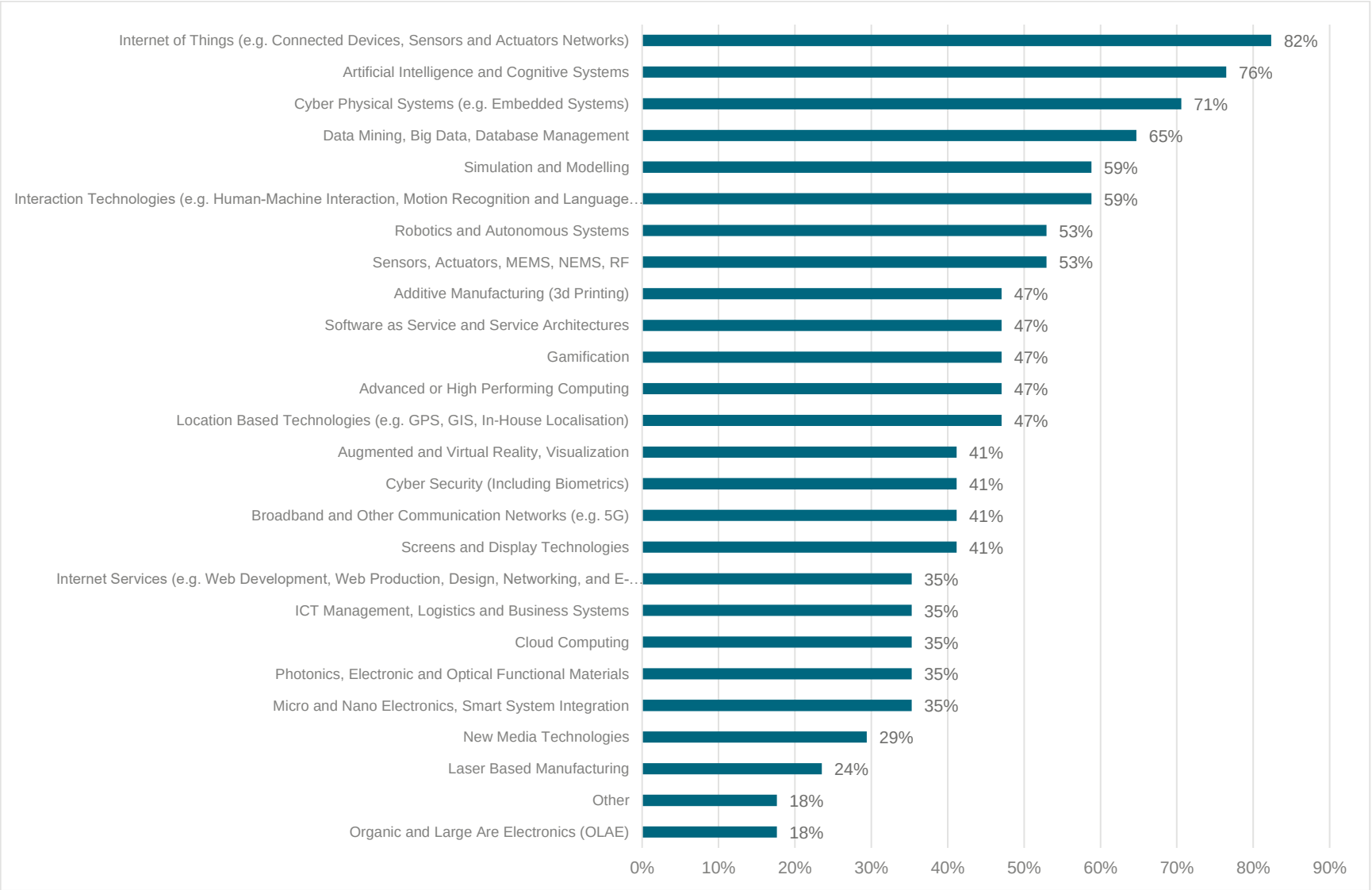


Figure 16 presents instead the activities offered by UK DIHs. Such activities follow a pattern comparable to the one observed at the global level. UK DIHs in proportion seem, however, to be more involved with all the different activities, showing on average higher percentages than the whole population. The most evident result is the extreme open approach of UK DIHs with almost all of them reporting that they engage with collaborative research. Another interesting result is the much higher relevance of "Visioning and strategy development for business", identified by more than 80% of the respondents against the 52% reported by all DIHs in the dataset.

FIGURE 16 THE SERVICES PERFORMED BY THE UK DIHS (BASED ON 18 RESPONDENTS)

4.2 LONDON'S DIHs ECOSYSTEM NETWORK

DIHs are a vital part of the vibrant ecosystems that are interacting with different stakeholders, performing a multitude of roles across many industries and at several phases of the innovation journey. Furthermore, it is also clear that the geographical dimension plays an important role in shaping the strategy and the business model of different DIHs. A conceptual framework, particularly suitable to unpack such a complex set of dynamics, can be developed from the Dynamic Network Analysis (DNA)[19]. This approach is particularly useful to analyse complex systems composed of entities of a different nature and their relationships. DNA describes systems as networks of different types of entities and explores relationships between entities of the same type and across groups. An example with three entities is provided in Figure 17.

[19] For an introduction to DNA see, for example, Carley, K.M. *Dynamic network analysis*.

FIGURE 17 AN EXAMPLE OF A META-NETWORK

	People	Knowledge	Task
People	Social network *Who knows who*	Knowledge network *Who knows what*	Assignment network *Who does what*
Knowledge		Information network *What informs what*	Need network *What knowledge is needed to*
Task			Precedence network *Which task must be done*

Source: Center for Computational Analysis of Social and Organizational Systems (CASOS) *ORA-LITE

The same logic can be fruitfully applied to the context of DIHs and by considering the information available (Figure 18). Of course, not all the potential combinations are necessarily at the same level of theoretical and empirical interest. Furthermore, the data available does not allow an answer to be provided to all of the listed questions. For example, it would be of great importance to map the existing collaborative efforts between different DIHs, but such information would require a dedicated primary data collection exercise. Linking different networks also allows an exploration of more complex issues. For example, examining an organisation-to-organisation network together with an organisation-to-competence network can identify how some competences are available in an ecosystem and which channels need to be activated to access them, thus expanding upon a traditional analysis that is often focusing on single organisations.

FIGURE 18 DIHS' META-NETWORKS AND THE POTENTIAL RESEARCH QUESTIONS

	Organisation (O)	Competences (C)	Service (S)	Industry (I)	Location (L)
Organisation (O)	Who collaborates with whom	Who controls which competences	Who provides which service	Who serves which industries	Who is active in which region
Competences (C)		Which competences are combined with which competences	Which competences are associated with the delivery of which services	Which competences are available to which industries	Which competences are available in which regions
Service (S)			Which services must be offered with others	Which services are offered to which industries	Which services are offered in which regions
Industry (I)				Which industries are interrelated	Which regions offer support to which industries
Location (L)					Which regions are connected with which regions

FIGURE 19 DYNAMIC NETWORK VISUALISATION OF THE LONDON DIHS ECOSYSTEM NETWORK

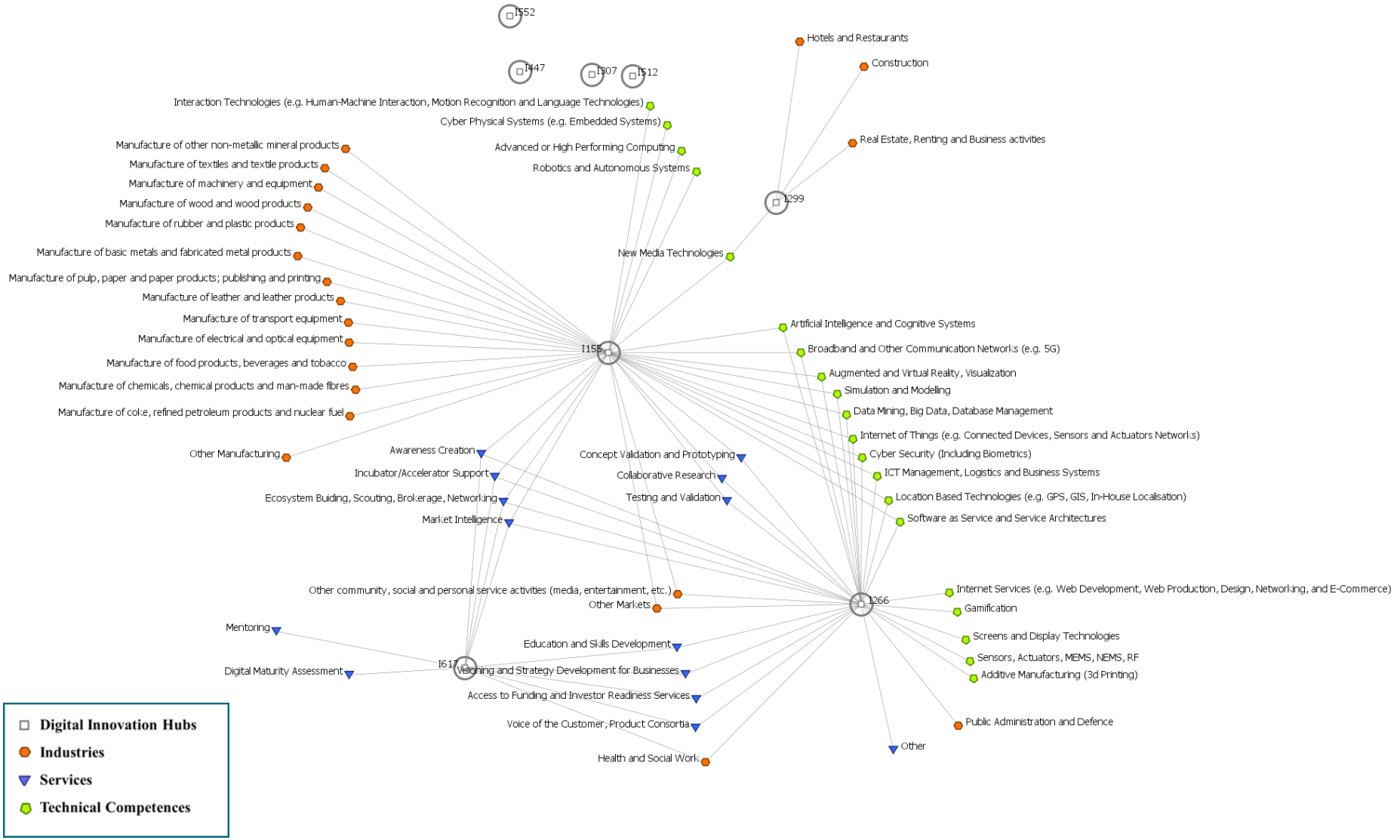


Figure 19 presents the visualisation of the London DIHs. Unfortunately data is available only for 4 DIHs, as the others did not provide any of the data required for this visualisation; one DIH, furthermore, did not indicate any activity performed. The visualisation links the DIHs (white circles) to the activities they perform (blue dots), the industries they serve (red dots) and their technological competences (green dots). While only partial, the representation offers already many interesting insights. Specialisation seems to emerge in terms of the industry focus, with only two industries (Health and Social Work and Other Community Social and Personal Services Activities) being supported by two DIHs. While such a specialisation is a positive factor, by ensuring broad industry coverage in the London area, it might also lead to an excess of demand for some DIHs or the risk of some industry needs not being addressed due to the reliance on a single hub. To mitigate such a risk, it is important to create a network of DIHs supporting the same industries, even across regions, to facilitate the sharing of knowledge and to ensure that any unexpected increase in demand of support can be met.

It is also interesting to observe that some activities are performed by all of the three DIHs that are reporting this information: Awareness Creation, Market Intelligence, Incubator/Accelerator Support and Ecosystem Building, Scouting, Brokerage and Networking. While, of course, the declination of some of these activities can be industry specific, there are obvious potential synergies and best practices which can be shared across the DIHs that are performing similar activities; for example, in terms of how to promote interorganisational networking or carry out a market analysis.

The figure also shows the competences controlled by different DIHs. In addition to providing a record of the competences available in the area, the visualisation identifies opportunities for DIHs to establish collaboration, by either building on each other's expertise in a similar domain to promote further advancement in their own specialisation, or to seek complementarities and partners with other hubs controlling a different set of competences and knowledge.

4.3 COMPETENCES, RESOURCES, FACILITIES, AND GOVERNANCE STRUCTURE OF FOUR UK INNOVATION HUBS

This section provides further insights about the competences, resources, facilities, and governance structure of four particular UK Innovation Hubs (Table 9). As highlighted in previous sections, this report acknowledges that the analysed organisations perform innovation hub functions, while not only being innovation hubs. For simplicity, this report refers to these organisations as innovation hubs.

TABLE 9 UK DIGITAL MANUFACTURING INNOVATION HUBS

Innovation Hubs	Mission	Focus Areas	Governance	Funding	Institutional Structure and Context	Functions and Services
TWI – The Welding Institute (Cambridge)	To help industry solve problems through expert advice and by assisting with the application of available technology, and develop the next generation of experts to address future industry challenges	Metal additive manufacturing, coatings and surface engineering, inspection and testing technologies, materials evaluation and corrosion management, welding, joining and cutting	Chief executive, executive team and council; industrial and professional memberships, 769 employees (2018)	Turnover: £72 million (2018)	TWI is a not-for-profit, limited company. It follows the UK Corporate Governance Code. The TWI Group contains 6 companies. It also has several international branches for international training certification and consultancy provision.	TWI carries out self-funded, publicly funded, and joint research projects. It has several engineering support services (technical, product/process development, technology acquisition, production support, asset management, failure analysis and repair) and training courses (welding, inspection, and non-destructive testing)
HSSMI (London)	To help manufacturing industry create an impact by providing industrial solutions in areas of upscaling,	Scale-up of products and processes, productivity enhancing opportunities, supporting the transition to a circular economy	Executive director, 51 employees	$2.71 million (Annual revenue 2019)	Not-for-profit organisation limited by guarantee. HSSMI started as a joint initiative between industry and academia supported	Strategic manufacturing consultancy projects, bespoke engineering services, participating or leading collaborative R&D projects, upscaling and automation strategy,

Innovation Hubs	Mission	Focus Areas	Governance	Funding	Institutional Structure and Context	Functions and Services
	circular economy and productivity	Hydrogen propulsion, advanced manufacturing simulation, circular economy, digital manufacturing tools, lean manufacturing and automation, E-drives, battery technology, manufacturing strategy, project management			by the Department for Communities and Local Government (DCLG).	manufacturing capability, value for money studies, investment studies, location strategy. It also has some specific services and courses, such as an electric vehicle powertrain school, and a circular economy maturity assessment
Digital Catapult (London)	To accelerate UK advanced digital technology innovation and adoption to drive growth in high impact sectors of the UK economy	Artificial Intelligence (AI ethics, predictive modelling, reinforcement learning, machine vision, edge computing, generative adversarial networks). Future networks (5G and IoT). Immersive (mixed, augmented and virtual reality and haptics). Distributed systems (distributed ledger technology, smart contracts, and decentralised marketplace).	8-member leadership team headed by CEO, 9-non-executive directors (Juergen Maier as chair), 23 technology and industry experts	£20 million	Not-for-profit organisation, part of the wider Catapult Network, supported by Innovate UK. Engages globally in other projects.	Services for start-ups (accelerators, augmentor, studios and immersive labs for demonstration, cybersecurity). Services for large businesses (connecting with start-ups, commercial solutions, collaborative R&D). Services for academia (knowledge exchange partnerships, joint projects, workshops, internships). Services for investors (connecting with early stage businesses, insight reports)
HVM Catapult Centres	To help companies design, develop and deliver their innovation by providing access to world-class facilities and skills to scale-up and prove-out high value manufacturing technologies	Advanced assembly, automation, biologics, biotechnology, casting, composites, design, digital manufacturing, electronics, flexible manufacturing, formulation, high temperature processing, joining, machining, manufacturing with polymers, materials characterisation, metal forming and forging, metrology, modelling and simulation, netshape and additive	The CEO is supported by an executive team (of 6), a management board (of 10) and a supervisory board (of 10)	£518 million (total R&D linked to activities in 2019/20)	Not-for-profit organisation, part of the wider Catapult Network, established by Innovate UK. Its Supervisory Board and a Management Board are composed of members from government, academia, and industry. It has seven	Technology development (access to world-class facilities and skills to scale-up and prove-out technologies), workforce development (apprenticeships, training courses, and student placements), problem solving (access to specialist knowledge, expertise and equipment), manufacturing expertise, policy insights and intelligence (national or local), research and testing, help in

Innovation Hubs	Mission	Focus Areas	Governance	Funding	Institutional Structure and Context	Functions and Services
		manufacturing, powder technology, power and energy storage, printable electronics, resource efficient and sustainable manufacturing, surface engineering, tooling and fixtures, visualisation and virtual reality			centres across the UK	finding finance (developing funding proposals, and at times making introductions to investors)

The four UK Innovation Hubs analysed are similar in their organisational structure, as they are all not-for-profit organisations, and, with the exception of TWI, they were all established with the support of the UK government. They also converge in the range of services they provide, with all of them carrying out collaborative research with public and private actors, consultancy of various types, and workforce training.

Digital Catapult and HVM Catapult stand out from the others as they provide demonstration and test facilities, whereas TWI is distinct in its focus on welding, joining, and other metal technologies and services. HSSMI's particularity, in turn, is its focus on supporting the implementation of circular economy concepts and other sustainable manufacturing technologies. HVM Catapult is considerably larger than the others with £518 million in funding for its 2019-2020 activities, and is also large in international standards, whereas HSSMI is the smallest of them with £2.71 million annual revenue. HVM Catapult seems to be the only one with a governing board with members from government, academia, and industry, signalling a high level of connection between actors from these different areas.

Overall, the UK Innovation Hubs studied here seem well structured, formalised, and are commanding significant resources. However, we can see a clear difference between the HVM Catapult and the other three, in terms of competences, resources, facilities, and governance structure.

APPENDIX 1:
International Innovation Hubs and their Governance

Table A1. List of International Innovation Hubs

International Innovation Hub	Country
Manufacturing x Digital	United States
Fraunhofer Gesellschaft	Germany
Digital Capability Center (DCC) Aachen	Germany
RISE	Sweden
A* STAR's Model Factory @SIMTech: Singapore Institute of Manufacturing Technology	Singapore
CONFIRM Smart Manufacturing	Ireland
Smart Manufacturing Innovation Centre	Japan
Smart Manufacturing Innovation Centre	Denmark
RICAIP: Research and Innovation Centre on Advanced Industrial Production	Czech Republic
IMCRC: Innovative Manufacturing Cooperative Research Centre	Australia
SmartFactoryOWL	Germany
Advanced Manufacturing Digital Innovation Hub	Lithuania
Swiss Smart Factory	Switzerland

MxD: Manufacturing X Digital

USA

Website	Location
https://www.mxdusa.org/	Chicago, USA

Description

MxD or Manufacturing x Digital (previously known as DMDII – Digital Manufacturing and Design Innovation Institute) is a member-driven non-profit organisation looking to accelerate and complement digital manufacturing capabilities to increase manufacturing competitiveness in the United States, and is funded by the U.S. Department of Defense. While DMDII was launched in 2014, MxD was launched in 2017.

Mission

MxD aims to equip U.S. factories with the digital tools and the expertise that they need to begin making every part better than the last. As a result, they are helping nearly 300 partners in increasing their productivity and winning more business. The 22,000-square-foot research factory is used to test and demonstrate new technology; train the workforce on these new systems and tools; and demonstrate the need for cybersecurity in manufacturing.

Focus areas

- These are future factory; cybersecurity; supply chain; digital engineering; workforce development; defence collaborations.
- Sectors: Defence, and others.
- 2020 Strategic investment plan.

Governance

- Top national manufacturing industry leaders sit on the board of directors.
- Board of Directors (11) include the following: Billy Bardin, Global Operations Director, Dow; Chandra Brown, CEO, MxD; Caralynn Nowinski Collens, co-founder of UI LABS; Tony Hemmelgarn, President and CEO, Siemens PLM Software; Jay Walsh, Vice President of Research at Northwestern University; Mark Wilson, Chief Operating Officer of Rolls-Royce North American Technologies; Katy George, Senior Partner, McKinsey & Company; Mary Isbister, President, GenMet Corporation; Shirish Pareek, MD, AMG Partners; and Marsha Serlin, Founder and CEO, United Scrap Metal.
- Management: Type of expertise of the staff running the test bed/ living lab (industry / academic experience):
    - The management team (61 roles) is categorised into senior leadership (5), projects & engineering (13), strategy & engagement (10), finance & business (12), board members (11), and executive council (10).
    - The senior leadership has a mix of backgrounds in industry, academia and government. A similar mix can also be seen at other management levels.
- The U.S. Department of Defense is MxD's founding partner. Together, the two advance the digital manufacturing technology and co-invest in a large research and development portfolio, which is now totalling more than $90 million across more than 60 projects.

Funding

- The U.S. Department of Defense awarded the organisation with $80 million in seed funding in 2014, following a national competition. The City of Chicago marshalled support for the bid, and,

along with the State of Illinois, provided much of the funding for the build out of nearly 100,000 square feet of space for the MxD's offices, events and factory floor.

- In its first five years, MxD has invested more than $90 million of public and private funds in 63 research and development projects across 35 states with targeted outcomes between Technology Readiness Levels (TRLs) four through seven.
- MxD's projects bridge the gap in the innovation "valley of death", so named because of the high number of innovative concepts and ideas that fail when they are crossing from public sector research to private sector commercialisation. Successfully bridging this valley will accelerate the adoption of innovative technologies in manufacturing, providing competitive advantages to the early adopters.
- Most MxD projects require a 1:1 cost share match.
- Some projects are worth around $1 million, e.g. "*Digitally enabling the supply chain: integrating existing tools and capabilities to guide application*".

INSTITUTIONAL STRUCTURE AND CONTEXT

- National strategic initiative supported by the U.S. Department of Defense.
- The U.S. Department of Defense awarded the organisation with $80 million in seed funding in 2014, following a national competition. In its first five years, MxD has invested more than $90 million of its public and private funds in 63 research and development projects across 35 states.
- MxD, previously called DMDII (Digital Manufacturing and Design Innovation Institute), is the second of the 14 institutes, known collectively as Manufacturing USA. MxD has also partnered with McKinsey & Company to setup the Digital Capability Centre (DCC) in Chicago as part of their global network of DCCs.
- MxD has relationships to other organisations which include the following:
- Founding partner: U.S. Department of Defense.
    - Tier 1 (6): Dow, Lockhead Martin, McKinsey & Company, Microsoft, Rolls-Royce, Siemens
    - Tier 2 (7): AT&T Business, Autodesk, Boeing, Fast Radius, John Deere, Johnson & Johnson, Software
    - Tier 3: Non-Profit (28), Small and Mid-sized Manufacturers (SMMs) (40), Solution Providers (151)
    - Academic (39 American universities)
    - Government: Quad Cities Chamber of Commerce, Consolidated Nuclear Security

FUNCTIONS AND SERVICES

- MxD develops project ideas from many sources, including its members, and from DoD stakeholders, public workshops, public requests for information (RFIs), and more. MxD's members help guide the prioritisation and development of projects through participation in the Technical Advisory Committee (TAC) and Executive Council (EC).
- R&D projects. So far, MxD has invested approximately $100 million in more than 60 applied R&D projects. Also, in 2018, the DoD helped establish the National Center for Cybersecurity in Manufacturing (NCCM) at MxD to better protect the manufacturing sectors against cybersecurity threats.
- Workforce development has focused on cybersecurity and digital engineering skill development.
- About 12,000 guests visit MxD each year for tours and meetings.

Source: MxD (2020a)

SOURCES

MxD (2020a) *Overview.* MxD website: www.mxdusa.org

MxD (2020b) *Strategic Investment Plan 2020.* MxD website: www.mxdusa.org

MxD (2020c) *Board of Directors.* MxD website: www.mxdusa.org

MxD (2020d) *Our Team.* MxD website: www.mxdusa.org

MxD (2018) *MxD Final Report Project 17-01-01 - Digitally enabling the supply chain: Integrating existing tools and capabilities to guide application*

Fraunhofer Institute for Manufacturing and Automation (IPA)

GERMANY

Website	Location
https://www.ipa.fraunhofer.de/en.html	Stuttgart, Germany

Description

The Fraunhofer IPA is an institute of the Fraunhofer-Gesellschaft, which is a recognised non-profit applied research organisation focusing on key technologies for the future and their commercial exploitation of business and industry. Based in Germany, the Fraunhofer-Gesellschaft currently operates in 74 institutes and research institutions throughout Germany.

Fraunhofer IPA – one of the Fraunhofer-Gesellschaft's largest institutes – was founded in 1959 and employs almost 1,000 workers at multiple sites (593 at IPA, Stuttgart). The focus of research and development work at Fraunhofer IPA is on organisational and technological issues related to the manufacturing industry. They develop, test and implement methods, components and devices right up to complete machines and production lines. Fraunhofer IPA's 15 specialist departments cover the entire field of manufacturing engineering. They are coordinated by six business units and work on an interdisciplinary basis with industrial enterprises.

Mission

Fraunhofer IPA: To conduct applied research for the economic production of sustainable and personalised products.

Fraunhofer Gesellschaft:*"Applied research is the foundation of our organisation. We partner with companies to transform original ideas into innovations that benefit society and strengthen both the German and the European economy. Our employees shape the future – in ambitious positions at Fraunhofer or in other areas of science and business. Fraunhofer therefore places great importance on their professional and personal development."*

Focus Areas

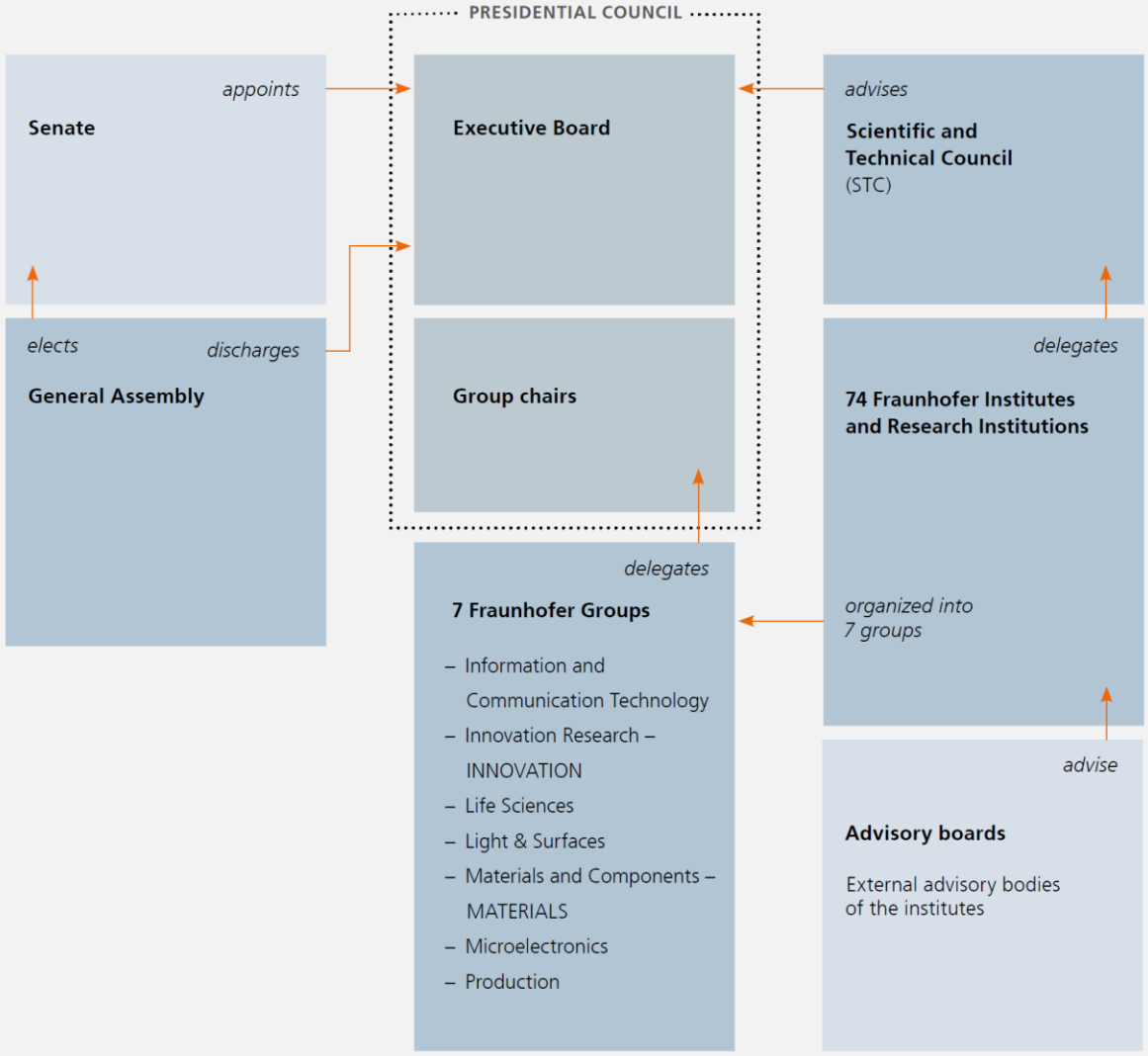
- These are battery production, bio intelligence, digital transformation, frugal manufacturing systems, AI for production, resilient value creation, and supply chain.
- Sectors: Automotive, machinery & equipment, electronics & microsystems, energy, medical engineering & biotechnology and the process industry.

Governance

- Fraunhofer IPA: Two Institute Directors with dual professorial appointments at University of Stuttgart, and a strong presence on industrial boards.
- Fraunhofer Gesellschaft: The Executive Board consists of the president and several other full-time members. Its duties include managing the Fraunhofer-Gesellschaft and representing its interests both inside and outside the organisation. It formulates the basic principles of the Fraunhofer-Gesellschaft's science and research policy, plans its growth and its finances, ensures its base funding, organises the distribution of funds among the individual institutes and appoints the institute directors.
- Each of the 74 Fraunhofer institutes cultivates its own market presence and manages its own budget. The chairs of the Fraunhofer Groups, together with the members of the Executive Board, make up the Presidential Council of the Fraunhofer-Gesellschaft. The Presidential Council participates in the Executive Board decision-making processes, and, as such, is entitled to make proposals and recommendations and has the right to be heard.
- The Senate has around 30 members from the worlds of science, business and public life, representatives of the federal and state governments, and members of the Scientific and Technical Council (STC). The Senate's duties include appointing members of the Executive Board, defining the outlines of Fraunhofer's science and research policy, and formulating

decisions concerning the establishment, devolution, merger or dissolution of research entities belonging to the Fraunhofer-Gesellschaft.

- The General Assembly is made up of the members of the Fraunhofer-Gesellschaft. Official membership is open to members of the Senate and the Executive Board, institute directors and senior management, and members of the advisory boards. Ordinary membership is open to individuals and legal entities who wish to support the work of the Fraunhofer-Gesellschaft. Honorary members may be elected from among the research staff and patrons of the Fraunhofer-Gesellschaft in recognition of outstanding services to the organisation. The General Assembly elects the members of the Senate, discharges the Executive Board of its functions, and formulates decisions concerning amendments to the Statute.
- The Scientific and Technical Council (STC) is the organisation's internal advisory body. It consists of the directors and senior management of the institutes and an elected representative of the scientific and technical staff of each institute. The STC provides advice to the Executive Board and other constituent bodies in matters of fundamental importance. It makes recommendations concerning research and HR policy, expresses its opinions regarding the creation of new institutes or the closure of existing institutes, and participates in the appointment of new institute directors.
- The advisory boards are the external advisory bodies of the institutes. They consist of representatives of science, business and public life. For each institute, approximately twelve members are appointed to the advisory board by the Executive Board with the approval of the director(s) of the institute. The advisory boards act as advisors to the institute directors and the Executive Board on matters concerning the research orientation and any structural changes to the institute.
- Although the Fraunhofer Gesellschaft is basically a decentralised organisation, its structure also allows for a centrally agreed strategy and effective centralised management. Various constituent bodies and committees are responsible for coordination, consultation and leadership across the organisation as a whole (see Figure 21).



Source: Fraunhofer Gesellschaft (2020a)

FUNDING

- Fraunhofer IPA: €76 million (annual budget 2019).
- Fraunhofer Gesellschaft: Pure basic research, as practiced at universities, is funded to almost 100% by public grants. Industrial R&D, up to prototype level, is largely financed by private enterprise.
- The Fraunhofer-Gesellschaft receives funding both from the public sector (approximately 30%) and through contract research earnings (roughly 70%).
- Annual research budget: 2.8 billion euros.
- Operating expenses in 2019: Euro 2,278,647.9 (1000 Euro)
- Capital expenditure in 2019: Euro 481,064.9 (1000 Euro)
- Total base funding and revenue from own activities: 2,760,117,141.38 Euro
  - Revenue from base funding in 2019: 1,004,330,677.17 Euro
    - Federal government: 846,646,386.66 Euro
    - State governments: 157,684,290.51 Euro

- Revenue from own activities in 2019: 1,700,142,014.75 Euro
  - Revenue from R&D activities in 2019: 1,693,613,739.32 Euro
    - Federal government: Project funding 594,856,665.44 Euro, contracts 22,602,915.75 Euro
    - State governments: Project funding 183,247,347.23 Euro, contracts 1,874,319.10 Euro
    - Business, industry and trade associations: 724,416,768.22 Euro
    - Research funding organisations and other sources: 166,615,723.58 Euro
  - Other interest and similar income: 55,644,449.46 Euro
- Equity in 2019: 15,355,630.19 Euro
- Total assets in 2019: 3,708,385,981.56 Euro

INSTITUTIONAL STRUCTURE AND CONTEXT

- Fraunhofer IPA:
  - 593 staff; 15 specialist departments; six business units, hosted by University of Stuttgart; industrial & academic networks.
- Fraunhofer Groups:
  - Institutes working in related subject areas cooperate in Fraunhofer Groups and foster a joint presence on the R&D market. They help to define the Fraunhofer-Gesellschaft's business policy and act to implement the organisational and funding principles of the Fraunhofer model.
- Fraunhofer Alliances:
  - The Fraunhofer Alliances facilitate customer access to the services and research results of the Fraunhofer-Gesellschaft. Common points of contact for the groups of institutes, active in related fields, provide expert advice on complex issues and coordinate the development of appropriate solutions.

FUNCTIONS AND SERVICES

Fraunhofer IPA:

- Develop, test and implement methods, components and devices right up to complete machines and production lines, R&D, training, patents database, and licensing.
- Demonstration facilities for testing and feasibility studies.
- Development projects: innovation workshops, technology scouting and process study, feasibility studies, prototype development, development of specifications and definition of services, implementation support.
- Optimisation projects: potential analysis, quick check, exploring project, production planning and optimisation, digitalisation and Industrie 4.0 projects, roll-out of successful solutions
- Specific project formats: systems engineering projects, consortia and partnerships, Enterprise Lab.
- Joint research, venture partnerships, transfer workshops, training, patents database and licensing

Fraunhofer Gesellschaft:

- Research and Development:

- Development, implementation and optimisation of processes, products and equipment until they are ready for use and for the market. Fraunhofer works in all the application-relevant fields of expertise for contractual partners from industry and the public sector.

- Further Training/Fraunhofer Academy:
  - The Fraunhofer Academy offers specialists and managers' training and development based on the research activity of the Fraunhofer institutes in cooperation with selected partner universities.
- Fraunhofer Intellectual Property Transfer Database:
  - Fraunhofer currently holds more than 6,800 patent families and facilitates the technology transfer to the industry. A selection of patents and patent applications has been pre-validated for out-licensing.

SOURCES

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Fraunhofer Gesellschaft (2020b) Website. www.fraunhofer.de

Digital Capability Center (DCC) Aachen

GERMANY

Website

- https://www.mckinsey.com/business-functions/operations/how-we-help-clients/capability-center-network/overview
- https://dcc-aachen.de/en/

Location
Aachen, Germany

DESCRIPTION

The DCC Aachen is the first of its kind in the world and was launched in March 2017 as part of the global DCC network. It is a joint venture between the management consultancy, McKinsey & Company; the ITA Academy, GmbH; and leading technology companies including the software provider, PTC.

MISSION

- Explore – Try – Apply.
- Focus: Learn how to start, scale and sustain digital manufacturing transformation, and develop the required technical, management, and people skills.
- The centre offers a textile learning factory of the future. The centre has a production line for the manufacture of a smart, customised wristband.
- The factory has a central location and delivers capability building in a real-life demonstration and learning environment as well as being a test base for piloting and scaling-up new digital solutions. The centre offers management workshops for managers and technicians across all industries who are responsible for operations. The aim is to support companies during their digital transformation in order to increase productivity and efficiency.

- FOCUS AREAS: Digital manufacturing, digital supply-chain management and warehousing, digital procurement, smart product development, marketing and sales, strategy and corporate finance.
- Sectors: Textile, and others.

GOVERNANCE

- McKinsey & Company's employees provide leadership and expertise to the global network of DCCs on topics related to digital manufacturing, digital supply chain and the technology ecosystem. However, it's not clear how the steering boards and advisory groups work.
- McKinsey & Company's employees hold management positions in the global network of DCCs on topics related to digital manufacturing, digital supply chain and the technology ecosystem.
- McKinsey & Company's employees hold (thought) leadership and managerial positions in the global network of DCCs.

FUNDING

- NA

INSTITUTIONAL STRUCTURE AND CONTEXT

- DCC Network: The DCC Aachen is the first of its kind in the world and was launched in March 2017 – McKinsey launched other DCCs later in Singapore, Chicago, Beijing, Venice, Salvador, Atlanta, Karlsruhe and Gurugram.

Growing DCC Network

	Country	Key institutional partnerships	Full-fledged production lines
Digital Capability Center Aachen	Germany	ITA Academy	Smart, customized wristband
Digital Capability Center Chicago	USA	DMDII	Compressor
Digital Capability Center Beijing	China	Tsinghua University	Iced-tea Gearbox/valve
Digital Capability Center Singapore	Singapore	Advanced Remanufacturing and Technology Centre, EDB singapore	Gearbox
Digital Capability Center Venice	Italy	LEAN EXPERIENCE FACTORY	Compressor

Source: Digital Capability Centre, Aachen (2020b)

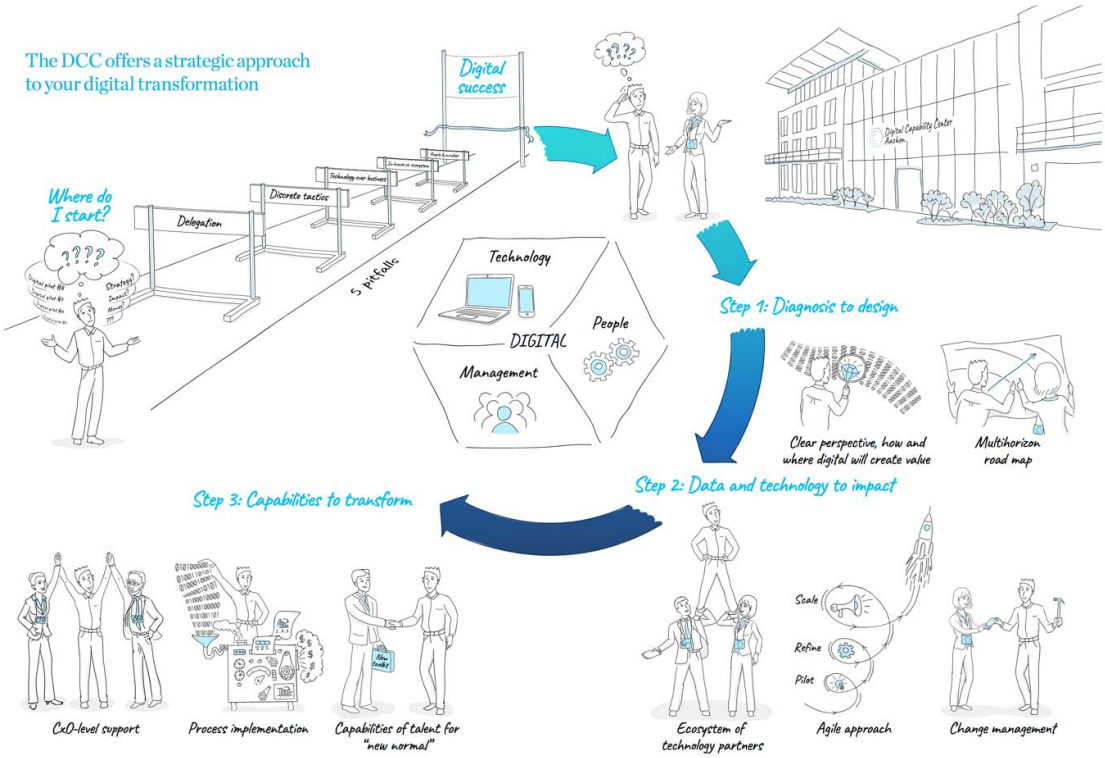
- Founding partner: McKinsey & Company, ITA Academy (Institut für Textiltechnik der RWTH Aachen University in Aachen, Germany)
- Global network supported by McKinsey & Company

FUNCTIONS AND SERVICES

- Workshops: Waste Walk – general understanding of Industry 4.0, Innovation Workshop, Digital Business Case, From Sensor to App, Industry 4.0 Analysis.
- Textile trainings: open (basic, innovation, customised) or for individual companies (basics of textile technology, home textiles, composites).
- McKinsey offers a choice of capability building programs at scale to support companies across all stages of their digital transformation journey.
- Typical stages of a digital journey include the following: (i) explore relevant Industry 4.0 solutions, (ii) experiment with targeted Industry 4.0 tools/levers, (iii) kick-start by piloting solutions, and (iv) scale up selected technologies. Typical engagement with the DCC Aachen is

through CxO workshops, deep dive experiential workshops, pilot preparation and assessment, and capability building at scale.

Strategic approach to digital transformation



Sources: McKinsey & Company (2020b)

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RISE – DigiCORE

SWEDEN

Website
https://www.testbedsweden.se/en/about
https://www.ri.se/en/test-demo/digicore

Location
Stockholm, Sweden

Description

RISE is an independent, state-owned research institute, which offers unique expertise and over 100 testbeds and demonstration environments for future-proof technologies, products and services.

DigiCORE is a lab and testbed at RISE in Västerås where organisations and research interact. It collaborates with RISE in Västerås, several research projects and the Automation Region. The lab contains hardware in the form of equipment from control rooms, large screens for visualisation, VR and AR glasses, powerful computers for deep learning, etc. In addition to the hardware, there is also software and licences for processing data, computation, prototyping and more.

Mission

DigiCORE:

- *"The lab is created to strengthen organizations in the digital transformation"*

RISE Group:

- Mission Statement: *"We bring scientific expertise to bear on ensuring sustainable growth, by building structures and processes for innovation that make our customers and partners competitive on the international stage. We act as a catalyst for innovation that, while it may occur without us, becomes more effective through our participation in the process."*
- Sustainability: The Board of RISE has identified and prioritised areas to influence the environment. Based on these areas, they have formulated goals that meet the UN's Sustainable Development Goals and that clarify RISE's contribution to sustainable development.

Focus Areas

- DigiCORE's focus areas: artificial intelligence, cyber security, data science, design, digitalisation, Internet of Things, climate neutral industry, mobility, service innovation
- DigiCORE's competences: analytics, big data, rffectiveness and efficiency, innovation management, interaction and user experience, machine learning and optimisation, product development, security trust, privacy and integrity, software and systems engineering
- The RISE group works on assignments from or in close collaboration with industry, academia and the public sector. A list of industries and areas that RISE engages in can be found on the RISE website (www.ri.se/en/our-offer)

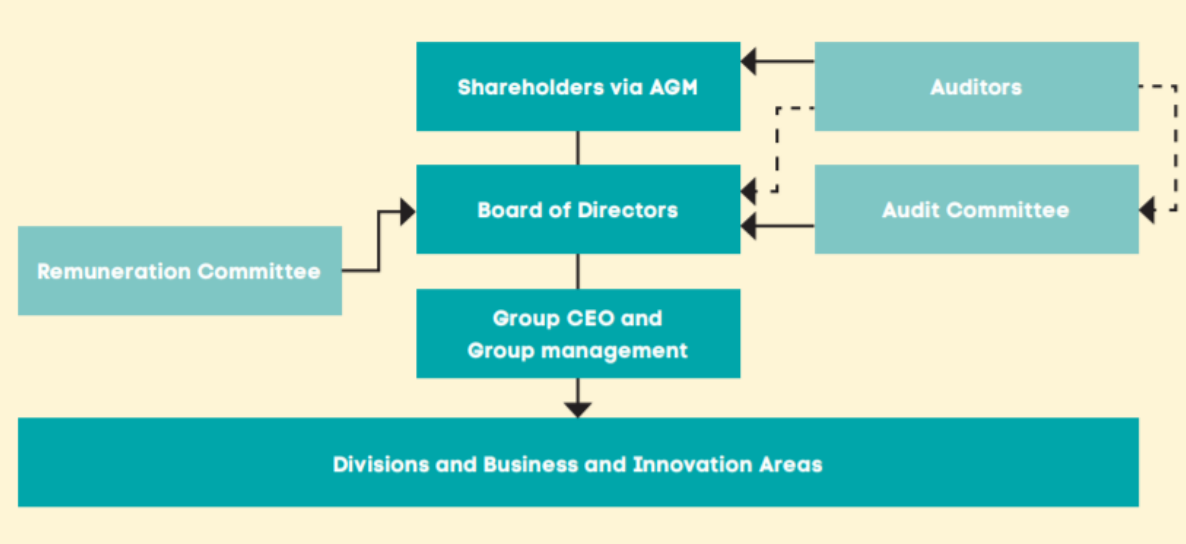
Governance

- The RISE group (known collectively as RISE) consists of a parent company, RISE Research Institutes of Sweden AB, and the wholly owned subsidiaries, RISE ICT AB and Innventia AB. On 1 October 2018 RISE acquired 2/3 of the Swerea Group and it now owns all the shares in Swerea AB. The Board of Directors is responsible for the company's organisation and the management of the company's affairs. RISE's group management consists of a CEO and managers for divisions and group-wide functions.
- The corporate governance of RISE AB is based on the Swedish Government's owner policy and guidelines for state-owned enterprises, the Swedish Companies Act and the Swedish Corporate Governance Code (the Code). The guidelines state that the Code is applied in accordance with the principle of 'comply or explain', which means that any failure on the part of RISE AB to comply with the Code must be explained. According to the Swedish Companies Act, the Board of Directors is responsible for the company's organisation and the management

of the company's affairs. Corporate governance includes maintaining transparency with regard to the owners so that they are able to monitor the company's development, as well as the development of any companies that the state owns or has influence over via RISE AB.

- The Swedish Government's ownership policy aims to ensure that state-owned enterprises act in an exemplary manner in the area of sustainable business and states that "*the fundamental premise of sustainable business is that companies should operate in a manner that promotes sustainable development*". This is to be achieved by balancing and reconciling economically, socially and environmentally sustainable development.

RISE Corporate Governance Structure



Source: Rise (2020a)

- The Board of Directors is to manage the affairs of the company in the interests of the company and its owners. In addition to applicable laws and recommendations, the work of the Board of Directors is governed by the formal work plan for the Board of Directors. The formal work plan regulates the division of responsibilities between the owner and the Board of Directors, between the Board of Directors and the CEO, and the form of the board's work, the number of meetings, authorised signatories, authorisation hierarchy and information pertaining to the board's committees.
- In order to improve and enhance the efficiency of the work that is concerned with risk assessments, internal control, external reporting and auditing, the Board of Directors has established an Audit Committee. The committee assists the Board of Directors in assuring the quality of the financial reporting. The Audit Committee is a preparatory unit whose proposals are submitted to the Board of Directors. The duties of the Audit Committee are detailed in the formal work plan for the Board of Directors.
- A Remuneration Committee is responsible for the preparation of matters regarding guidelines for remuneration and other terms of employment for the CEO and other executives, as well as for matters regarding general salary levels for senior executives. The so-called 'grandfather principle' applies in the appointment of senior executives, i.e., the CEO consults with the Chairmen of the Remuneration Committee/Board of Directors.
- RISE has established a Research Council that has 19 members, especially selected to represent RISE's stakeholders from the business community, academia and the public sector. The chairman of the council is Mikael Dahlgren, Research Director at ABB. The main responsibilities and duties of the Research Council are to provide guidance to the Board of Directors in the establishment of cross-function venture projects, in the distribution of venture funds and in strategic issues regarding the direction of research, and in issues prioritised by

trade and industry. In addition, the Research Council shall provide advice and support on contemporary research matters.

- The auditors are assigned to review RISE's financial statements, accounting records and consolidated financial statements, as well as the management of the company by the Board of Directors and CEO, on behalf of the shareholders. The Auditor-in-Charge also submits an auditor's report to the annual general meeting. According to the Articles of Association, RISE AB is to engage one or two authorised public accountants, with or without alternate auditors, or a registered audit company to perform the audit activities on behalf of the shareholders

FUNDING

- The research institutes in the RISE Group are commercial, for-profit research and innovation entities, with projects that are primarily competitively won. The state invests strategic competence funds and funds for structural development in the institutes through RISE AB. The purpose is to create value and competitiveness in both small and large companies which, in turn, contribute to growth and support the shift towards sustainable development throughout society. RISE is for-profit, but does not distribute profit. The financial targets set by the board and the Annual General Meeting are aimed at guiding RISE towards a high degree of efficiency and professionalism.
- Net sales in 2019: 3,568 million SEK:
    - 50% Trade and Industry
    - 24% Public funding bodies
    - 20% Government grants
    - 6% EU funds
- Operating profit in 2019: 63 million SEK.
- Profit after financial items in 2019: 54 million SEK.
- Net profit for the year in 2019: 47 million SEK.
- Equity in 2019: 1,041 million SEK.
- Total assets in 2019: 3,749 million SEK.

INSTITUTIONAL STRUCTURE AND CONTEXT

- RISE is a member of several national and international organisations:
    - EARTO (European Association of Research and Technology Organisations)
    - EUROLAB (collaborative organisation for European testing laboratories)
    - MIS (Environmental and Sustainability Auditors in Sweden)
    - CSR Western Sweden
    - EURAMET (European Association of National Metrology Institutes)
    - Climate 2030 – Västra Götaland in transition (mobilisation of efforts by Region Västra Götaland, Västra Götaland County Administrative Board and other stakeholders)
    - Fossil Free Sweden (initiative bringing together Swedish actors with the ambition to make Sweden one of the first fossil-free welfare countries in the world)

FUNCTIONS AND SERVICES

DigiCORE:

- Inspiration: Lectures and guided tours of the lab, workshop for mapping needs and opportunities.
- Concretisation: Concept development workshop and technology specific help (AI, Analytics, Big Data, CPS, IoT, ML, prototyping, system testing, UX, visualisation and XR [VR/AR]).
- In-depth: Support in implementing technology, participation in a research project, data analyses, networking with start-ups and other technology companies.

RISE GROUP:

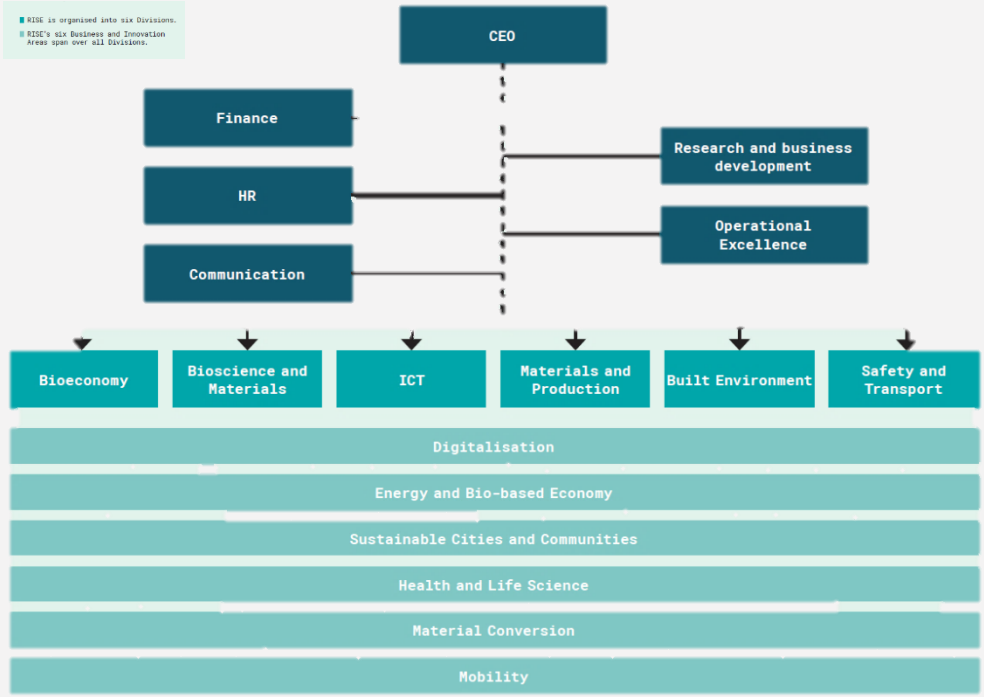
- 126 testbeds and demonstration environments
- 6476 projects with customers in 2019
- RISE cooperates with companies, academia and the public sector in three areas:

  Industrialisation and quality assurance:
  - Certification, calibration and inspection
  - Testbeds
  - National metrology centres

  Research and development:
  - Applied research for innovation
  - Service innovation and design processes
  - Courses for lifelong learning
  - Innovation support for SMEs
  - Expert support

  Vision and strategy:
  - Innovation partnerships
  - Future scenarios and roadmaps
  - Innovation support services

RISE Organisation and divisions



Source: Rise (2020a)

- 3 areas: Innovation support services, R&D, industrialisation and quality insurance; these areas include but are not limited to the provision of expertise, courses, training, certification, events, access to networks, and SME support.
- Test beds and demonstration environments, technical evaluation and verification as well as prototypes and pilot production are some of RISE's offerings in industrialisation and verification.

SOURCES

RISE (2020a) *Annual Report and Sustainability Report 2019.* RISE website: www.ri.se/en

Rise (2020b) *Website*. RISE website: www.ri.se/en

Testbed Sweden (2020) *Website*. Testbed Sweden website: https://www.testbedsweden.se/en/about

A*STAR's Model Factory @SIMTech: Singapore Institute of Manufacturing Technology

SINGAPORE

Website

- www.a-star.edu.sg/simtech/model-factory@simtech/overview
- www.a-star.edu.sg/simtech

Location

Singapore

DESCRIPTION

A*STAR launched its Model Factory Initiative at two locations in 2017/2018, one of which is part of the Singapore Institute of Manufacturing Technology (SIMTech), which is a research institute of the Singapore Agency for Science, Technology and Research (A*STAR). Model Factory @SIMTech is part of the Manufacturing Control TowerTM (MCTTM) program.

MISSION

- SIMTech Mission: To develop targeted high-value manufacturing technologies and human capital to enhance Singapore's competitiveness.
- SIMTech is committed to serving manufacturing industry to develop industrial, intellectual and human capital.

FOCUS AREAS

- These are robotics & automation, digital manufacturing, additive manufacturing, and advanced materials.
- Sectors: Aerospace, electronics, chemicals, machinery & systems, marine & offshore, precision modules & components, biologics & pharmaceutical manufacturing, and medical technology manufacturing.

GOVERNANCE

- The organisational structure of SIMTech is presented in below. Model Factory @SIMTech is part of the Manufacturing Control TowerTM (MCTTM) program.

Organisational Structure of SIMTech

Source: SIMTech (2020b)

- The funder is involved in SIMTech.

FUNDING

- Exact figures are not available but SIMTech has a pool of 450 researchers.
- Under the last five-year Research, Innovation and Enterprise (RIE) 2015 Plan, the Singapore government committed $16 billion during the period of 2011 to 2015 to establish Singapore as a global research and development (R&D) hub. The government will be sustaining its commitment to research, innovation and enterprise, and will invest $19 billion for the RIE2020 Plan over the period 2016 to 2020.
- The Agency of Science, Technology & Research (A*STAR) offers different funding options to support individuals, resources, ideas and major initiatives.

INSTITUTIONAL STRUCTURE AND CONTEXT

- SIMTech is a research institute of the Singapore Agency for Science, Technology and Research (A*STAR).
- Agency: EDB Singapore, Enterprise Singapore, e2i, Skills Future, Workforce Singapore.
- Association: ASPR, ASME, Genie, Print & Media Association Singapore, SASS – Singapore Association of Shipsuppliers and Services, Singapore Manufacturing Federation, SPETA.
- Research: A*STAR Advanced Remanufacturing and Technology Centre, A*STAR Institute of High Performance Computing, A*STAR Institute for Infocomm Research, A*STAR National Metrology Centre, Korea Smart Factory Foundation, Nanyang Technological University Singapore, National University of Singapore, Technische Universitat Braunschweig, Technical University of Munich.
- Technology: ASTERISK, Boston Consulting Group (BCG), Beckhoff, Dassault Systemes, Erowa System Solutions, Efunity, Fanuc, Hexagon Manufacturing Intelligence, iPlast 4.0, Intelligent Path Optimiser (IPO), Makino, Mobile Industrial Robots (MIR), Microsoft, ntuc Learning Hub, Pepperl+Fuchs, Rockwell Automation, Sato, Sick Sensor Intelligence, Skymech, Universal Robots.

FUNCTIONS AND SERVICES

- Extent to which they offer access to facilities; use cases; knowledge exchange; practical support to companies; access to capabilities and funding:
    - A number of demonstrators are available under the following five categories: shop floor, resource management, enterprise, supply chain & logistics, and nerve centre.
    - Industry Assist - building technology capabilities through individual company-funded projects, Collaborative Industry Projects (CIPs), consortia and sharing of research facilities.
    - Knowledge Transfer - filling skills or technology gaps via SkillsFuture training courses using Learn-Practise-Implement model, Annual Manufacturing Forum - SIMTech flagship conference-conference, lecture, seminar, workshop, customised short course and master class.
    - Technology Transfer - sharing SIMTech-developed technology with industry through Technology Licensing, Open Innovation and Risk Sharing in Commercialisation.
    - Manpower Sharing and Transfer - providing access to R&D expertise via Technology for Enterprise Capability Upgrading (T-UP), Staff Attachment and Technical Advisors
    - The Model Factory@SIMTech is available for any visits by industry. It is not available for visits by the public or by children as it is an actual production environment. Visits are

conducted only on Tuesdays and Thursdays and are subject to a maximum of 25 persons per visit.

Model Factory@SIMTech

Source: Model Factory @SIMTech (2020b)

SOURCES

Model Factory @SIMTech (2020a) *Overview.* Model Factory website www.a-star.edu.sg/simtech/model-factory@simtech/overview

SIMTech (2020a) *Overview* . SIMTech website: www.a-star.edu.sg/simtech

SIMTech (2020b) *Organisation Structure* SIMTech website: www.a-star.edu.sg/simtech

Model Factory @SIMTech (2020b) *Demonstrators* [Model Factory website: www.a-star.edu.sg/simtech/model-factory@simtech/demonstrators

CONFIRM Smart Manufacturing

IRELAND

Website
https://confirm.ie/

Location
Limerick, Ireland

DESCRIPTION

CONFIRM is a not-for-profit, national strategic initiative supported by Science Foundation Ireland (SFI): the Irish national foundation for investment in scientific and engineering research.

MISSION

- *"Our mission is to transform industry to become leaders in Smart Manufacturing."*
- Objectives:
  - Research: Undertake research to develop future smart manufacturing technologies.
  - Engage: Use of talent & engagement with the public promotes a positive perception of manufacturing in Ireland.
  - Community: Community of practice aims to embrace the 4th Industrial revolution together.

FOCUS AREAS

- These are smart manufacturing: data analytics, product & process control, enterprise modelling & simulation, software systems, network systems & IoT, sensors, robotics & controls, and materials processing

GOVERNANCE

- This consists of the Operations Team, Principal Investigators, Funded Investigators, and Executive Committee.
- Governance Committee: The primary function of this committee is to ensure that CONFIRM operates in line with best practice by adhering to the rules and regulation of their funding body SFI.
- Industrial Advisory Committee: This group is made up of regional and national industry leaders who are bipartisan and represent the best interest of CONFIRM's industry partners.
- Scientific Advisory Committee: Comprising of International Manufacturing Academic and Industry thought leaders who provide the centre with independent, impartial scientific advice.

FUNDING

- CONFIRM has secured Euro 45 million in funding with over 100 industry partners engaged in its network.

INSTITUTIONAL STRUCTURE AND CONTEXT

The CONFIRM Smart Manufacturing Research Centre was established in 2017, as part of a national strategic initiative supported by Science Foundation Ireland (SFI), which is the Irish national foundation for investment in scientific and engineering research. The foundation of the CONFIRM Smart Manufacturing DIH is a key part of the CONFIRM vision to accelerate the adoption of digital technologies and smart manufacturing innovations among SMEs and MNEs in the Irish manufacturing sector. CONFIRM DIH is aligned with Ireland's regional Research and Innovation Strategies for Smart Specialisation (RIS3), which places a strong focus on the key areas of SME support, enhanced competitiveness, and the local delivery of assistance to

entrepreneurs and smaller firms via the new local innovation support structures. Ireland's published RIS3 strategy document provides the national and regional context for Smart Specialisation.

FUNCTIONS AND SERVICES

- CONFIRM's new headquarters, a bespoke 1619 m2 facility, is based in Park Point, Limerick. This facility will enable a community of practice where CONFIRM will host 70 researchers, 12 operational and management staff, resident and visiting investigators from CONFIRM's 9 national research partners, international collaborators, industry partners, as well as test-bed and prototype facilities.
- Across their partner institutes, they have equipment that can enable an industries' transformation towards smart manufacturing. facilities and this includes the following:
    - Process & Product Development Labs – Tyndall National Institute
    - Process Technology Services – Tyndall National Institute
    - JAMIR Composite Joining Suite – University of Limerick
    - Universal Robotics UR Series Cobots – University of Limerick
    - MAXIEM 1530 Water-Jet Machining Centre – University of Limerick
    - Ultrasonic Welding Facility – University of Limerick
    - Injection Moulding Smart Manufacturing Cell – Athlone Institute of Technology
- The CONFIRM Digital Innovation Hub (DIH) is focused on the application of digital innovation across the manufacturing value chain: It provides the skills and services required to place Irish-based industry at the forefront of the smart manufacturing revolution, helping companies of all sizes – ranging from SMEs to larger organisations – to compete globally at the highest level. The CONFIRM DIH coordinates R&D and innovation activities:
    - It provides communication & outreach to the manufacturing industry.
    - It promotes a positive perception of manufacturing in the wider society.
    - It contributes to the development of a skilled human resource pipeline for the manufacturing industry.
    - It provides a liaison between companies and a network of experts.
    - It promotes new collaborative multi party national and international research projects to implement digital technologies for Irish based manufacturing companies.
- Training: CONFIRM offers training and workshops to inform its various cohorts including the general public, schools, industry, and stakeholders on smart manufacturing and Industry 4.0. These programs bridge the gap between these cohorts and academia so there is an awareness of research and developments in the manufacturing industry.

SOURCES

Confirm (2020) *Website.* Cofirm website: https://confirm.ie/

Smart Manufacturing Innovation Centre

SOUTH KOREA

Website	Location
https://www.demo-factory.kr/SMIC_ENG_index.php	Ansan, South Korea

Description

The Smart Manufacturing Innovation Center (SMIC) is an organisation that conducts research, examining and testing on smart manufacturing. Smart factory leaders and organisations, both domestic and foreign, are looking for solutions about the future of smart manufacturing with the Smart Manufacturing Innovation Center. The Smart Manufacturing Innovation Center is working together to actualise the value of innovation, collaboration and transformation in smart manufacturing. SMIC showcases the future of manufacturing by demonstrating smart manufacturing technologies. SMIC connects technology providers with companies that would like to adopt a Smart Factory model. The facility specifically focuses on SMEs.

Mission

This is to build an advanced smart factory, which can connect 'virtual production' to 'actual production'.

Focus Areas

IIoT, Cloud computing, VR/AR, Big data, CPS/Digital Twin, AI, 5G Wireless, Smart Machine, 3D printing.

Governance

- Support organisations include the following:
  - Ministry of Trade
  - Industry and Energy
  - Gyeonggi Province
  - Ansan city hall
  - KIAT
  - KEIT
  - KOSF
  - KETI
  - Gyeonggi Technopark

Funding

- 50% of the facility was funded by companies and 50% with government funds.

Institutional Structure and Context

NA

Functions and Services

- *"The vast majority of firms in Korea are SMEs, they don't have enough resources; financial resources, human resources to collect broad information about smart factory, and except the very few small number of the big companies like multinational companies, they didn't really have enough resources to identify what a smart factory is".* SMIC addresses this gap and provides Smart Factory insights and support.
- SMIC supports the advancement of the smart factory, proof of concept by industry, product certification, and the training of technicians. Their main services includes the following:

- Networking, Domestic/Global Exhibition
- Domestic Exhibition, Global Exhibition, IOCEM, Demo Factory Day, Factory Hakerton
- Technical Consulting & Solution advertising
- Smart Factory Solution Education
- Global conference

SOURCES

SMIC (2020) *Website.* SMIC website: www.demo-factory.kr/SMIC_ENG_index.php

Interview with SMIC in 2019

MADE – Manufacturing Academy of Denmark

DENMARK

Website	Location
https://en.made.dk/	Copenhagen, Denmark

Description

MADE - Manufacturing Academy of Denmark is the Danish national innovation and research platform for the manufacturing industry in Denmark. It was launched as an independent association in 2014 by Danish companies, universities, RTOs, various associations and through public and private funds. As such, MADE is also recognised as the Danish Industry 4.0 initiative for the digitalisation of the manufacturing industry and is appointed as the operator of the publicly supported Danish Innovation Network for Advanced Manufacturing.

Besides being the Danish national platform for innovation and research in manufacturing, MADE is also positioning and representing Denmark in international platform collaborations and projects. MADE is a European Digital Innovation Hub (DIH) and thereby part of a large network of DIHs across Europe. Digital Innovation Hubs (DIHs) are one-stop-shops that help companies to become more competitive regarding their business and production processes, products or services using digital technologies. As a DIH, MADE helps Danish companies in finding a project, funding and/or collaboration opportunities and partners internationally.

Mission

- MADE's main mission lies in applying research, driving innovation and strengthening education to improve the competitiveness of Danish manufacturing (EU Digital Transformation Monitor (2020c).
- MADE aims to facilitate the development of innovative world-class manufacturing solutions in Danish industry, enabling Denmark to compete globally and create employment within Denmark.
- MADE achieves its goals through the development of strategic partnerships between research institutes, RTOs and industry. MADE supports and strengthens the manufacturing industry in Denmark through the implementation of state-of-the-art manufacturing technology via applied industrial research projects and a range of various innovation activities and educational initiatives.

Focus areas

- MADE's research and innovation themes are focused on developing and implementing advanced manufacturing and Industry 4.0 solutions in the Danish manufacturing sector.
- MADE's work is focused on applied research, innovation, and education in technologies and solutions that can strengthen the Danish manufacturing industry.
- Sectoral industries: Education and Knowledge Creation, Food Processing and Manufacturing, Advanced Manufacturing broad terms.
- Technology fields: Machining (turning, drilling, moulding, planning, cutting), electronic measurement systems.
- S3 EU priority areas: ICT trust, cyber security & network security, advanced manufacturing systems.
- Emerging industries: Digital Industries, Mobility Technologies.
- Research and innovation themes are defined by the needs of Danish industry and global trends and technological development.

- Specific research themes and collaborations (https://en.made.dk/research/)
- The initiative primarily targets the SMEs' larger companies and the other organisations that are also part of the association (EU Digital Transformation Monitor (2020c).

GOVERNANCE

- The platform is managed by the independent association, MADE (Manufacturing Academy of Denmark) (EU Digital Transformation Monitor (2020c).

FUNDING

- DKK 380 million ($60 million) for the 2014-2019 period, of which 48% comes from companies, 38% from Innovation Fund Denmark, 9% from universities, and 6% from private funds and associations.
- The initiative is financed by mixed public-private sector funds amounting to €50 million between 2014 and 2019 across two PPP initiatives (EU Digital Transformation Monitor (2020c).
- The funds are acquired from participating companies, universities, associations, private foundations and public funds (EU Digital Transformation Monitor (2020c).
- Sponsors:
  - Confederation of Danish Industry
  - The Manufacturing Industry
  - Industriens Arbejdsgivere København
  - Innovation Fund Denmark
- Value-addition for policy-makers: A national platform led by industry focusing on maximising the impact of the public and private investments in the Danish manufacturing industry and through links to the European manufacturing ecosystem (EU Digital Transformation Monitor (2020c).

INSTITUTIONAL STRUCTURE AND CONTEXT

- The following are the details of the MADE cluster:
  - Total members of the cluster: 170
  - Number of SME member: 107
  - Number of start-ups among SME members: 12
  - Number of larger company members: 35
  - Number of research organisations/universities/technology centres: 8
  - Number of other ecosystem actors: 8

FUNCTIONS AND SERVICES

- Knowledge – MADE generates new knowledge in production technologies, digitalisation and management for inspiration and application in the Danish manufacturing industry.
- Technology – MADE introduces Danish manufacturing companies to the newest technologies, methods and processes, and gives access to experts, test facilities and demonstration projects.
- Support for SMEs – MADE helps small and medium sized enterprises with the implementation of state of the art methods and technology and with establishing contact to leading experts or project partners.
- Network – MADE creates connections between the leading companies, specialists and educational institutions in Denmark and internationally.
- International partnerships – MADE represents Denmark internationally, especially within EU projects, as the national platform for knowledge sharing and innovation in Danish manufacturing

and offers members the opportunity to join the projects through MADE and/or benefit from the results.

SOURCES

MADE (2020a) *MADE – Manufacturing Academy of Denmark.* MADE website: https://en.made.dk/

MADE (2020b) *MADE – Research.* MADE website: https://en.made.dk/

EU Digital Transformation Monitor (2020c) *Denmark – Manufacturing Academy of Denmark (MADE)*

RICAIP: Research and Innovation Centre on Advanced Industrial Production

CZECH REPUBLIC

Website	Location
http://ricaip.eu/	Prague, Czech Republic

DESCRIPTION

The Research and Innovation Centre on Advanced Industrial Production (RICAIP) is the European Centre of Excellence in AI and industrial robotics and Industry 4.0 related areas. RICAIP is based on a strategic partnership between leading Czech and German research institutions. The founding partners are CIIRC CTU (Czech Institute of Informatics, Robotics and Cybernetics at Czech Technical University) together with CEITEC BUT (Central European Institute of Technology at Brno University of Technology), DFKI (German Research Centre for Artificial Intelligence) and ZeMA (Centre for Mechatronics and Automation Technology), both seated in Saarbrücken. These four founding partners of the RICAIP Centre jointly contribute to RICAIP by making their core facilities available and enable RICAIP to operate in a distributed way. RICAIP was established in 2016.

MISSION

- Mission – *"World-class research network for application-oriented research in the advanced production area"* (RICAIP 2020d).
- RICAIP's mission is to create a collaborative ecosystem for academia and industry as well as with national and regional authorities to produce valuable high-impact and application-oriented research results for producing and manufacturing companies. By creating and leveraging this ecosystem, RICAIP claims to make a significant contribution to the fundamental and applied research in artificial intelligence, machine learning, computer science and robotics across Europe. With their partners, RICAIP establishes a unique R&D infrastructure across Europe and contributes, with innovative solutions, to the competitiveness of Europe, European companies and industrial partners. The RICAIP network itself offers unique possibilities for the training and education of students, research professionals and industrial employees. RICAIP aims to promote interdisciplinary research and collaboration with non-technical disciplines to address current needs and demands of society (RICAIP 2020d).
- RICAIP's Communication Strategy and Standards includes mission, vision and USP (RICAIP 2020d) and a summary of RICAIP's main principles and testbed facilities (RICAIP 2020b).
- The aim of the RICAIP project is to develop a strong cooperation at the international level evolving the concept of Industry 4.0. RICAIP will virtually connect the testbed facilities in the Czech Republic (Prague, Brno) and Germany (Saarbrücken) and integrate them into a new Czech-German research infrastructure in advanced distributed industrial production.
- The intention is to develop RICAIP as the European research infrastructure: the first of its kind in Europe. The RICAIP Centre will become an international hub for Industry 4.0, especially for multi-site industrial production and multi-site production system development, and will change industrial research to become more interdisciplinary; therefore, bringing excellence and new solutions to the sector.
- The idea of a geographically distributed, but virtually integrated experimental testbed with an open access policy will help to integrate research activities in the subject field internationally and help to leverage the huge investments by a wider SME community. This will also be a strong driving force for standardisation efforts. RICAIP aims to set the grounds for an intensive cooperation between industry and academia.

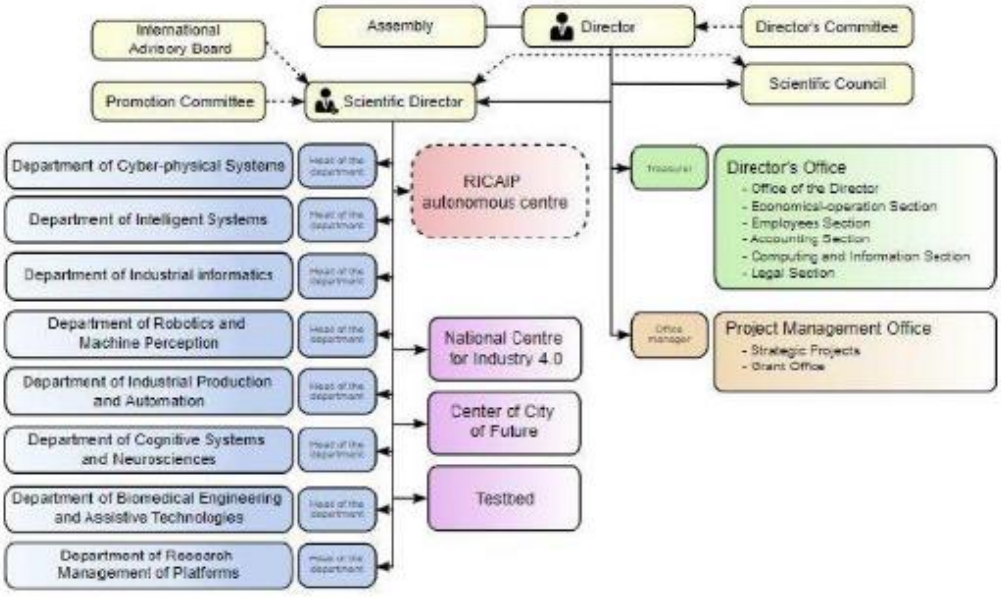
FOCUS AREAS

- These are Industry 4.0, industrial production, artificial intelligence, virtual and augmented reality, remote industrial production control, and rapid adaptation.
- Sector: Manufacturing.

GOVERNANCE

- RICAIP Director: Dr. Tilman Becker
- RICAIP Steering Committee (4) consists of the directors of the four founding institutions (all professors):
  - Prof. Vladimír Mařik (Scientific Director CIIRC CTU)
  - Prof. Radimír Vrba (Director CEITEC BUT)
  - Prof. Jana Koehler (DFKI)
  - Prof. Rainer Müller (Director ZEMA)
- RICAIP Executive Board (7) consists of seven members (mainly drawn from the four founding institutions):
  - Dr. Tilman Becker (RICAIP Director)
  - Dr. Pavel Burget (CIIRC CTU)
  - Dr. Vít Dočkal (CIIRC CTU)
  - Ing. Jan Nedvěd (CEITEC BUT)
  - Prof. Pavel Václavek (CEITEC BUT)
  - Dipl.-Ing. Christoph Speicher (ZeMA)
  - Prof. Antonio Krüger (DFKI)

Organisational structure of CTU CIIRC – RICAIP autonomous centre



Source: RICAIP, 2020e

FUNDING

- The RICAIP Centre is supported by the EU, European Structural and Investment Funds, and the Operational Program Research, Development and Education (based on grant agreement No. 857306 and Project CZ.02.1.01/0.0/0.0/17_043/0010085)

- European Union's Horizon 2020 research and innovation programme under grant agreement No 857306 (14.986M Euro; 1/9/2019 – 28/2/2026).

INSTITUTIONAL STRUCTURE AND CONTEXT

The following four are the founding partners who also run RICAIP:

1) CIIRC-CVUT Czech Institute of Informatics, Robotics, and Cybernetics, CTU in Prague:

- Czech Institute of Informatics, Cybernetics, and Robotics, CTU in Prague (CVUT-CIIRC), was established as a multidisciplinary university institute at the Czech Technical University in Prague in July 2013. The CIIRC is an effective platform for demanding interdisciplinary R&D projects not only across the CTU but also within the whole of the Czech Republic. CIIRC opens the space for mutually beneficial cooperation with CTU faculties and institutes, other universities, the Academy of Sciences of the Czech Republic, industrial R&D, companies, and analogical foreign institutions. CIIRC has created the environment that is supporting the know-how transfer to industry and other application areas. CIIRC contributes to the National Initiative Industry 4.0 of the Czech Government. The first Testbed for Industry 4.0 in the Czech Republic is being built in CIIRC.
- České vysoké učení technické v Praze (Czech Technical University in Prague, ČVUT/CTU) is the largest technical university in the Czech Republic and one of the oldest ones in Europe. In 2017, CTU occupied the 201st-250th position in the “Computer Science and Information Systems” category of the QS World University Rankings. CTU has eight faculties (Civil Engineering, Mechanical Engineering, Electrical Engineering, Nuclear Science and Physical Engineering, Architecture, Transportation Sciences, Biomedical Engineering, Information Technology) and about 21,000 students.
- Further details: www.ciirc.cvut.cz/en

2) BUT-CEITEC Central European Institute of Technology – Brno University of Technology:

- CEITEC was established as a multidisciplinary scientific centre in the area of life sciences, material sciences and advanced technologies in 2010. At the BUT, CEITEC provides strong expertise in the area of automation, cybernetics, robotics and instrumentation. CEITEC provides a unique connection of R&D teams in Material Science (materials, nano and micro technologies, embedded systems, communication and control technologies) and Life Science and a state-of-the-art research infrastructure is available for the project solution. The research group, Cybernetics in Material Science, will participate in the project. The group is aimed at the development of sensors, embedded systems, control algorithms and their applications in industry.
- Funded by EU Structural Funds, CEITEC constructed 14,000 m2 of new research facilities and purchased state-of-the-art equipment valued about 100M Euro. The RG mission is to develop advanced control, sensor and communication technologies with a high application potential in industry and to support other research teams in laboratory experiments in automation, electrical and non-electrical quantities measurement, data acquisition, signal processing and laboratory robotics.
- The university (BUT) consists of eight faculties covering a broad range of technical science and it is one of the major research institutions in the Czech Republic with more than 2,000 Ph.D. students and 1,000 academics staff.
- Further details: http://vutbr.ceitec.cz/en/

3) DFKI German Research Centre for Artificial Intelligence:

- DFKI is the leading German research institute in the field of innovative software technology. In the international scientific community, DFKI ranks among one of the most recognised “Centres of Excellence” and, currently, it is the biggest research centre worldwide in the area of Artificial Intelligence and its application in terms of the number of employees and the volume of external

funds. DFKI has 5 sites across Germany, integrates 18 research departments and living labs. The presence that it has among DFKI's shareholders of the largest German and international companies (BMW, Volkswagen, SAP, Deutsche Telekom, Microsoft, Intel, Google, etc.) determine the focus of its research and innovation activities, as well as its close relations with industrial partners.

- DFKI was one of the German research organisations that was behind the national Industry 4.0 Strategy; the CEO of DFKI, Prof. Wahlster, is a chairman of one of the five Working Groups of this initiative. Several departments of DFKI pursue research that is contributing to the implementation of the Industry 4.0 vision (e.g. Intelligent User Interfaces, Robotics Innovation Centre, Innovative Factory Systems, etc.). DFKI participates in dozens of national (funded by e.g. BMBF, BMWi) and international (funded by H2020, EIT Digital, EU Structural funds, etc.) research and innovation projects. Importantly, the industry (e.g. the shareholders) provides substantial direct support to the research in this field.
- Further details: www.dfki.de/

4) ZeMA Centre for Mechatronics and Automation Technology:

- ZeMA is a non-profit research institute and organisation which was founded in 2009. The institute is led by Prof. Dr.-Ing. Rainer Müller (CEO) and Andreas Noss (CFO). It is connected with the country, Saarland, the local university of applied sciences (Saarbrücken) and the University of Saarland. The institute with its three research division sensors and actuators, manufacturing processes and assembly processes is working in EU funded projects. Due to its industry-related research activities, the institute is also working closely with producing companies (e.g. automotive, aircraft, consumer goods) in research and industry projects.
- With its research divisions and its alignment, the institute has grown steadily in the last years, employing about 117 employees in its different academic fields. ZeMA is, furthermore, the coordinator for the Industrie 4.0 platform, "Power4Production", and the human-robot-collaboration platform, "Robotix-Academy", in the greater region of Saar-Lor-Lux and Germany. Besides research and development and the transfer of results to industry, ZeMA is also working in the education of engineers.
- Further details: www.zema.de/

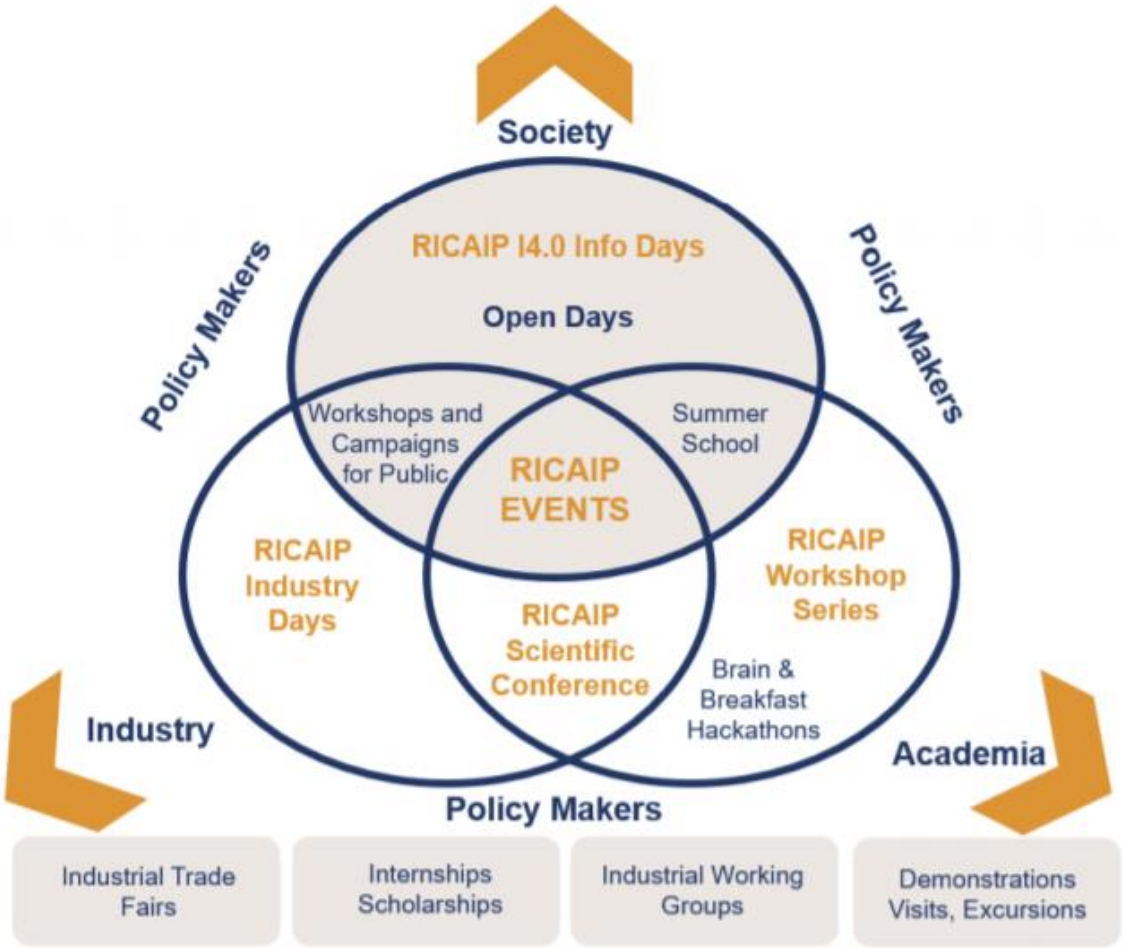
FUNCTIONS AND SERVICES

- Testbed facilities - Experimental physical manufacturing facility enabling the demonstration of new and innovative production systems and the production of products (RICAIP 2020b).
- Very high variability set of machines and transportation tools fully integrated and operated in a multi-site dimension.
- Evaluation and feasibility of new processes and technologies at the testbed with interdisciplinary support during the transfer and implementation of solutions in the shop-floor.
- RICAIP will virtually connect the testbed facilities in Germany (Saarbrücken) with the Czech Republic (Prague and Brno).
- RICAIP's Dissemination Strategy and Standards are available online (RICAIP 2020c). Figure below shows an indicative concept of RICAIP' branded events.

RICAIP: Testbed Facilities

Source: RICAIP, 2020b

An indicative concept of the RICAIP's Branded Events in the context of other actions



Source: RICAIP, 2020c

SOURCES

RICAIP (2020a) *RICAIP.* RICAIP website: http://ricaip.eu/

RICAIP (2020b) *RICAIP – New international hub for Industry 4.0* RICAIP website: http://ricaip.eu/

RICAIP (2020c) *RICAIP Dissemination Strategy and Standards.* RICAIP website: http://ricaip.eu/

RICAIP (2020d) *RICAIP Communication Strategy and Standards.* RICAIP website: http://ricaip.eu/

RICAIP (2020e) *RICAIP Welcome Services.* RICAIP website: http://ricaip.eu/

RICAIP (2020f) *RICAIP Explanatory Video.* RICAIP website: http://ricaip.eu/

CIIRC-CVUT (2020) *CIIRC-CVUT Czech Institute of Informatics, Robotics, and Cybernetics, CTU in Prague.* Website: www.ciirc.cvut.cz/en

CIIRC (2020) *CIIRC Video.* Website: www.youtube.com/watch?v=-TDAU2ksf1E

BUT-CEITEC (2020a) *BUT-CEITEC Central European Institute of Technology – Brno University of Technology.* Website: http://vutbr.ceitec.cz/en/

BUT-CEITEC (2020b) *BUT-CEITEC Video* [Online]. Available at http://ricaip.eu/wp-content/uploads/2018/10/CEITEC.mp4 (Accessed: 21 November 2020)

DFKI (2020) *DFKI German Research Centre for Artificial Intelligence* DFKI website: www.dfki.de

ZeMA (2020a) *ZeMA Centre for Mechatronics and Automation Technology* ZeMA website: www.zema.de

ZeMA (2020b) *ZeMA Video.* Website: http://ricaip.eu/wp-content/uploads/2018/10/Video-ZeMA-Zuschnitt.mp4

EU Horizon 2020 (2020) *Research and Innovation Centre on Advanced Industrial Production*

IMCRC: Innovative Manufacturing Cooperative Research Centre

AUSTRALIA

Website	Location
https://www.imcrc.org/	Carlton, Victoria, Australia

Description

The Innovative Manufacturing CRC is a Cooperative Research Centre that helps Australian companies increase their global relevance through research-led innovation in manufacturing products, processes and services. In collaboration with companies, research organisations, industry associations, and government, IMCRC achieves the following:

- Co-funds, on a dollar-for-dollar basis, broad, multidisciplinary and industry-led research projects that deliver commercial outcomes.
- Advances the wider cause of manufacturing transformation through industry education and public advocacy.

Mission

This is to help Australian companies increase their relevance through research-led innovations in manufacturing business models, products, processes, and services.

Focus areas

IMCRC currently has the following two primary focus areas, which will evolve over time:

- Advanced Manufacturing Technology Utilisation:
    - This cncludes, for example, additive manufacturing (3D printing), automated and assistive robotics, advanced materials, sensors and data analytics, augmented and virtual reality and high value product development.
- Industrial Transformation Program (ITP):
    - This is integrating new digital technology platforms with business model innovation to deliver targeted business improvement through the value chain, by focusing on digital and data driven manufacturing, innovation, leadership and the uptake of digital manufacturing (Industry 4.0), particularly with a SME manufacturers.

Governance

- IMCRC was registered in 2015 as Innovative Manufacturing CRC Limited based in Carlton, Victoria, Australia.
- Its Constitution was provided to the Australian Securities and Investments Commission (ASIC) on 26 July 2017.
- Its management team includes the following people: David Chuter, Managing Director and CEO; Dr Jason Coonan, Chief Operating Officer; and Dr Matthew Young, Manufacturing Innovation Manager.

Funding

- IMCRC operates until mid-2022 with up to $30 million in funding available to co-fund industry-led research projects. Industry cash is matched on a dollar for dollar basis, where eligible research is conducted by IMCRC's participant universities and/or CSIRO (IMCRC 2020c).
- IMCRC seeks in-kind contributions; however, those are not matched with cash from the IMCRC, and nor is capital expenditure funded.

- Further details here (IMCRC 2020b).

INSTITUTIONAL STRUCTURE AND CONTEXT

- Partners include industry, research organisations, government & industry associations and collaborators.

FUNCTIONS AND SERVICES

- IMCRC advances the wider cause of manufacturing transformation through industry education and public advocacy.
- MCRC collaborates with businesses, research organisations, industry associations and government, investing in partnerships that support innovation and improve the competitiveness, productivity and sustainability of the Australian manufacturing industry.
- IMCRC co-funds, on a dollar-for-dollar basis, broad, multidisciplinary and industry-led research projects that deliver commercial outcomes. Across key industry growth sectors, IMCRC encourages and enables small and medium enterprise (SME) participation in collaborative research, and co-fund multidisciplinary projects to tackle industry specific problems and deliver manufacturing outcomes.
- Further details on projects can be found in IMCRC (2020d).

SOURCES

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IMCRC (2020c) *Helping catalyse the transformation of Australian manufacturing.* IMCRC website: www.imcrc.org/

IMCRC (2020d) *IMCRC Projects.* IMCRC website: www.imcrc.org/

SmartFactoryOWL

GERMANY

Website	Location
https://smartfactory-owl.de/	Ostwestfalen-Lippe, Germany

DESCRIPTION

SmartFactoryOWL is a multivendor platform for research and demonstration for digital transformation of the manufacturing Industry. Companies can test and develop new technologies supported by interdisciplinary experts who co-create production, work and business processes. The Research Institutes Fraunhofer IOSB-INA, Institute for industrial IT (inIT) and further sections of the OWL University of Applied Sciences and Arts all contribute to the development of a versatile, resource efficient and usable factory.

MISSION

SmartFactoryOWL is an Industry 4.0 real lab, which offers companies and research institutes the possibility to co-create technologies for future factories. In cooperation with the Centrum Industrial (CIIT), SmartFactoryOWL constitutes an innovation cluster for industrial automation (SmartFactoryOWL 2020).

FOCUS AREAS:

- These are figital manufacturing, industrial automation, ICT, robotics/human machine interaction, high performance computing/cloud-based simulation services, additive manufacturing, high-performance production (flexibility, productivity, precision and zero defect), and intelligent/sensor-based equipment.

GOVERNANCE

- Details of a 5-member management committee are available online (https://smartfactory-owl.de/) The members are drawn from the participating organisations, predominantly from Fraunhofer IOSB-INA.

FUNDING

- 5 million Euro (Fraunhofer IOSB 2020)

INSTITUTIONAL STRUCTURE AND CONTEXT

- SmartFactoryOWL is an innovation platform and “transmitter” between the research institutes, the Fraunhofer IOSB-INA and the OWL University of Applied Sciences and Arts, on the one hand, and external partners, on the other. These include, above all, industrial partners, but also scientists, students and start-ups as well as society and politics. A participatory research approach is pursued in which it integrates players from society, business, politics and science into technology development.
- As a real laboratory and certified test environment for Industry 4.0, the SmartFactoryOWL also offers companies the opportunity to test and further develop their products and technological solutions in ideal and real test conditions by using practice-oriented demonstrators on a production area of approx. 2,000m².
- In October 2009, Fraunhofer IOSB-INA was founded in Lemgo as one of four locations of the Fraunhofer Institute for Optronics, Systems Engineering and Image Exploitation (short: IOSB) focusing on industrial automation technologies. Since the beginning of 2012, it has been expanded in the middle of Ostwestfalen-Lippe to become Germany’s first Fraunhofer

Application Centre with the support of the state of NRW. The research work of the scientists from Lemgo focuses on cognitive processes in industrial automation based on networked embedded systems. The solutions developed are intended to support people in their work with increasingly complex technical systems. With the assistance systems thus created, machines and systems are given the ability to configure themselves according to the plug-and-play principle or to optimise themselves to a minimum of what is possible in energy consumption.

- The OWL University of Applied Sciences and Arts, located in Lemgo, is a research university in the technology region of East Westphalia-Lippe with a focus on engineering sciences. For several years, it has been one of the 10 strongest research universities for applied sciences in Germany. The Institute for Industrial Information Technology (inIT) of the Department of Electrical Engineering and Computer Engineering plays a major role in this as one of the leading research institutions in the field of intelligent automation. With over 60 employees, the inIT harmonises information and communication technologies (ICT) with the high demands of automation technology. Due to the cooperation with the research areas “ProErgo- Ergonomic Design of Production Machines” and “DiMan-Direct Digital Manufacturing in the Context of Industry 4.0” from the Department of Production and Economics, the SmartFactoryOWL is able to work on research questions in an interdisciplinary way from the point of view of the technologies used, work organisation and personnel deployment.

FUNCTIONS AND SERVICES

- Research, production and seminar areas to inform an audience about research results in the areas of the digital transformation of the industry, future of work and process optimisation.
- On a 2,000m² production and innovation area, technologies are presented in a way that an audience can experience their benefits first hand.
- SmartFactoryOWL aims to help companies to identify fields of action in the transfer of knowledge and technology and in the implementation of projects by matching them with experts in a suitable way.
- AI Living Lab – an open data platform for collaborative research of Artificial Intelligence in Industry 4.0.
- Services to SMEs (European Commission 2020):
    - Demonstration: the 2,000m² large factory demonstrates several industry 4.0 technologies and enables SMEs to understand what those technologies comprise.
    - Pilot Production: SMEs can extend parts of their production into the SmartFactoryOWL to test and evaluate new technologies or processes.
    - Prototype Development: SMEs can enable their products for industry 4.0 with new hardware and software components offered by the institutes.
    - Technology Services:
        - Lab Tours: SMEs can visit the SmartFactoryOWL to feel and touch Industry 4.0 technologies.
        - Excursion: SMEs can visit the SmartFactoryOWL and cooperating companies in groups from far located regions.
        - Networks: SMEs can participate in networks in order to interact with other companies about Smart Production.
        - Demonstration of Industry 4.0 enabled demonstrators.
        - Trainings: SMEs can participate in training on different topics (e.g. robotics, assistant systems, IT security).
        - Specific consulting: SMEs can receive special consulting by experts on their specific questions.
        - Transfer - quick-checks: SMEs can check their production on its potential for digitisation technologies.

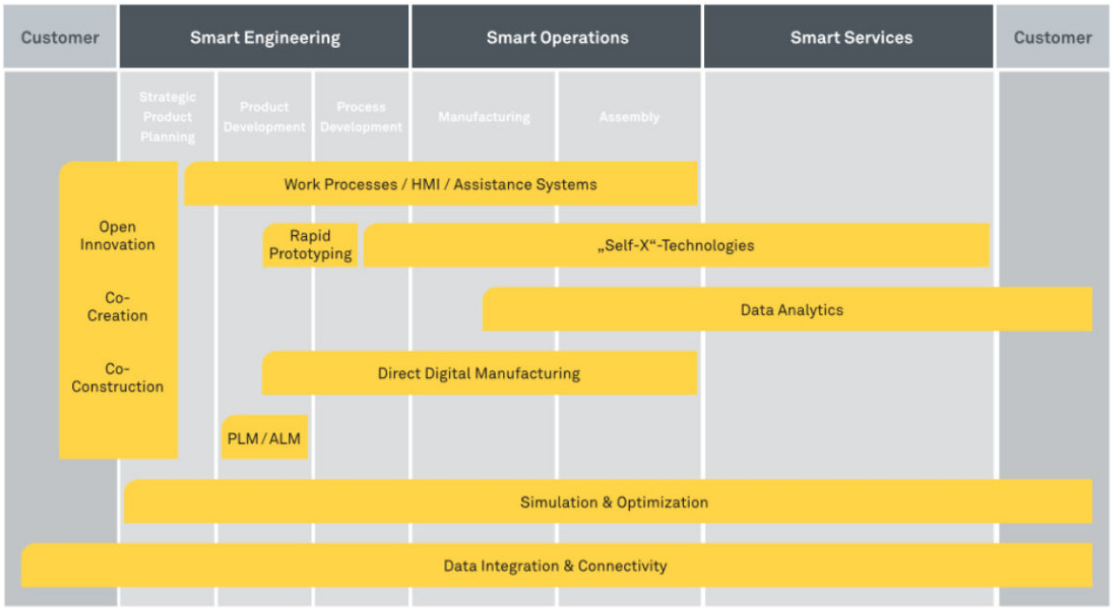
- Transfer projects to improve upon a focused question at the SME production or development site.

- See figures below for an overview of the SmartFactoryOWL, the competencies that it offers and the scope of technologies that it works on (SmartFactoryOWL 2020).
- Training offered by SmartFactoryOWL can be found online (https://smartfactory-owl.de/)

An overview of SmartFactoryOWL

Source: SmartFactoryOWL, 2020

SmartFactoryOWL Competencies



Source: SmartFactoryOWL, 2020

Scope of technologies at SmartFactoryOWL

Source: SmartFactoryOWL, 2020

SOURCES

SmartFactoryOWL (2020) *Overview.* SmartFactoryOWL website: *https://smartfactory-owl.de/*

European Commission (2020) SmartFactoryOWL. Website: https://ec.europa.eu/growth/tools-databases/kets-tools/infrastructure/smartfactoryowl

Fraunhofer IOSB (2020) Die SmartFactoryOWL. Fraunhofer IOSB website: https://www.iosb.fraunhofer.de/

Advanced Manufacturing Digital Innovation Hub

LITHUANIA

Website	Location
https://intechcentras.lt/about-dih/?lang=en	Lithuania

Description

Advanced Manufacturing DIH is led by the non-profit public organisation - Intechcentras. The one-stop-shop centre provides business enterprises with up-to-date information, expert assistance and access to technology for testing digital innovations. It also helps to carry out and conduct experiments with products, processes or business models.

Mission

This is to boost the competitiveness of Lithuanian companies by bringing together Lithuanian ecosystem members.

Focus areas

- These are digital manufacturing, services promoting digitisation, standardisation and legal regulation, human resources and cyber security. The Lithuanian national initiative for digitising industry, Pramonė 4.0.

Governance

- The LINPRA Board (or Presidium) consists of representatives of leading Lithuanian engineering industry companies, science and education institutions.

Funding

- Exact figures are not available but the sources are as follows:
    - Horizon 2020, European Social Fund, COSME, national basic research funding, private funding, partner resources, memberships

Institutional structure and context

- AM-DIH is hosted by the Engineering Industries Association of Lithuania (LINPRA), and is led by a non-profit public organisation created to support the AM-DIH - Intechcentras.

Functions and Services

- TRL4-9 validations and demonstrations, Industry 4.0 trainings and audits, engineering technological training, EU funding projects networking
- Awareness creation
- Ecosystem building, scouting, brokerage, networking
- Collaborative research
- Concept validation and prototyping
- Testing and validation
- Pre-competitive series production
- Commercial infrastructure
- Incubator/accelerator support

- Education and skills development

SOURCES

Intechcentras (2021) Advanced Manufacturing Digital Innovation Hub, Website: https://intechcentras.lt/

European Commission (2021) Advanced Manufacturing Digital Innovation Hub. Website: https://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-tool/-/dih/1349/view

Swiss Smart Factory

SWITZERLAND

Website	Location
https://www.sipbb.ch/en/forschung/swiss-smart-factory/	Biel, Switzerland

Description

The Swiss Smart Factory (SSF) is the first test and demonstration platform for Industry 4.0 in Switzerland, which is run by a private Swiss non-profit organisation, Switzerland Innovation Park Biel/Bienne (SIPBB).

The SSF's vision is to become Switzerland's leading, internationally-recognised centre of competence in application-oriented research and transfer of Industry 4.0, as well as to create an ecosystem of partners, through which unique innovations and activities relating to Industry 4.0 can be developed.

Mission

To become Switzerland's leading, internationally recognised competence centre for Industry 4.0.

Focus areas

These are smart sensors & actuators; smart networking & automation; AR/VR; AI & smart data; cloud- & edge computing; autonomous robots & cobots.

Governance

SSF is one of the SIPBB's four Competence Centres. Switzerland Innovation Foundation coordinates the five locations like SIPBB.

Funding

- Approx. CHF 70 million for SIPBB (federal loan guarantees).
- 2018 revenues: 68% (CHF 1.6 million) from public sources (KTI, Innosuisse, EU-Projects) and 32% (CHF 787,000) from industrial sales and R&D projects.

Institutional structure and context

- A private Swiss non-profit organisation, SIP Biel/Bienne (SIPBB), works with its operating company, Switzerland Innovation Park Biel/Bienne Ltd., and 40 members from industry and research.
- SIPBB is part of the national and international network of the Switzerland Innovation Foundation.

Functions and Services

- Allocated premises, technology services and R&D competencies to be utilised in both Swiss and foreign innovation projects; IoT-based pilot production facility**.**
- Incubator/accelerator.
- Test and demonstration platform.
- Research and Innovation projects.
- Training and further education

Sources

Switzerland Innovation Park Biel/Bienne (SIPBB) (2021) Swiss Smart Factory website: www.sipbb.ch/en/forschung/swiss-smart-factory/

Switzerland Innovation Park Biel/Bienne (SIPBB) (2019) *Rapport de gestion 2018.*

APPENDIX 2:
Living Labs

Table A2: List of Living Labs

Living Lab	Country
JOSEPHS®	Germany
The City of the Future Living Lab	Italy
Lab4living UK	United Kingdom
The Seongnam Senior Experience Complex	South Korea

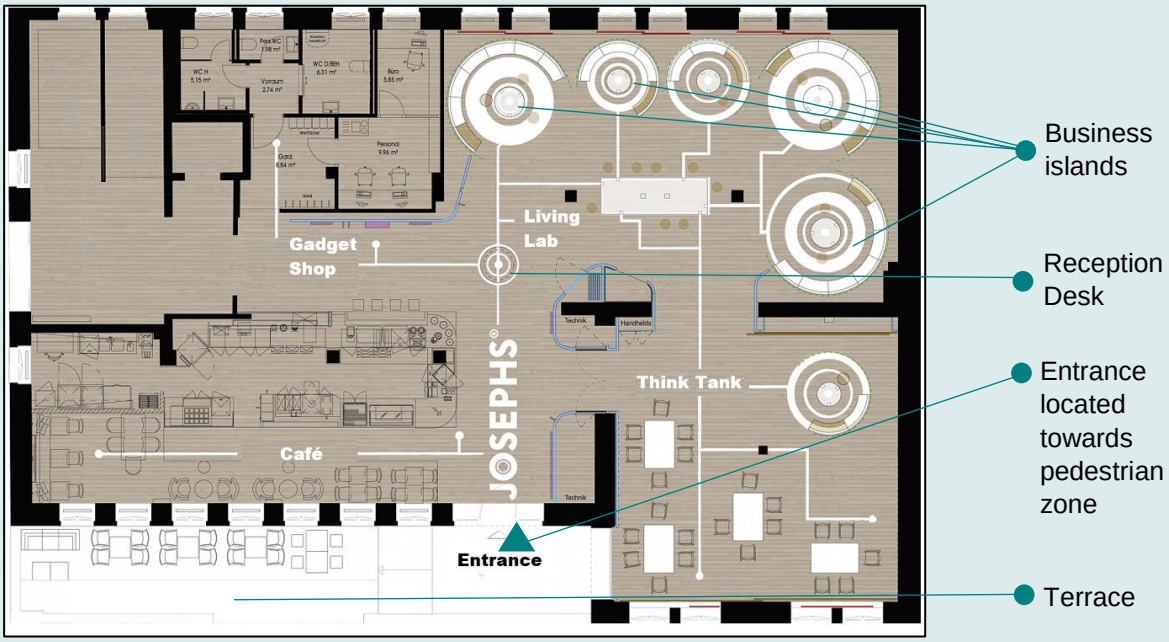
JOSEPHS®	**Location** Nuremberg, Germany

Description

JOSEPHS® is a living lab located in the city centre of Nuremberg, south of Germany. It is a physical space enabling the active involvement of users in the development, introduction and commercialisation of new services and products. JOSEPHS® invites visitors to experience ongoing innovation journeys of established brands as well as new start-ups. Companies present ideas, early prototypes, or even products and services at an advanced development stage, in order to receive authentic feedback from users (Greve et al., 2020a). JOSEPHS® was initiated by the Fraunhofer Center for Applied Research for Supply Chain Services (SCS), which belongs to Fraunhofer Gesellschaft (cross-reference to earlier section), in cooperation with the Chair of Information Systems I at Friedrich-Alexander University Erlangen-Nuremberg (FAU). Fraunhofer SCS is operating the LL and conducts applied research at JOSEPHS®. Furthermore, Fraunhofer SCS is responsible for securing funding and administrative activities. On the other hand, FAU delivers design focused research, and develops methods as well as tools for data collection purposes at JOSEPHS®. The LL is funded by the Bavarian Ministry for Economic Affairs and Media, Energy and Technology.

Established in May 2014, JOSEPHS® is a physical space of 400 m² that is attracting visitors through four different areas: LL, think tank, Café, and the Gadget Shop, which are presented in figure below.

Layout of JOSEPHS®



Source: Fraunhofer-Gesellschaft (2014)

The LL area is where companies have their products or services tested by users. This open space is divided into five business islands, each occupied by a company for three months under one common theme. During the period of three months, on average, about 3000 users try out the products and services and provide their feedback to improve them. JOSEPHS® also has a 'Think Tank', which is often used to run university seminars, events with an external speaker, or lead user workshops for companies to further deepen their co-creation activities. The Think Tank can also be rented for closed company events. JOSEPHS® hosts a Café which attracts visitors without them necessarily knowing that JOSEPHS® has more to offer. This helps in lowering barriers to interaction. Finally, the smallest

space within JOSEPHS® is occupied by Ultra Comix's "Gadget Shop". The shop offers gift ideas, such as board games and books.

Project Example

Companies can use JOSEPHS'® real-life environment to test physical, as well as digital ideas and prototypes, under simulated circumstances with a diverse, self-selected group of users. The firms utilising the LL for innovation purposes come from a wide variety of backgrounds and sizes, ranging from start-ups in consumer products to technology providers and larger firms (Beutel et al., 2017). Not only do business-to-consumer firms use this space, but also business-to-business enterprises that would like to explore what the end-consumer thinks about their offering. However, not all of the companies that come to JOSEPHS® have had experience with co-creation or LLs.

One company that has engaged with co-creation at JOSEPHS® is PersonalisedBuggy. The company is a German start-up that manufactures luxurious strollers using environment-friendly materials. The focus of the company lies on sustainability, high-quality materials as well as design. Customers can select their preferred design and materials for their stroller through an online configurator. Due to the custom production, the company works with small businesses that are highly flexible and able to realise changes quickly. With regards to their suppliers, PersonalisedBuggy pays close attention to the highest social and environmental standards. Given their local sourcing of materials, and, overall, their high-quality standards and customised approach to producing luxurious strollers, PersonalisedBuggy targets the high-end market with retail prices averaging above €1000 per stroller.

As a start-up with limited financial resources, PersonalisedBuggy's business island at JOSEPHS® has been sponsored by the Bavarian Centre for the Cultural and Creative Industries which supports start-ups in the region. The aim of the Bavarian Centre for the Cultural and Creative Industries is to further strengthen the economic performance of cultural and creative professionals and to contribute to their success at national and international level. As a result of their support, start-ups can exploit the knowledge and experience of JOSEPHS'® staff and gain access to co-creators in order to address some of their most pressing innovation challenges.

As most of JOSEPHS'® co-creators do not represent PersonalisedBuggy's typical customers, so instead of testing the actual product, the company focused more on their online configurator. The online configurator allows people to customise strollers to their needs and wants. Through the living lab, the company wanted to better understand the market's acceptance of their online configurator.

Sources

JOSEPHS® (2021). Website: https://josephs-innovation.de/wp/
JOSEPHS® (2021). Facebook page: www.facebook.com/josephslab/

Interviews, focus groups, documentary information, observations

The City of the Future Living Lab	**Location** Milan, Italy

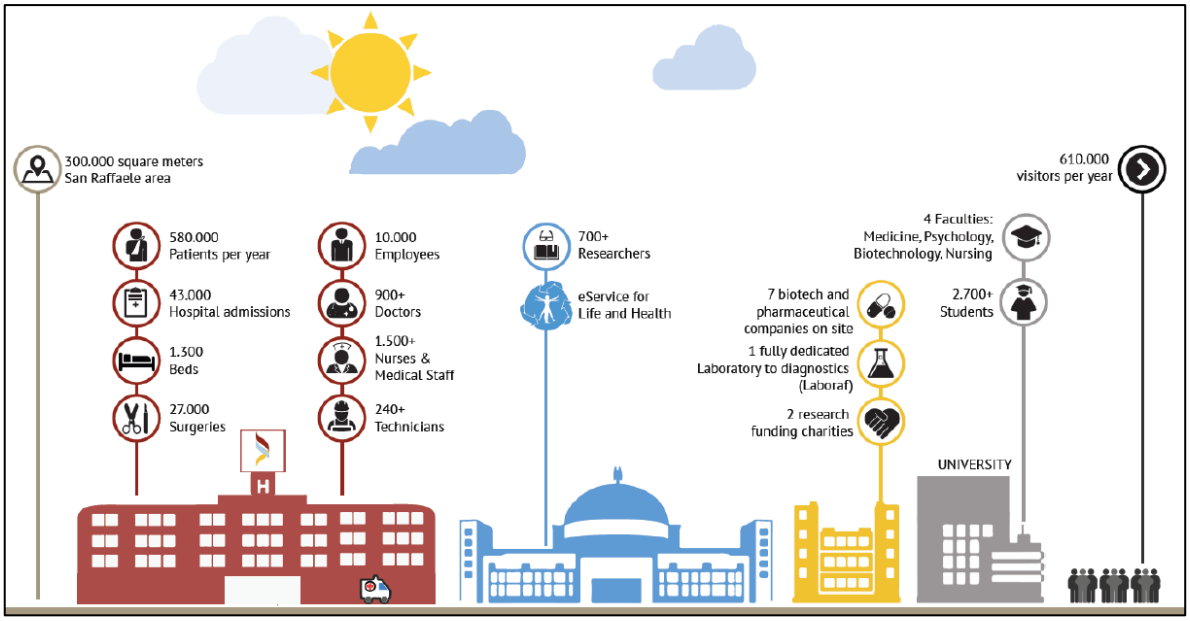
Description

San Raffaele Hospital has set-up the City of the Future Living Lab in Milan, Italy. The living lab represents both a virtual as well as a real research environment and community. The City of the Future Living Lab is an ecosystem consisting of different stakeholders which work alongside each other sharing knowledge whilst interacting with a variety of ICTs. More specifically, the City of the Future Living Lab is a miniature version of a city and includes a hotel, a hospital, stores and offices, a supermarket and a post office, a shuttle and bus service as well as streets and parks. Such an environment helps foster innovation, whilst supporting the transition from fundamental to applied research.

San Raffaele Hospital & Science Park

San Raffaele Scientific Institute's City of the Future Living Lab in Milan has been created to observe an extended number of users interacting with a great number of services within a real city environment, as well as to engage them in a co-creation process that triggers and helps flourish tomorrow's e-Services. The unit is managed and organised by the Advanced Technology in Health & Wellbeing (previously called eServices for life and health), a department of Ospedale San Raffaele (OSR) that is specialised in the application of Information Technology to health, with the objective of developing and delivering services for everyday life, well-being and nurturing innovation across different domains and disciplines.

San Raffaele Hospital's Science Park and The City of the Future Living Lab



Source: Vicini, 2012

Project Example

The City of the Future Living Lab engages in co-creation with a variety of stakeholders. For example, a team of paediatricians, doctors, child psychologists, nutritionists, designers and engineers were all involved in the efforts of developing an interactive kiosk. The Totem for Kids service for children in the hospital involved the City of the Future team that is analysing, testing and modifying a series of software and hardware solution to select the best prototype to be deployed in the pediatric ward. A first version of the kiosk was placed in the ward and hospital children were observed interacting with it by means of an intensive ethnographic study. At the same time, its software, and camera positioned on the kiosk, obtained relevant information regarding their interactions. In this example, the end user played a key role actively contributing to improving this prototype.

Sources

Vicini, S., Bellini, S. and Sanna, A., 2012. The city of the future living lab. *International Journal of Automation and Smart Technology*, *2*(3), pp.201-208.

Lab4living

Location

Sheffield, UK

Description

Lab4living is a living lab founded in 2007. The main focus of the living lab is the use of co-creation to address issues associated with care, ageing and disability. Lab4living draws upon the expertise of the Art and Design Research Centre (ADRC) and the Centre for Health and Social Care Research (CHSCR) at Sheffield Hallam University.

The university hosts the physical living lab, where data collection can take place to investigate the interaction of users with their environment. Activities of the living lab, often integrating creative arts, design with healthcare approaches and disciplines, have resulted in over 100 projects and collaboration with more than 80 organisations internationally.

The objective of the living lab, which is to maximise its visibility and impact, is evidenced by some of its actions. In 2011, Lab4Living launched the Design4Health conference, and this is expected to run every 2 years, and, in 2017, it contributed to the launch of a new journal “Design for Health”, published by Taylor & Francis Online.

Project Example

The projects to which lab4living contributed to are very diverse. For example the Life Café’ Kit consists of a set of resources to facilitate discussion around what people perceive as important in life and care. The resource contributes to the identification of new approaches to end of life and palliative care and was developed by building on the experiences of community living individuals. Other projects targeted have very different demographics; for example, the “whose diabetes is it anyway?” initiative focuses on supporting young people to deal with diabetes. Another area of particular importance to lab4living is understanding the manufacturing process, with several projects having taken place in a commercial setting. The facilities available to the living lab allow the support of a testing and prototyping process, but also its aim is to observe how people interact and engage with their environment as part of the making process.

Sources

Lab4living (2021) *Website*: www.lab4living.org.uk

European Network of Living Labs (ENoL) (2021) *Lab4living.* ENoL website https://enoll.org/

University Alliance (UA) (2021) *Lab4living.* UA website: www.unialliance.ac.uk/

Seongnam Senior Experience Complex	Location Seongnam, South Korea

Description

The Seongnam Senior Experience Complex started in 2013 as an 'Experience Complex' without a living lab. The area in which the facility is located is called the 'Pangyo Techno Valley' and is characterised by an older demographic making it an ideal place to engage with seniors. The space was already used by seniors and companies in 2016 and the idea of a living lab was initiated. The Seongnam Senior Experience Complex not only continued to attract their seniors but also involved them more actively in the development of products, services and technologies. Predominantly it was micro companies but also, increasingly, large firms now engage with this living lab. Staff, who are often seniors themselves, guide the elderly through the living lab presenting the companies and the products that they are testing in the space. The staff are specifically trained for the interaction with seniors. Products, services and technologies that are exhibited in the Seongnam Senior Experience Complex have to be aimed at seniors in order to qualify for the space. The development stages of these products, services and technologies vary ranging from early stage prototypes to commercialised products.

The Seongnam Senior Experience Complex Testing Facilities

Healthcare Technology

The Seongnam Senior Experience Complex includes a range of complementary facilities and services that appeal to senior citizens. For example, a café, a library, gym and medical centre is on-site offering a variety of services to the people. The medical centre offers different health checks, such as measuring bone density and metabolism. The service is mutually beneficial: seniors can take advantage of the service and the centre uses the data for research purposes. In a similar vein, the gym provides information on seniors' fitness levels that are used for research purposes.

The living lab is completely government funded and aimed at local companies. However, it is also open to companies from other regions which are paying rent (subsidized by the government as well) in order to use the facilities.

Project Example

The companies using the Seongnam Senior Experience Complex would like to receive direct feedback from seniors in order to create products, services and technologies that are aligned with the needs of their customers. Companies with already commercialised products come in order to further refine and improve their products. The companies explore a range of aspects in the living lab which include, for example, usability and market acceptance from customers in relation to their products but they also want to get exposure and understand the price acceptability of their customers. As part of the co-creation process, sometimes new challenges and problems are observed when testing a product or service with elderly people. The products tested in the facility are very diverse, including, for example, beds, hygiene products, household goods such as forks and a toothbrush. Also bathtubs and kitchen furniture are tested and co-created at the Seongnam Senior Experience Complex. The building also contains smart home devices and sensors for seniors to test and engage with.

Sources

Interviews, Observations

APPENDIX 3: International DIHs

Table A3: List of International DIHs

International DIHs	Country
European Digital Innovation Hub the Northern Netherlands / Region of Smart Factories	Netherlands
Industrial Ring (Anella Industrial)	Spain
Smart Connected Supplier Network Netherlands	Netherlands
Innovation Centre Kosovo (ICK) (Qendra Inovative e Kosoves)	Kosovo

European Digital Innovation Hub the Northern Netherlands / Region of Smart Factories – Netherlands

The Digital Innovation Hub Northern Netherlands / Region of Smart Factories (DIH/RoSF) is a non-profit service oriented competence centre used to accelerate the digital transformation (Industry 4.0) of the Industry in The Northern Netherlands. With the launch of the DIH, an acceleration of digitalisation in the entire economy is aimed for through three tracks:

- 'Go Digital' aims to get all companies to the stage of consciousness/competence with regard to digitalisation.
- 'Play the Champions League' aims to connect their frontrunners with the EU innovation programs and to share their competences with additional regions.
- 'Create & Share talents and competences' by three regional demo factories that annex skills labs.

The DIH receives regional funding, partner's resources and national specific innovation funding. The initiative is supported by an economic development agency, networks, cluster organisations, an incubator/accelerator, universities, national and regional government and an industry association. The hub has several links to national and regional initiatives for digitising industry. For example, the DIH contributes to the Dutch Smart Industry Agenda in order to realise the most flexible and digitally connected manufacturing industry in Europe. As part of the Dutch Smart Industry Agenda, five regional Digital Innovation Hubs (DIH's) will be established in order to accelerate the transformation of the manufacturing sector. The DIH/RoSF is the Hub for the Northern Netherlands and plays a key role in the regional policy to become a frontrunner in digitalisation, as it will be part of the following RIS strategy.

Organisational form	**Turnover**
(part of) Public organisation (part of RTO, or university)	>5.000.000 Euro

TRL Focus

- TRL2 - Technology concept and/or application formulated
- TRL3 - Analytical and experimental critical function and/or characteristic proof of concept
- TRL4 - Component and/or breadboard validation in laboratory environment
- TRL5 - Component and/or breadboard validation in relevant environment
- TRL6 - System/subsystem model or prototype demonstration in a relevant environment
- TRL7 - System prototype demonstration in an operational environment
- TRL8 - Actual system completed and qualified through test and demonstration

Mission

Produce Smart Products in a Smart Factory to build up a strong and sustainable economy, and to keep people at work and solve societal challenges.

Market sectors

- Manufacture of rubber and plastic products
- Manufacture of basic metals and fabricated metal products
- Manufacture of machinery and equipment
- Manufacture of electrical and optical equipment

- Other manufacturing

Technological competences	**Services Provided**
• Micro and nano electronics, smart system integration • Sensors, actuators, MEMS, NEMS, RF • Photonics, electronic and optical functional materials • Cyber physical systems (e.g. embedded systems) • Robotics and autonomous systems • Internet of Things (e.g. connected devices, sensors and actuators networks) • Artificial Intelligence and cognitive systems • Location based technologies (e.g. GPS, GIS, in-house localisation) • Interaction technologies (e.g. human-machine interaction, motion recognition and language technologies) • Advanced or High performance computing • Data mining, big data, database management • Augmented and virtual reality, visualisation • Simulation and modelling • Software as a service and service architectures • Additive manufacturing (3D printing) • ICT management, logistics and business systems • New media technologies	• Awareness creation • Ecosystem building, scouting, brokerage, networking • Visioning and strategy development for businesses • Collaborative research • Concept validation and prototyping • Testing and validation • Pre-competitive series production • Digital maturity assessment • Incubator/accelerator support • Access to funding and investor readiness services • Mentoring • Education and skills development

European Commission (2021) *European Digital Innovation Hub the Northern Netherlands / Region of Smart Factories.* European Smart Specialization Platform website: https://s3platform.jrc.ec.europa.eu/home

Industrial Ring (Anella Industrial) – Spain

The Industrial Ring (Anella Industrial) is a foundation that brings together engineers, manufacturers (OEM and TIER1), technology providers, associations, research centres, universities and government with the aim to identify, develop and promote best practices around 4.0 Industry or the Industrial Internet. Anella Industrial and the projects managed by Anella are part of the Catalan regional strategy for industry. It is currently part of a H2020 competitive project, BOOST4.0, serving as a hub for implementing the big data services developed in the project. Anella Industrial is obtaining regional as well as private funding and is supported by a variety of partners. These include start-ups, SMEs, Mid-caps, an economic development agency, RTOs, large enterprises, industry association and regional government. Employing an open innovation approach, companies and the entire value chain participate actively in identifying needs that are difficult to solve by a single company, creating multidisciplinary groups to create and build collaborative solutions that help companies achieve their business objectives. The Industrial Ring is a community open to different strategic sectors of Catalonia. It is acting as coordinator and catalyst for collaboration between companies.

Organisational form	**Turnover**
Foundation	0-250.000 Euro

TRL Focus

- TRL4 - Component and/or breadboard validation in laboratory environment.
- TRL5 - Component and/or breadboard validation in relevant environment.

Objectives

- Drive innovation by creating use cases and pilots.
- Providing infrastructure solutions to enable testing in real environments.
- Promote success stories and provide forums for sharing best practices and results.
- To facilitate the adoption of new technologies in SME companies.
- Participate in forums and international organisations to develop standards.

Market sectors

- Transport, storage and communication
- Manufacture of machinery and equipment
- Manufacture of electrical and optical equipment
- Manufacture of transport equipment

Technological competences	**Services Provided**
• Broadband and other communication networks (e.g. 5G) • Internet of Things (e.g. connected devices, sensors and actuators networks) • Location based technologies (e.g. GPS, GIS, in-house localisation) • Advanced or high performance computing • Software as a service and service architectures • Cloud computing	• Awareness creation • Ecosystem building, scouting, brokerage, networking • Collaborative research • Concept validation and prototyping • Testing and validation • Commercial infrastructure

European Commission (2021) *Industrial Ring.* European Smart Specialization Platform website: https://s3platform.jrc.ec.europa.eu/home

Smart Connected Supplier Network – Netherlands

Smart Connected Supplier Network (SCSN) is a Dutch "Smart Industry" initiative that enables digital collaboration in the supply chain. SCSN originated, among other things, from the innovation project, Links in the Chain, which is part of the Factory of the Future Innovation Program and is supported by the province of Noord-Brabant. To safeguard the developments made during this project in the long term, an independent management organisation has been set up: the Smart Connected Supplier Network Foundation.

The purpose of the Foundation

- Professional and sustainable management, maintenance and improvement of the SCSN standard;
- ensuring that the interests of all SCSN members are carefully weighed;
- continuously guaranteeing the quality of the SCSN standard and its use;
- coordinating the management of the technical infrastructure, including the address book;
- taking care of general communication about and promotion of SCSN, including providing a first point of contact;
- maintaining contact with relevant other standards and organisations;
- being a sustainable, financially independent organisation that is financed by contributions from members.

The activities of the hub are aligned with the Dutch national initiative for digitising industry, Smart Industry - Dutch Industry fit for the Future. SCSN is led by Brainport Industries and supported by TNO. Other partners that support this initiative include large enterprises, mid-cap companies, SMEs, start-ups, national as well as regional government, and industry associations. SCSN obtains funding through a number of ways, including Horizon 2020 funding, national basic research funding, national specific innovation funding, regional funding, private funding, partner resources and memberships. SCSN is an open initiative and the documentation regarding the application and use of it is completely public. The SCSN messages can be viewed via the Semantic Treehouse management environment.

Different supply chain partners do not collaborate in a digital way yet due to the different and non-interconnected ICT systems that they employ. In order to address this challenge, the partners of the SCSN digital innovation hub established a standard for information sharing based on semantic technology, and, in so doing, they facilitated optimal interoperability between the supply chain partners for the most prominent information streams. Implementation and scaling are becoming easier and this enables manufacturing companies to reduce the administrative burden and helps them to avoid errors. Further, it also offers agility of the entire supply chain as well as a more successful management of risks. As a result, this decreases the time-to-market for manufacturing companies and suppliers, enabling them to react faster to changing market demands.

Several hundred **manufacturing companies** are currently connected to the SCSN network. Participants vary from larger OEMs and first-tier suppliers, to smaller second and third-tier suppliers, but also (steel) wholesalers and even steel manufacturers. Manufacturing companies can connect to SCSN via a Service Provider. The Service Provider ensures that the IT systems are correctly connected to the SCSN network and the processes messages. Manufacturing companies are free to choose a service provider that best suits their needs. The different service providers in the SCSN's network each have their own proposition. The service providers each transfer part of these costs to the SCSN Foundation (the independent management organisation of SCSN).

Organisational form	**Turnover**
Foundation	1.000.000-5.000.000 Euro

TRL Focus • TRL6 - System/subsystem model or prototype demonstration in a relevant environment. • TRL7 - System prototype demonstration in an operational environment. • TRL8 - Actual system completed and qualified through test and demonstration.	
Objectives • This is to foster the general conditions and governance of a reference architecture for International Data Spaces and interfaces with the aim of achieving an international standard. • This is to develop and continue to work on the standards for International Data Spaces based on use cases. • This is to support certifiable software solutions and business models.	
Market sectors • Manufacture of machinery and equipment • Manufacture of electrical and optical equipment	
Technological competences • Software as a service and service architectures • ICT management, logistics and business systems	**Services Provided** • Collaborative research • Concept validation and prototyping • Testing and validation • Technological competences • Software as a service and service architectures • ICT management, logistics and business systems
European Commission (2021) *Smart Connected Supplier Network.* European Smart Specialization Platform website: https://s3platform.jrc.ec.europa.eu/home	

Innovation Centre Kosovo (ICK) (Qendra Inovative e Kosoves) - Kosovo

Innovation Centre Kosovo (ICK) is the leading local integrator of innovative businesses and entrepreneurship, supporting the visibility of Kosovo as the future business destination. The mission of ICK is to create new jobs and business prosperity by supporting entrepreneurs, start-ups and existing businesses. As such, the role of ICK is to foster entrepreneurship, innovation and commercially based business development, with a focus on information and communication technology.

The establishment of ICK was financially supported by The Norwegian Ministry of Foreign Affairs. It was initiated as a project of Athene Prosjektledelse, Norway and the Kosovo Association of Information and Communication Technology (STIKK) with Crimson Capital LLC in June 2012, with Kosovo being the main cooperating partner on this initiative. ICK is funded by the Embassy of Sweden in Prishtina and Royal Norwegian Embassy in Prishtina. The centre partners with Chambers of Commerce, Association of Regional Development Agencies, a university and a SME.

Innovation Centre Kosovo (ICK) is a centre that is connecting scientific research and development with the business sector, focusing on creating new job opportunities oriented towards the future, based on knowledge and new technology. The Centre supports both start-ups and existing companies (SMEs). ICK creates new jobs through the creation and growth of businesses and through the training of young people for job opportunities in the labour market. ICK serves as a hub for connecting new ideas and technology with human and financial resources to create or expand commercially viable companies that can successfully capitalise on market opportunities, generating sales, trade, local productive capacity and skilled employment. Innovation Centre Kosovo offers incubator services, mentoring, consulting and training to entrepreneurs and managers in business planning, accounting, finance, product/service development, marketing/ sales, human resources, technology development and transfer, and matchmaking with local, regional and international businesses.

Although, Kosovo currently has no national initiative for digitising its industry, ICK is an important actor on the implementation of Kosovo's ICT strategy. The centre is also a member of the National Council for Innovation and Entrepreneurship, appointed by the Office of the Prime Minister of Kosovo. Furthermore, ICK is member of a number of international associations such as the European Alliance for Innovation (EAI).

Organisational form	**Turnover**
Foundation	500.000-1.000.000 Euro

TRL Focus

- TRL9 - Actual system proven through successful mission operations.

Objectives

- ICK aims to advance innovation and entrepreneurship to new levels, in which the entrepreneurial spirit and culture of innovation are reflected amongst individuals, companies and government, though creating a functional ecosystem in which ventures are supported to produce growth and sustainability.

- ICK supports the aspiration of individuals, private institutions, governments and foreign investors to achieve development by generating innovative ideas and introducing new products, services and operations that will improve the overall quality of life of Kosovo citizens, and increase the competitiveness of the local economy.

Market sectors

- Wholesale and retail trade
- Public administration and defence
- Education
- Manufacture of electrical and optical equipment
- Other markets
- Financial intermediation

Technological competences

- Internet of Things (e.g. connected devices, sensors and actuators networks)
- Artificial Intelligence and cognitive systems
- Location based technologies (e.g. GPS, GIS, in-house localisation)
- Interaction technologies (e.g. human-machine interaction, motion recognition and language technologies)
- Cyber security (including biometrics)
- Data mining, big data, database management
- Augmented and virtual reality, visualisation
- Simulation and modelling
- Gamification
- Software as a service and service architectures
- Cloud computing
- Additive manufacturing (3D printing)
- ICT management, logistics and business systems
- Internet services (e.g. web development, web production, design, networking, and e-commerce)
- New Media technologies

Services Provided

- Awareness creation
- Ecosystem building, scouting, brokerage, networking
- Visioning and strategy development for businesses
- Concept validation and prototyping
- Testing and validation
- Pre-competitive series production
- Commercial infrastructure
- Incubator/accelerator support
- Market intelligence
- Access to funding and investor readiness services
- Mentoring
- Education and skills development

European Commission (2021) *Innovation Centre Kosovo (ICK).* European Smart Specialization Platform website: https://s3platform.jrc.ec.europa.eu/home

APPENDIX 4:
Characterising Demonstration Environments

Table A3: Characterising Demonstration Environments

Cluster 0		Cluster 1		Cluster 2		Cluster 3		Cluster 4	
Keyword	Count	Keyword	Count	Keyword	Count	Keyword	Count	Keyword	Count
pilot plant	184	techniques : interferometric	23	simulation	47	optimization	49	performance assessment	23
co2 capture	83	stars: fundamental parameters	22	modeling	31	wireless sensor networks	35	data assimilation	22
biomass	62	astrometry	22	optimization	31	simulation	32	remote sensing	18
modelling	61	techniques: interferometric	21	robust control	26	scheduling	30	waste isolation pilot plant	17
desalination	59	galaxies: evolution	19	model predictive control	25	machine learning	30	forecasting	16
reverse osmosis	58	stars : fundamental parameters	18	fault diagnosis	24	algorithms	28	simulation	15
simulation	57	methods: numerical	15	control	21	neural networks	27	epistemic uncertainty	14
modeling	55	circumstellar matter	14	modelling	20	genetic algorithms	26	transuranic waste	13
gasification	55	planetary systems	12	cfd	19	fault diagnosis	24	radioactive waste	12
ultrafiltration	47	binaries: close	12	test bed	19	genetic algorithm	24	performance	12
biogas	41	galaxies: dwarf	11	process control	19	performance	23	numerical weather prediction	11
wastewater treatment	40	infrared: stars	10	heat transfer	19	uncertainty	21	modeling	11
scale-up	39	binaries : spectroscopic	10	predictive control	18	reinforcement learning	21	calibration	11
optimization	37	binaries: spectroscopic	10	mass transfer	18	experimentation	19	aleatory uncertainty	11
pyrolysis	34	techniques: photometric	10	adaptive control	17	localization	18	ensembles	11
hydrogen	33	techniques: high angular resolution	9	testbed	17	global optimization	16	validation	11
combustion	32	stars: formation	9	pilot plant	16	metaheuristics	16	compliance certification application	10
renewable energy	32	binaries: general	9	computational fluid dynamics	16	particle swarm optimization	14	precipitation	10
nanofiltration	31	infrared : stars	8	system identification	16	fault detection	14	green roof	10
fouling	30	molecular electronics	8	numerical simulation	16	data assimilation	14	sensitivity analysis	10
wastewater	30	surveys	8	electric vehicle	15	heuristics	14	climate change	10
fluidized bed	27	instrumentation: high angular resolution	8	calibration	14	design	13	subjective uncertainty	10
coal	27	stars: atmospheres	8	hardware-in-the-loop	14	feature selection	13	machine learning	10
iter	26	binaries: eclipsing	8	dynamic simulation	14	measurement	12	radioactive waste disposal	9
carbon dioxide	25	methods: data analysis	8	scale-up	13	fuzzy logic	12	latin hypercube sampling	9
solar energy	25	black hole physics	8	optimal control	13	process control	12	forecast verification	9
membrane bioreactor	25	galaxies: formation	8	condition monitoring	12	testbed	12	performance evaluation	9
chemical looping combustion	24	stars : pre-main-sequence	8	structural health monitoring	12	deep learning	12	retention	8
anaerobic digestion	24	techniques: radial velocities	8	kalman filter	12	evolutionary algorithms	12	stochastic uncertainty	8
syngas	23	binaries : visual	8	real-time control	11	energy efficiency	11	uncertainty analysis	8
hydrogen production	22	stars: oscillations	7	microgrid	11	load balancing	11	daylighting	8
calcium looping	21	shock waves	7	sliding mode control	11	evolutionary computation	11	ensemble kalman filter	8
kinetics	21	stars: late-type	7	nonlinear control	11	adaptive control	11	skill	8
biodiesel	21	binaries: visual	7	diesel engine	11	integer programming	11	model evaluation	8
mass transfer	21	cosmology: theory	7	parameter estimation	11	wireless sensor network	11	yucca mountain	8
process simulation	20	stars: evolution	7	parameter identification	11	artificial neural networks	11	soil moisture	8
absorption	19	galaxies: active	7	dynamics	11	sensor networks	11	energy consumption	7
hydrodynamics	19	planets and satellites: detection	7	model predictive control (mpc)	11	clustering	11	energy efficiency	7
adsorption	19	graphene	7	neural network	10	sensitivity analysis	10	optimization	7
membrane	19	dark matter	7	quadrotor	10	reliability	10	radar observations	7
drinking water	18	stars: abundances	6	reliability	10	combinatorial optimization	10	yeast	7
carbon capture	18	instrumentation: interferometers	6	smart grid	10	data mining	10	fouling	7
pretreatment	18	ism: molecules	6	stability	10	routing	10	structural health monitoring	7
water reuse	18	spectroscopy	6	fuzzy logic	10	networked control system	10	radars	7
mea	18	accretion, accretion disks	6	wireless sensor networks	9	multi-agent systems	10	hydrometeorology	7
heat transfer	18	atmospheric effects	6	wireless sensor network	9	anomaly detection	10	monitoring	7
efficiency	17	hydrodynamics	6	mathematical modeling	9	collision avoidance	10	reliability	6
optimisation	17	techniques: image processing	6	hydrodynamics	9	multi-objective optimization	10	pilot plant	6
control	17	galaxies : active	6	artificial neural network	9	stability	9	thermal comfort	6
life cycle assessment	17	stars: interiors	5	genetic algorithm	9	distributed algorithms	9	design	6

Continued next page

Table A3: Characterising Demonstration Environments (*Continued)*

Cluster 5		Cluster 6		Cluster 7		Cluster 8		Cluster 9	
Keyword	Count	Keyword	Count	Keyword	Count	Keyword	Count	Keyword	Count
cloud computing	104	photocatalysis	57	pilot plant	167	wireless sensor networks	160	living lab	73
testbed	95	pilot plant	52	wastewater treatment	94	testbed	85	living labs	51
wireless sensor networks	62	photo-fenton	37	reverse osmosis	92	performance	67	open innovation	46
internet of things	56	kinetics	30	wastewater	75	design	65	innovation	45
security	55	co2 capture	30	membrane bioreactor	74	wireless networks	52	sustainability	27
performance	43	titanium dioxide	25	ultrafiltration	73	routing	52	experimentation	24
simulation	41	solar photocatalysis	24	activated sludge	63	ieee 802.11	51	co-creation	23
grid computing	37	wastewater treatment	21	fouling	63	energy efficiency	50	testbed	22
openflow	37	catalyst	19	nanofiltration	56	openflow	50	smart city	21
experimentation	36	pesticides	19	nitrification	51	tcp	48	design	15
design	33	pyrolysis	17	anaerobic digestion	49	experimentation	46	smart grid	15
virtualization	32	carbon dioxide	16	biofilm	46	wireless sensor network	44	collaboration	15
performance evaluation	32	biomass	15	biogas	46	congestion control	43	internet of things	15
sdn	30	solar photo-fenton	15	membrane fouling	44	security	42	testbeds	12
smart grid	30	hydrodesulfurization	14	microfiltration	42	performance evaluation	42	cities	11
internet of things (iot)	29	biodegradability	14	denitrification	42	algorithms	41	participation	11
quality of service	28	water treatment	13	adsorption	38	network coding	39	action research	10
testbeds	26	oxidation	13	co2 capture	35	wireless mesh networks	35	sustainability transitions	10
software-defined networking	25	phenol	13	biomass	35	wireless	33	sustainable development	10
resource management	23	ozone	13	membrane	32	quality of service	32	evaluation	10
wireless sensor network	23	toxicity	12	ozonation	32	internet of things	32	smart cities	9
iot	22	absorption	12	nitrogen removal	31	qos	30	simulation	9
machine learning	21	modeling	12	modelling	29	ieee 802.15.4	30	machine learning	9
algorithms	21	adsorption	12	water treatment	29	measurement	30	education	9
monitoring	21	simulation	11	mbr	28	sdn	28	participatory design	9
energy efficiency	21	ozonation	11	heavy metals	27	5g	28	technology	9
middleware	21	advanced oxidation processes	11	pretreatment	27	ofdm	27	performance	9
emulation	20	solvent extraction	11	coagulation	27	sensor networks	27	urban living labs	8
measurement	18	hydrogen peroxide	10	disinfection	25	mobility	25	circular economy	8
intrusion detection	18	wastewater	10	ozone	25	fairness	24	energy efficiency	8
cyber-physical systems	18	hydrotreating	10	scale-up	25	wlan	24	pilot plant	7
distributed computing	18	scale-up	10	filtration	25	video streaming	24	data mining	7
interoperability	17	sunlight	10	biodegradation	24	cloud computing	24	ict	7
ontology	17	mea	9	pilot scale	23	voip	24	learning	7
future internet	16	tio2	9	drinking water	23	software-defined networking	23	measurement	7
ubiquitous computing	16	flue gas	9	pharmaceuticals	23	reliability	23	user innovation	7
qos	16	reactive distillation	9	wastewater reuse	22	load balancing	22	urban living lab	7
sensor networks	15	biodiesel	9	fluidized bed	22	802.11	21	ambient assisted living	7
routing	15	solar photoelectro-fenton	9	fermentation	21	multicast	21	governance	7
scalability	15	catalysis	9	nutrient removal	21	medium access control	21	co-design	7
software defined networking	15	activated carbon	9	modeling	21	cognitive radio	20	innovation labs	7
resource allocation	14	esterification	9	constructed wetlands	21	internet of things (iot)	19	future internet	7
network virtualization	14	ferrioxalate	8	photo-fenton	21	throughput	19	energy	6
reliability	14	deactivation	8	anammox	21	data center	18	social innovation	6
big data	14	nanofiltration	8	desalination	20	optical networks	18	usability	6
federation	14	extraction	8	flocculation	19	optimization	18	renewable energy	6
distributed systems	14	water detoxification	8	municipal wastewater	19	scheduling	18	virtual reality	6
internet	14	methanol	8	groundwater	18	mimo	18	security	6
scheduling	13	solar radiation	8	nitrogen	18	rate adaptation	17	crowdsourcing	6
network management	13	photocatalytic oxidation	7	carbon dioxide	18	time synchronization	17	smart environments	6

APPENDIX 5:
DIHs and their Innovation Functions

Table A4: List of Digital Innovation Hubs by innovation function

Innovation function	DIH	Country
Knowledge generation	Centre for Applied Data Analytics and Machine Intelligence, CeADAR	Ireland
	BI-REX - Big Data Innovation & Research Excellence	Italy
	OuluHealth	Finland
Knowledge Diffusion	EOSC-DIH	Netherlands
	FIWARE Innova iHub	Italy
	Urban ICT Arena	Sweden
	AFIL (The Lombardy Cluster for the Advanced Manufacturing)	Italy
	Healthday.si - Digital Innoation Hub in Healthcare and Biotech	Slovenia
Knowledge Application	Digital Innovation Hub for Smart Manufacturing Pomurje Technology Park	Slovenia
	Silesia Smart Systems	Poland
	AddedValue	Hungary
	Baltic Maritime Digital Innovation Hub	Lithuania
	Foundation for Research and Technology – Hellas (FORTH) / PRAXI Network	Greece

Technology Development

KNOWLEDGE GENERATION

Function

Technology demonstration

DIH	Location
Centre for Applied Data Analytics and Machine Intelligence, CeADAR. Website: www.ceadar.ie	Dublin, Ireland

Description

The primary outputs of the CeADAR centre are industry prototypes and demonstrators along with state of the art reviews of data analytics technology, tools, best practice methodologies and processes. The Centre has an extensive catalogue of technology demonstrators, IP and big data analytics technology reviews, which are all immediately available for evaluation by members.

Service Example

- **Client profile:** The RealValue consortium is a partnership which has the full participation and commitment from the whole energy supply chain. The consortium includes the following: technology developers (BEGGY, Glen Dimplex, Intel); energy system modelling specialists (UCD, DIW, RTU); energy market specialists (VTT); socio-economic experts (Oxford University); electricity network operators (ESBN, EirGrid) and energy utilities (MVV, SSE). RealValue was designed to accelerate innovation and develop the business models necessary for small-scale storage, allowing it to form an integral part of the future EU energy landscape.
- **Client needs:** RealValue aimed to demonstrate how local small-scale energy storage, optimised with advanced ICT, could bring benefits to market participants throughout the EU.
- **Provided solution to meet the needs:** Smart Electric Thermal Storage (SETS) was deployed in physical demonstration trials in 1250 homes in Germany, Latvia and Ireland but the analysis also considered other storage technologies and energy vectors, including integration with district heating and micro-generation. SETS is a direct replacement for existing electric thermal storage heaters and water tanks with a combined load of 55GW across the EU. It also replaced direct electric resistance heaters with a further connected load of 93GW. To validate the physical demonstrations at large scale, RealValue used modelling & virtual simulation to demonstrate the technical and commercial potential in millions of homes across representative EU regions. Thorough research studies are an integral part of RealValue and included a techno-economic and behavioural analysis that could inform EU regulation and policy decision makers. RealValue developed business models to quantify the potential of small-scale storage as an aggregated controllable load. It provided system services or released value through price arbitrage within existing energy market structures, and highlighted any barriers associated with integration into the electricity grid.

More details

http://www.realvalueproject.com/

Technology Development

KNOWLEDGE GENERATION

Function

Manufacturing demonstration

DIH	Location
BI-REX - BIG DATA INNOVATION & RESEARCH EXCELLENCE. Website: https://bi-rex.it/	Bologna, Italy

Description

BI-REX is one of the eight Competence Centres founded by the Italian Ministry of Economic Development within the 4.0 Industry National Plan framework. The centre, as reported in its chart is a not-for-profit consortium which carries out its external activities following its non-profit aim and is focused on Big Data. BI-REX is a public-private consortium that was established on the 11th of December 2018 in Bologna and is gathering in its partnership 56 actors: 12 bodies between the universities and research centres and 44 enterprises of excellence working in the field of services finance and logistics, energy, automotive and aerospace, mechatronics, ICT, biomedical and agree-food. BI-REX collects the know-how of the Emilia Romagna High Technology network (existing industrial research laboratories, infrastructures, Digital Innovation Hubs - DIH) but with a national and international road map. One of the main goals of the centre is to assist companies, especially SMEs, in the adoption of Industry 4.0 technologies.

Service Example

- **Client profile:** a company working in the additive manufacturing sector. The company is very small, but aims at improving the level of its production by investing in 3d-metal-printing technology. Before investing in this technology, the company needs to test the 3d-metal-printing equipment in order to be sure it responds to its expectations.
- **Client needs:** to access 3d-metal-printing technology to test its suitability with reference to the company business.
- **Provided solutions:** Bi-Rex Digital Capability Center is an advanced production line, a smart factory pilot where new Industry 4.0 technologies are integrated with traditional ones, in a digitally interconnected environment. This pilot plant hosts the main innovative I4.0 technologies, and among them is the selective laser melting machine that is available for use by companies and SMEs, with the assistance of a highly specialised technician. It is important to remark that the Digital Capability Center will be continuously under development, to add the last I4.0 technologies. In this way, client companies will always have the opportunities to test the most innovative tools and equipment, in order to be competitive towards national and foreign enterprises working in the same field.

More details

https://bi-rex.it/en/linea-pilota-en/

Technology Development

KNOWLEDGE GENERATION

Function

User co-creation/utility demonstration

DIH	Location
OuluHealth. Website: https://ouluhealth.fi/	Oulu, Finland

Description

OuluHealth is one of the leading digital health innovation ecosystems in Europe. Members of the OuluHealth ecosystem represent the whole spectrum of health and social care, including specialised medical care, primary health and social care, health and wellbeing industry and commerce, health technology research and education, and citizens. The main stakeholders of OuluHealth are Oulu University Hospital (OYS), University of Oulu, Oulu University of Applied Sciences, VTT Technical Research Centre of Finland, and BusinessOulu and the Department of Healthcare and Social Welfare of the City of Oulu. The OuluHealth ecosystem also encompasses more than 600 health and life science companies, where at least 240 of them are high-tech companies (http://ouluhealth.fi/companies/).

Service Example

- **Client profile:** Monidor Ltd is a health-technology startup which specialises in the development of small smart devices for digital health to help healthcare professionals in their daily work. Monidor has developed a small and easy to use device that ensures a proper intravenous therapy for every patient.
- **Client needs:** End-user testing for their product
- **Provided service:** OuluHealth provided co-creation and testing services in the living lab (OuluHealth Labs). Healthcare professionals tested the product and provided valuable feedback informing on further development. Moreover, Monidor had the opportunity to test their product in Lund and Uppsala (Sweden) as OuluHealth Labs is a member of the Nordic Test Beds.

More details

http://ouluhealth.fi/ouluhealth-labs-test-environments-simulations-aid-companies/

Technology Development

KNOWLEDGE DIFFUSION

Function

Service innovation and design processes

DIH	Location
EOSC-DIH. Website: https://eosc-dih.eu/	Amsterdam, Netherlands

Description

The EOSC-hub Digital Industry Hub is a non-profit multi-dimensional entity that allows research e-Infrastructures to support business organisations to stimulate the innovation potential of research infrastructures, as well as helping SMEs, start-ups and other innovative actors to tap into the academic world both in accessing knowledge as well as technical services. The final goal is to create a one stop shop that brings IT services, research data, and expertise into a single place to support innovation in industry.

Service Example

- **Client profile:** TEXA, an Italian SME founded in 1992, designs, produces and sells diagnostic instruments for cars, motor bikes, and other vehicles. A serious challenge of this industry is that vehicle manufacturers generally have limited knowledge of a vehicle's life once it leaves them. A service that can predict failures, mechanical problems or damage at the component level, and offer detailed information on these components, would be extremely valuable, saving manufacturers and fleet managers both time and money. This service would gather and analyse data from TEXA's sensors, which could be used to redesign parts and modify maintenance schedules. This type of analysis requires significant computing power.
- **Client needs and provided solution:** CINECA, with the support of T2I, an Italian research organisation that helps companies through the design, development and testing of new products and services, has developed for TEXA four data analytics prototype services. These are based on the information gathered from TEXA's On-Board Diagnostics (OBD) systems. These services cover areas that may affect the reliability, condition, or service needs of a vehicle - such as how it is driven, failure patterns, and overall health of the vehicle. A Cloud HPC-powered workflow was developed. This was designed to easily integrate into TEXA's existing automotive data analytics services. A service architecture has been defined that connects the existing TEXA infrastructure,
  which is equipped to collect data from installed black boxes to a HPC Cloud provider.
- **Benefit:** TEXA estimated the net present value of these new services to reach an overall value of €1.2 M over the first 3 years of its availability. The ability to use a HPC-enabled workflow to analyse data from their diagnostics systems will enable a better oversight of their fleet vehicles and predict failures in time for these to be addressed
  quickly.

More details

https://www.fortissimo-project.eu/it/partners/texa-spa

Innovation System Development

KNOWLEDGE DIFFUSION

Function

Use cases

DIH	Location
FIWARE Innova iHub. Website: https://fiwareinnova.org/	Perugia, Italy

Description

FIWARE Innova iHub is a NOT-FOR-PROFIT association that supports the digital transformation process and promotes intelligent solutions in the Smart City and Smart Agri Food sectors, acting as a FIWARE reference hub in Italy. At the moment, in this country, FIWARE Innova iHub is the first and the only FIWARE iHub, and the only FIWARE certified expert. The FIWARE evangelists that are part of the association and represent the largest number of FIWARE evangelists in Italy.

Service Example

- **Client profile:** Local authority administrators and technicians of municipalities in Pesaro and Urbino Province.
- **Need:** understand the opportunities offered by the new technologies for cities and rural areas; on how to better use urban data and how to transform cities and towns in smart cities.
- **Provided solution:** reflections on the concepts needed to start the digitalisation process, and examples of applications and solutions to design an urban participatory project, urban lab and urban planning, starting from local to international experiments with concrete use cases.

More details

https://fiwareinnova.org/en/portfolio-items/progettare-le-citta-del-futuro-favorendo-un-diverso-approccio-al-valore-del-cittadino/

Innovation System Development

KNOWLEDGE DIFFUSION

Function

Network linkages

DIH	Location
Urban ICT Arena. Website: https://urbanictarena.se/	Kista, Sweden

Description

The Electrum Foundation in Kista Sciene City realised the disruptive effect of digitisation and decided to adapt and develop the collaboration by opening up and evolving from triple helix to quadruple helix by adding the individual/citizen/end-user. The result is an open testbed and co-creation arena where the possibilities of digitisation can be developed, tested and showcased in an urban environment.

Service Example

- Smart and connected archives - the Stockholm archives were developing a new archive and wanted it to be smart and connected according to the Digital Strategy - Smart and Connected City of the City of Stockholm.
- By arranging a workshop that is mixing small and large companies, academia and representatives from the public sector on a national, regional and local level, they managed to create a meeting where the following goals where reached:
  - The industry, academia and public sector understood each other's needs and conditions better.
  - They all got new networks to work with.
  - An insight of what digitisation could contribute grew exponentially.
  - The idea of a new local open lab for the smart and connected archives was born.

Innovation System Development

KNOWLEDGE DIFFUSION

Function

System intelligence

DIH	Location
AFIL (The Lombardy Cluster for the Advanced Manufacturing). Website: https://www.afil.it/	Milan, Italy

Description

AFIL is the result of a process driven by the Lombardy Region aimed at creating bodies which favour the aggregation of different regional players that are active in the field of Research and Innovation (R&I) within the priority areas identified in the Regional Smart Specialisation Strategy. AFIL is a no-profit private organisation aimed at fostering connections between all key relevant stakeholders (competence centres, industry, users and suppliers, technology experts and investors) that are able to boost the Industry 4.0 revolution and are facilitating Lombardy SMEs' access to EU value chains.

Service Example

- AFIL roadmap group periodically revise the Lombardy Advanced Manufacturing Roadmap, with the involvement of AFIL members that are asked to provide inputs, comments, suggestions according to the needs and challenges that they are facing. These updates are then transferred to the Lombardy Region that leverage on the roadmap to formulate future calls and revise its strategy accordingly.
- **Clients:** Lombardy Region
- **Clients' needs:** Align regional strategies with companies' emerging needs
- **Solution provided:** AFIL organise specific meetings to collect companies' needs and future challenges. Then the cluster developed the Roadmap for Advanced Manufacturing, in order to transfer the emerged input to the Lombardy Region.

More details

https://www.afil.it/wp-content/uploads/2018/07/AFIL_Roadmap_110714_Complete.pdf

Innovation System Development

KNOWLEDGE DIFFUSION

Function

Institution Development

DIH	Location
Healthday.si – Digital Innoation Hub in Healthcare and Biotech Website: www.healthday.si/	Ljubljana, Slovenia

Description

Technology park, Ljubljana, started an initiative, HealthDay.si, in 2014 to accelerate the placement of digital innovations into the healthcare system of Slovenia and globally. After 4 years, the HealthDay.si initiative reached its critical mass and began forming as a Digital Innovation Hub with clear goals and a vision. Technology Park Ljubljana is a non-for-profit organisation and consequently also DIH.Healthday.si is a non-for-profit initiative that is striving to support digital transformation in the healthcare sector. DIH HealthDay.si is a platform developed by the technology park Ljubljana which functions to assist companies with innovative healthcare solutions, to gain a better understanding of healthcare economics, for easier navigation through complex regulatory and certification procedures for medical devices. It supports companies with the technical compliance of digital solutions, quality management and provision of financing as well as providing the other resources needed for an accelerated application of innovative products and services in healthcare. A range of training courses and workshops were developed and delivered for companies by the key national experts to raise competences in areas such as the application and registration procedures of digital health solutions to the national Health Council, medico-economics, certification and technical compliance of digital health solutions, marketing in medicine, quality management and financing innovation in healthcare.

Service Example

- **Client profile:** Healthcare-based SMEs, medical device developers & suppliers, ICT-based SMEs
- **Client needs:** Emerging start-ups and scaling SMEs within the field of healthcare encounter challenges unbeknownst to companies in other sectors. One of the major barriers is ensuring product regulatory compliance. Digital healthcare companies do not acknowledge these aspects at the start of their development process, but rather act as a tech-based company, and following the lean methodology of business development they rapidly push to release a MVP that does not have all (if any) of the required certificates or clinical study results that may support the product's claims. It is, therefore, essential that entrepreneurs and innovators in healthcare put efficacy and regulatory compliance at the core of their innovation process, while, all the time, lean methodology principles are still applied, but just from a different angle. Understanding and grasping the full scope of the regulatory framework, both on the EU-level and on the national level, is a daunting and complex task and calls for expert advice that most companies are unable to afford. DIH HealthDay.si has recognised this need on the market and has launched a programme for SME support in 2019, which is specifically aimed at filling the knowledge gap on regulatory affairs for healthcare-based SMEs that would like to have their medical devices, software or procedures registered and certified, and, therefore, are then qualified to be included in the healthcare system. The programme is expected to run on a 6-month rate.

- **Solution:** Five healthcare-based SMEs were chosen, based on the following criteria: ability to scale their business, team, market penetration and, most importantly, where does their product land on a regulatory level – has it been clinically proven, certified, approved by a medical board etc. Selection was done through 1:1 interview with each of the applicants. DIH HealthDay.si developed an individual roadmap and an action plan for a 6-month period for each chosen SME. Both were made in close partnership with selected experts and focused on the mandatory steps that needed to be undertaken to reach the next stage in their development; e.g. performing a clinical study or receiving a medical device certificate. Additionally, they are given access to top-notch experts from the field through a series of seven workshops and an opportunity to interact with said experts on an individual level. Currently, the companies enrolled are Saving Ltd, Feelif Ltd, Smart Optometry Ltd, Lucis Ltd in collaboration with Slovenj Gradec General Hospital, and BLCKB Ltd.

More details

http://www.healthday.si/dih

Capability Development

KNOWLEDGE APPLICATION

Function

Workforce development

DIH	Location
Digital Innovation Hub for Smart Manufacturing Pomurje Technology Park. Website: http://p-tech.si	Murska Sobota, Slovenia

Description

Pomurje Technology Park is a community with more than 200 regional based companies, with strong international connections and that have a wealth of experience in EU programs. The number of members is constantly growing, as more and more companies recognise the advantages and benefits provided by having membership in an internationally oriented entrepreneurial and supportive environment.

Technology Park devotes special attention to promoting the transfer of knowledge, experience and technologies to the economy, which is reflected in the creation of new jobs and higher added value. In this way, it contributes to the higher competitiveness of innovative entrepreneurship in the region and promotes the creation of new, growth-focussed and knowledge-based companies.

Technology Park is an organisation with a supportive and stimulating business environment for the development of technology entrepreneurship. By providing its members with the necessary infrastructure, services, target oriented training, mentoring and promotion, it motivates entrepreneurial potential in the region and assists in the realisation of entrepreneurial initiatives with high levels of knowledge and market potential. At the same time it enables matchmaking and synergies with the domestic and foreign developmental, research, financial and market environments.

Service Example

- **Client profile:** SMEs in the start-up and in the scale-up phase
- **Client needs:** Access to information and know how
- **Proposed solution:** Technical and management courses for SMEs to be able to deal efficiently with the newly developed business models and related digitised products or processes - online courses, video presentations and training material accessed via an online tool.

More details

http://www.knowledge-base.si/

Capability Development

KNOWLEDGE APPLICATION

Function

Consulting / business advisory services

DIH	Location
Silesia Smart Systems. Website: https://sckp40.pl/	Gliwice, Poland

Description

SILESIA SMART SYSTEMS (previously Slaskie Centrum Kompetencji Przemysłu 4.0 - Silesian Competence Centre of Industry 4.0) - platform for cooperation between business support organisations, scientific units and universities, focusing on supporting industrial enterprises in the processes of digital transformation. They support industrial companies, which want to undergo digital transformation, or consider changes to their business model, or want to implement smart products involving digital technologies. SILESIA SMART SYSTEMS is now a consortium of complementary entities, cooperating with each other, using the synergy of influence, experience and competence.

Service Example

Following the complex presentations of the Industry 4.0 idea, 17 companies have undergone audits addressing the digital maturity stage, which identified those areas in which the implementation of the Industry 4.0 concept could improve current operations . Audit results were summarised in the form of reports to be used in a further smart development of manufacturing processes and management.

Capability Development

KNOWLEDGE APPLICATION

Function

Access to expertise, facilities

DIH	Location
AddedValue. Website: www.addedvalueinstitution.com	Budapest, Hungary

Description

Added Value Economics Research and Development Institute Association is the coordinator of the AddedValue DIH. This is a regional network of the most prestigious research and innovation organisations. AddedValue DIH caters for the specific needs and gaps of enterprises in its region, (nationally and globally) particularly SMEs, manufacturing companies and stakeholders nationwide. AddedValue DIH is supporting the manufacturing industry in all economic sectors. In addition, key sectors highlighted in the Smart Specialisation Strategy will be supported, including artificial intelligence. Moreover, key sectors with increased economic output, such as public administration and information technology, will also be supported. The AddedValue DIH is a non-profit organisation with a legal personality, institutionalised, and is a charitable public benefit organisation. It is research and knowledge-dissemination based, and is completely transparent.

Service Example

- **Digital Business Planning:** Creating Digital Platforms: more efficient, easier administration for SME finance. AddedValue DIH has created a digital platform that makes it easier for businesses to streamline their business processes through saving time and money. The operation of businesses has become more efficient and cost-free. The businesses are able to handle their affairs flexibly thanks to the digital administration. The application is applied to 2000 SMEs.
- **Client profile:**SMEs.
- **Client needs:** Diagnosing a company's internal and external operations using digital platforms.
- **Provided solution to meet the needs:** AddedValue DIH has been able to develop software that can be used to diagnose the Company's internal and external operations using digital platforms. The company has become even more successful and can get an accurate picture of its operation.

More details

https://www.addedvalueinstitution.com/?page_id=424

Capability Development

KNOWLEDGE APPLICATION

Function

Quality assurance

DIH	Location
Baltic Maritime Digital Innovation Hub. Website: https://maritimedih.eu/	Klaipeda, Lithuania

Description

Baltic Maritime Digital Innovation Hub (BM DIH) is a non-profit organisation which aims to become a digital innovation support platform that helps companies, institutions and organisations in the region of Klaipėda to create added value through digital technology, better business and production processes. The Baltic Digital Innovation centre functions as a one stop shop service to digitise businesses in the Klaipėda region. The main strategic objectives are to initiate and develop the public sector, business and scientific cooperation in the field of digital innovation using the most advanced means of communication. Its aims are to mobilise the necessary infrastructure for research and experimental development (R&D), initiate the development of new products and services, to implement product prototyping and testing, and provide quality assurance (validation), standardisation, and certification, for the management of digital innovation projects, in order to participate in EU and national programmes.

Service Example

- **Client profile:** public sector organisations. Client needs: digitisation of services and internal processes. Provided solutions: vendor selection, technical specification development, project management, investment project preparation, quality assurance and testing services in the following areas:
  - eDemocracy service expansion.
  - Development of digital cultural heritage content library services.
  - Development of consumer rights protection information system.
  - Modernisation of customs electronic services.
  - Development of electronic document archive services.

More details

http://www.ioprojects.lt

Capability Development

KNOWLEDGE APPLICATION

Function

Technology Transfer

DIH	Location
Foundation for Research and Technology – Hellas (FORTH) / PRAXI Network. Website: www.forth.gr	Athens, Greece

Description

The Foundation for Research and Technology - Hellas (FORTH)- was established in 1983, and is one of the largest research centres in Greece with well organised facilities and highly qualified personnel, and it consists of seven Research Institutes located throughout Greece: Heraklion, Rethymnon, Patras and Ioannina. The Foundation's headquarters are located in Heraklion, Crete. The research and technological directions of FORTH cover major areas of scientific, social, and economic interest, such as Computer Sciences, Molecular Biology, Lasers, Telecommunications, Medical Engineering, Microelectronics, Robotics, Biotechnology, Materials, Chemical and Biological Engineering, Applied and Computational Mathematics, Biomedical Technologies, Bioinformatics as well as Historical and Cultural Studies. Over the years, FORTH has become one of the top European research centres, thanks to its high impact research results and its valuable socioeconomic contribution.

The PRAXI Network is the leading technology transfer and innovation support organisation in Greece, bringing together 30 years of unique know-how in assisting small and medium-sized enterprises (SMEs) and research organisations throughout the country. Its mission is to make Greek enterprises and research organisations more competitive via the linkage between research and industry, the promotion of innovation and entrepreneurship as well as the transnational cooperation.

Service Example

- PRAXI Network's mission is to make Greek enterprises and research organisations more competitive via the linkage between research and industry, the promotion of innovation and entrepreneurship as well as the transnational cooperation. Its services are extended from information to mediation, and it has advisory support that is covering the whole spectrum of activities related with innovation, technology transfer, research collaboration and commercial exploitation of research results, such as the following:
- Technology transfer services
- With over 25 years' experience in technology transfer, the PRAXI Network has
  - provided assistance in the commercial exploitation of research results (pre-assessment, preliminary market research, patent search, etc.),
  - assessed technology needs and spotted the most suitable technology solutions and partners,
  - identified qualified partners from abroad for technological, business and research cooperation,
  - promoted Greek technologies abroad undertaking technology marketing actions (publications, company missions, international exhibitions, matchmaking events),
  - provided business information on issues related to market, competition etc.,
  - advised on intellectual property management, licensing, spin-off creation etc.

More details

http://www.praxinetwork.gr

Institute for Manufacturing: IfM

The IfM is part of the University of Cambridge's Department of Engineering. With a focus on manufacturing industries, the IfM creates, develops and deploys new insights into management, technology and policy. We strive to be the partner of choice for businesses and policy-makers, as they enhance manufacturing processes, systems and supply chains to deliver sustainable economic growth through productivity and innovation.

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