Anna van Buerenplein 1
2595 DA Den Haag
P.O. Box 96800
2509 JE The Hague
The Netherlands

www.tno.nl

T +31 88 866 00 00

TNO report

TNO 2018 R10453

Going Digital: Field labs to accelerate the digitization of the Dutch Industry

Date	May 31 2018
Author(s)	Claire Stolwijk, Matthijs Punter
Copy no	
No. of copies	
Number of pages	47 (incl. appendices)
Number of appendices	
Sponsor	Ministry of Economic Affairs (Netherlands)
Project name	Going Digital Smart Industry Field labs in the Netherlands
Project number	060.33135/01.02

Executive Summary

This study focuses on how the Dutch Smart Industry field labs accelerate the digitization of the Industry. Smart Industry field labs are public private partnerships that develop, test and implement Smart Industry solutions. Typical field labs include users of such solutions, (potential) suppliers and knowledge institutes. Each field lab contributes to one or more Smart Industry transformations, such as smart products, servitization and digital factories. ICT is one of the key enablers for these transformations.

This study provides insights on the creation process of the field labs, their main features (e.g. they work on average on 5-6 of the investigated activities per field lab, and address together more than 15 sectors etc.), their practice (they do not have a hierarchical organization structure and use a project based approach), international dimension (most of them cooperate with foreign partners) impact (e.g. jobs, spin-offs) and ICT developments.

The study is based on an analysis of the 10 first established ‘field labs’ and shows the importance of these initiatives to accelerate the development of digital technologies on high and medium TRL level. The study indicates that more than 72 million Euros have been invested in these field labs since 2015 of which about 43% is private financing. The study also indicates that the investigated field labs have been able to generate impact on their innovation ecosystem: the 10 field labs have on average 8 projects and in total 5 spin-offs, 5 field labs mention that their partners generated on average 79 jobs per field lab, which is partly caused by the field lab, 7 field labs have on average 27 students per field lab and 4 field labs have on average 6 PhD’s per field lab.

The study highlights three underlying ICT innovations (next generation factory automation & connected products, AI enabled digital infrastructures and data spaces for network centric collaboration) which are required to support the Smart Industry transformations. The study concludes that most focus in the analyzed field labs is currently on AI enabled digital infrastructures and network centric collaboration.

For each ICT innovation the study identifies several underlying technologies. The analyzed field labs use most of these technologies, mainly at a high TRL level: using available technologies and deploying them in an industry-context. In some cases, a shift has occurred towards medium-TRL-levels to address gaps between needs and available technologies. For instance, when existing (high level TRL) technologies prove not fit-for-purpose or lack certain capabilities for scaling-up.

This study is intended as contribution by the Netherlands to the Going Digital project of the OECD and is a follow up on the case study of 2017 called “ICT developments in field labs”, which contributed to the OECD project Next Production Revolution.

Contents

1 Introduction

1.1 Objective

This report is intended as a contribution to the OECD project called Going Digital on behalf of the Netherlands. The report represents one of the country policy case studies conducted in the context of the OECD TIP project on Digital and Open Innovation, with a specific focus on platforms to promote research and innovation in key digital technologies. Examples include CSIRO's Data 61 in Australia, Smart Industry Field labs in the Netherlands, the Catapult Centres in the UK, and the technology and innovation platform It's OWL in Ostwestfalen-Lippe (Germany). This report is a follow up on the study called ICT Developments in Smart Industry field labs that was published in 2017.[1]

This report focuses on the set of 10 earliest established Smart Industry platforms in the Netherlands, called Smart Industry 'field labs' (Region of Smart Factories, Campione, FreshTeq, The Garden, Smart Connected Supplier Network, Smart Dairy Farming/JoinData, Smart Bending Factory, Multi material 3D printing, and Ultra-personalized products and services).[2]

This study focuses on how the Dutch Smart Industry field labs accelerate the digitization of the Industry.

This report provides the following new insights compared to the previous report:
- *The creation process of the field labs;*
- *The main features of field labs;*
- *The field labs in practice;*
- *The international dimension of the field labs;*
- *The impact of the field labs;*
- *An overview of the most recent ICT developments within the selected field labs.*

The scope of our analysis is defined by the set of 10 earliest established Smart Industry field labs. This set was chosen to address a broad range of (ICT) technologies, market domains and geographical regions. Industries range from the manufacturing industry to the creative industry and agriculture. Based on the outcomes we will provide recommendations to various stakeholders for further acceleration of research and innovation in ICT technologies by field labs.

1.2 Reading guide

- **Chapter 2** provides the methodology and highlights the various components of the **research framework**: the role of field labs, the relevant ICT technologies for digitization in industry and the technology readiness level to assess their evolution.

---

[1] See for the previous report: http://publications.tno.nl/publication/34623516/GpWLTz/TNO-2017-R10006.pdf
[2] An overview of all field labs can be found via this link: https://www.smartindustry.nl/fieldlabs-2/

- **Chapter 3** provides insights in the **broader context** of this report: the objectives of the Smart Industry programme, the underlying implementation agenda 2018-2020 and an overview of the field labs.
- **Chapter 4** provides an overview of the **results** per field lab and per technology.
- **Chapter 5** presents the **conclusions and recommendations**.

2 Research method

2.1 Introduction

In this chapter we discuss the elements of the framework we used for our analysis.

The framework consists of three components aimed at:

1. Identifying the role of field labs in relation to ICT innovations in industry (see section 2.2).
2. Providing an overview of relevant ICT-innovations required in the (digital) transformation of industry (see section 2.3).
3. Identifing the TRL (Technology Readiness Level) of the innovations in each field lab as an indication of the development stage of ICT (see section 2.4).

The framework results in:

- 15 field lab related questions and
- 8 ICT related questions

which we discussed with the field labs (see appendix B for these questions).

We use the outcome of the resulting analysis to:

- Identify how field labs accelerate research and innovation in ICT
- Show which ICT-technologies are covered in each field lab
- Identify topics that are not covered in the field labs

2.2 Framework components: The role of field labs in ICT innovations

The use of field labs as mechanism accelerate research and innovation in ICT increased of the past years both on national and on international level. The number of Smart Industry field labs in the Netherlands increased from 10 in 2014 to 32 in 2018. On European level there are already more than 450 similar initiatives called Digital Innovations.[3]

Field labs are shared facilities in which companies and knowledge institutions develop, test and implement Smart Industry solutions. In addition, Field Labs strengthen connections with research, education and policy on a specific Smart Industry theme.[4]

The European Commission[5] has funded several of these initiatives. These initiatives share a common goal to create the conditions for long-term business success for their partners, including the support of SMEs and startups in their innovation activities. [6]

---

[3] http://s3platform.jrc.ec.europa.eu/-/now-online-digital-innovation-hubs-catalogue?inheritRedirect=true

[4] https://www.smartindustry.nl/fieldlabs-2/

[5] https://ec.europa.eu/digital-single-market/en/blog/digital-innovation-hubs-ict-2015

[6] See C. Stolwijk and M. Punter (2017), ICT Developments in field labs, http://publications.tno.nl/publication/34623516/GpWLTz/TNO-2017-R10006.pdf

We want to address the role of field labs as mechanism to accelerate research and innovation in ICT technologies. To investigate this role we focus on the following topics (1) the creation process of the field labs, (2) main features of the field labs, (3) field labs in practice, (4) international dimension of the field labs, (5) impact of the field labs, (6) the ICT developments within field labs (see section 2.3 for the ICT framework).

2.3 Framework components: Relevant ICT innovations for Smart Industry

ICT innovations relevant for Smart Industry can be divided into (see Figure 1):

1 Smart Industry Transformations,
2 Enabling ICT innovations for Smart Industry,
3 driven by new ICT technologies.

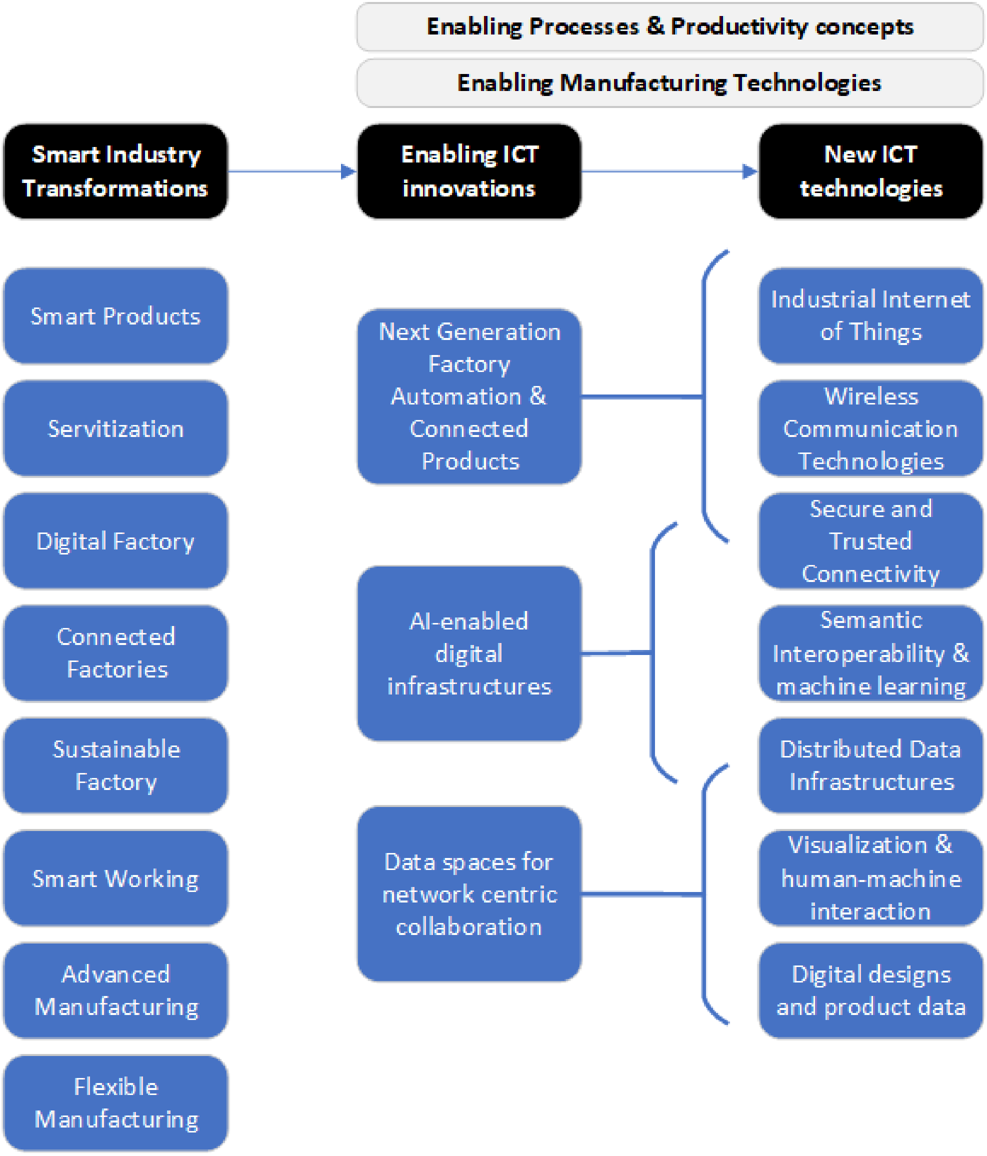

Figure 1 ICT innovations for Smart Industry

2.3.1 *Smart Industry Transformations*

The Dutch Smart Industry roadmap 2018 identifies 8 transformations. These include[7]:

- **Smart products** are products that are smart and connected. They are designed based on minimal total life-cycle costs (in terms of energy, material and transport costs), they are user friendly and attractive, have embedded intelligence and use flexible electronics, to communicate with their environment/users, they are customer specific and highly personalized. The product will make reuse of components and are a designed for flexible (n=1) production.
- **Servitization** means that organizations shift from a product-driven business model to a service-driven business model. Products are being offered as a service, e.g. by leasing equipment and ensuring an agreed availability. Customers pay for the usage of the service ,e.g. the number ofprints, X-ray images or time a machine is used etc. New technologies such as Industrial IoT (Internet of Things), 5G and immutable blockchain applications enable remote monitoring of equipment and other required data streams. The service provider uses big data analytics, including AI technologies and intensive customer contact to improve the quality of the provided services. As a result products and systems can potentially get a longer life and/or are refurbished because customers do not demand a new product but a service.
- **Digital Factory** is a factory which is completely digitally and cyber-secure connected. The products, processes and equipment have a digital version (digital twin) for design, (AR/VR) simulation, process modelling & control, use registration and maintenance. Next to the CAD data of all objects, the data collection on its use with process and maintenance data can be used to train AI algorithms and improve these algorithms. Based on the real-time data received through IoT coupling, the digital models and the historic data it is possible to monitor, control and optimize a factory and the factory processes as well as to simulate them for planning and training.
- **Connected Factories** concern firms that are digitally and cyber safe connected with each other at the integral value chain level. Drawings, orders, transport details, invoices and production/quality data are digital identified and can be, without vendor lock-in, exchanged. The goal is to optimize, to decrease costs, remove all errors and the speed delivery over the value chain. This will result in delivery time reduction through automated delivery times between submission of design up to delivery and payment, with constant monitoring of the progress.
- **Sustainable Factory** uses less energy and material, recycled/refurbished material and components. It uses as much sustainable energy as possible. The products are suited for reuse/refurbishing and are designed with most optimal total life cycle cost in mind and are suitable for business models that focus on servitization.
- **Smart Working** means that people are fully supported by technologies and understand them. Operators become supervisors who can recognize problems and solve them within multidisciplinary teams. Human technology interaction should be simple enough so that people can effectively use the technology (inclusive technology). Smart working also involves (social/legal) conditions as set by the desired economy & society. The Human-machine relation will have to be reinvented at all aggregation levels. This is related to Inclusive Technology

---

[7] Smart Industry Roadmap 2018

and Human-Machine Interaction. The challenge is to integrally design, introduce and manage socio-technical systems.
- **Advanced Manufacturing** is defined as developments that *“depend on the use and coordination of information, automation, software, sensing, and networking and/or make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology”*.[8] Advanced Manufacturing contributes to increased efficiency, quality and reliability. It requires process monitoring and modelling approaches, novel optimization and maintenance. Improvements in manufacturing technology will be data-driven and can be based on measurements or models. Reduced tolerances on product properties require higher accuracy of the existing (simulation) models, whereas a higher level of maturity is important as well to make them useful on the factory floor as part of the control system.
- **Flexible Manufacturing:** is about producing products in lot-size one for the price of mass produced product. They are produced on order, not on stock. This concern smaller, highly flexible factories located close to the customers, sometimes called metropolitan manufacturing to bring industrial jobs back to the region. In case of suppliers, these factories are located nearby the main OEMs.

These transformations include – in many cases – a fundamental shift in the business models, ways of working, market-approach and, accordingly, the overall competitiveness of organizations.

2.3.2 *Enabling ICT innovations*

There are various underlying enabling innovations to support these transformations. These relate to (combinations of):
- **New processes and productivity concepts** such as new ways of organizing a production processes, smart supply chains or new service delivery concepts.
- **New manufacturing technologies** such as robotics and technologies for additive manufacturing (3D printing).
- **New ICT innovations and technologies**.

The focus of this research is on new ICT innovations and technologies. ICT plays an important role in controlling the production environment and allowing customers and suppliers to work together. Data is increasingly required as an asset for new concepts such as value chain participation and tailoring products to the exact needs of the customer.

We have identified three generic ICT innovations in Smart Industry that relate to one or more of the transformations[9, 10]:

---

[8] Executive office of the president, 2011: https://www.smartindustry.nl/wp-content/uploads/2018/02/Smart-Industry-Roadmap-2018.pdf
[9] NWA Route Smart Industry: http://smartindustry.nl/wp-content/uploads/2017/07/Nationale-Wetenschapsagenda-Route-Smart-Industry.pdf
[10] Smart Industry implementation agenda 2018: https://www.smartindustry.nl/wp-content/uploads/2018/03/SI-Implementation-Agenda-2018-English.compressed.pdf

Next generation factory automation & connected products

New digital technologies enable flexible and zero defect manufacturing. This includes new sensors and digital equipment which are ‘data enabled’, meaning that the data they generate can be used by other processes for steering the production process, doing analytics, etc.[11] Within a factory environment new data infrastructures are needed to manage this data. Sometimes this needs to be done in a real-time fashion (with analytics being performed locally using edge-computing), in other cases data is shared through a cloud-like environment for use by other stakeholders. Increasingly this next generation factory data-environment is part of a multi-stakeholder environment as data needs to be accessed by third parties e.g. for service and maintenance purposes. New 5G wireless capabilities enable ubiquitous connectivity.

AI-enabled digital infrastructures

New artificial intelligence capabilities allow for easy combining, linking and analyzing datasets coming from multiple sources. Semantic web technology is used to express the meaning of data. Reference ontologies and semantic reasoning allow for linking datasets[12]. Advanced analytics and machine learning concepts allow for finding patterns in existing datasets providing insight e.g. in possible risks or improvements. These digital infrastructures are used as a basis for new data service offerings, providing added value and enabling new business models and revenue streams.

Data spaces for network centric collaboration

Network centric collaboration is facilitated using new decentralized data infrastructures which allow for the controlled sharing of data. Data is either shared through distributed ‘connectors’ or through a shared ledger (as is the case in blockchain technology). This enabled ‘data sovereignty’: each organizations has full sovereignty over the sharing and use of its data[13]. New visualization technologies are used to engage users (whether business owners, end-users or workers in a factory environment) and support their work, e.g. using augmented reality and mobile devices. Data spaces enables collaboration on product data and digital designs between designers, potential users and manufacturers. Data is used as a ‘digital twin’ of a production process, an existing or a future product. This allows for customization of new products (‘n=1’), improved maintainability and design-for-manufacturing.

The table below provides an overview of the interrelationship between these enabling ICT innovations and the overall Smart Industry transformations.

---

[11] World Economic Forum, Industrial Internet of Things: Unleashing the Potential of Connected Products and Services:
http://www3.weforum.org/docs/WEFUSA_IndustrialInternet_Report2015.pdf

[12] See for example: M. K. Uddin, A. Dvoryanchikova, A. Lobov and J. L. M. Lastra, "An ontology-based semantic foundation for flexible manufacturing systems," *IECON 2011 - 37th Annual Conference of the IEEE Industrial Electronics Society*, Melbourne, VIC, 2011, pp. 340-345.

[13] See for example: Industrial Data Space – Digital Sovereignty Over Data, European Commission, Digitising European Industry, WG2:
https://ec.europa.eu/futurium/en/system/files/ged/ids_deiwg_0812_public.pdf

Table 1 Overview of the enabling ICT innovations and their link to the overall Smart Industry transformations

	Enabling ICT innovations			**Other enabling technological innovations (non-ICT) - examples**
Transformations	*Next generation factory automation & Connected products*	*AI-enabled digital infrastructures*	*Data spaces for network centric collaboration*	
Smart Products	x	x		Battery technologies, micro-electronics
Servitization	x	x	x	New financial and service models
Digital Factory	x	x	x	Robotics, Additive manufacturing
Connected Factories	x	x		Supply chain collaboration
Sustainable Factory	x	x	x	New materials and energy technologies
Smart Working	x	x	x	Operator support systems, employability concepts, worker training
Advanced Manufacturing	x	x		Nano-technology
Flexible Manufacturing	x			Robotics, single piece flows

2.3.3 *New ICT technologies*

Advances in the underlying technologies are driving the ICT-enabled innovations for industry. For instance: industrial internet of things capabilities are needed to support the next generation of factory automation and connected products. New distributed data infrastructures are needed to set-up data spaces for network centric collaboration.

To get a good understanding of the ICT innovations in the various field labs it is therefore also important to get an understanding of the advances of these underlying technologies: field labs can be a platform for guiding these advances by providing requirements, providing a testbed for their development or to seek their large scale adoption.

Most technologies are used in multiple ICT innovations. For each technology we outline the current state of play and the (likely) future development.

- Industrial Internet of things: products and equipment will increasingly be equipped with smart sensors and communication devices for tracking and measurement purposes. Examples include smart sensors, embedded software and related communications equipment.
  - *Current state of play:* sensors are tightly integrated with the ICT-system that processes the data. For instance a dedicated PLC (digital controller) connected to a factory automation system.
  - *Future development:* sensors will be ‘loosely’ coupled and can be flexibly connected to multiple information systems. Internet-technology is used to

connect to each sensor. Standards such as OPC-UA provide a stepping-stone to such developments.[14]

- Wireless communication technologies: new wireless communication technologies are needed to connect products and services.
  - *Current state of play*: Devices are equipped with local networking capabilities (e.g. Bluetooth, Zigbee or WiFi) to connect to systems in the vicinity or use a GSM/3G-network to communicate with remote organizations. New technologies such as LoRa provide long-range/low-power communication and provide low-bandwidth connectivity with remote organizations.
  - *Future development:* New 5G wireless communication technologies provide even more pervasive networking capabilities.[15] Manufacturing is an important 'vertical' driving the requirements for future 5G developments. Public (telco-operated) and private (company-network) networks are likely to converge.

- Secure and trusted connectivity: to allow for the controlled sharing of data technologies are needed to limit access to data to trusted parties only.
  - *Current state of play:* Data is secured using public private key mechanisms and connected authorization and identity management tools.
  - *Future development*: Homomorphic encryption technology allows for the encrypted sharing of data. The receiver cannot decrypt the data but can perform certain algorithms on the data and see the result. In general more focus will be put on resilience and cybersecurity [16].

- Semantic interoperability and machine learning: organizations need to be able to interpret each other's data. Technology is needed to facilitate this interoperability.
  - *Current state of play:* Organizations use EDI- or XML-based integration schemes to share data. Data is exchanged using standardized messages. Business Intelligence technology is used to analyze datasets for statistical purposes.
  - *Future development*: New advanced semantic web technologies allow for more easy sharing and interpretation of data as they not only include the syntax (layout) of the data, but also the meaning of the data and links to relevant other datasets. New machine learning will be used to identify patterns in data and use these patterns for predictive and prescriptive analytics (providing recommendations to the user).[17]

- Distributed data infrastructures: to share data in networks of organizations distributed data infrastructures are needed to find, distribute and retrieve data.

---

[14] See for example: Struktur der Verwaltungsschale Fortentwicklung des Referenzmodells für die Industrie 4.0-Komponente: https://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/struktur-der-verwaltungsschale.pdf

[15] 3GPPP Whitepaper on 5G and Factories of the Future: https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Factories-of-the-Future-Vertical-Sector.pdf

[16] CIO Journal, Cybersecurity in the Age of Smart Manufacturing, see: http://deloitte.wsj.com/cio/2018/02/27/cybersecurity-in-the-age-of-smart-manufacturing/

[17] J. Pullmann, N. Petersen, C. Mader, S. Lohmann and Z. Kemeny, "Ontology-based information modelling in the industrial data space," *2017 22nd IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)*, Limassol, 2017, pp. 1-8.

  - *Current state of play:* Data is shared through centralized community platforms where all organizations upload their data. New developments also include more decentralized approaches where each organization remains in control over its own data, e.g. by using ‘connectors’ to share data and ‘data brokers’ to provide a ‘yellow-pages’ to possible data providers and consumers.
  - *Future development:* Data infrastructures will increasingly become powered by cloud technologies. Through distributed ledgers (blockchains) data will be shared by everyone in a community without the need of a centralized infrastructure.

- <u>Visualization and human-machine interaction</u>: with digital data becoming increasingly pervasive it is important to be able to allow people to work with it. This requires technology for visualization and human-machine interaction.
  - *Current state of play:* Tablets, touchscreens and similar connected devices and their underlying software.
  - *Future development:* More pervasive human-machine interactions, e.g. holographic projections or displays embedded in workplace tools.

- <u>Digital designs and product data</u>: increasingly production is driven by digital designs. Organizations use ICT to collaboratively work on these designs after which it is used by the production environment to steer the manufacturing process.
  - *Current state of play:* Product lifecycle management systems, product data management systems and CAD/CAM-tools.
  - *Future development:* Fully digital designs – organizations no longer share the final design document (e.g. PDF file), but also the underlying digital model (e.g. enhanced STEP-file). This digital model is used as an input for further designs and production. It is combined with manufacturing and usage data and used as basis for a ‘digital twin’ of a product or manufacturing process.

2.4 Framework components: Technology Readiness Levels of ICT innovations

In our analysis of the Dutch Smart Industry field labs we do not only investigate which technology domains are covered by each field lab, but we also used the principle of the ‘Technology Readiness Level’ to assess the stage of development. We used a simplified categorization of Figure 2:

- **Low** (TRL 1-4) – Invention and concept validation: a new technology is being developed. The field lab is used to validate the concept.
- **Medium** (TRL5-7) – Prototyping, incubation, pilots and demonstration: a new technology is being prototyped and demonstrated as part of the field lab.
- **High** (TRL8-9) – Market introduction and expansion: the field lab is used to introduce a new technology (that is already there) to the market. E.g. an ICT-technology that is already established in other markets and is now being introduced in the manufacturing-domain.

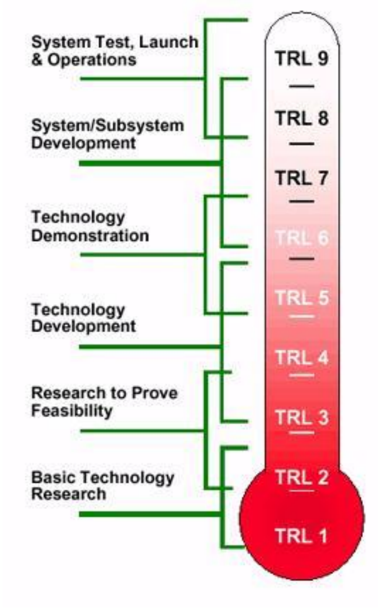

Figure 2: Technology Readiness Levels. Source: Nasa

Based on the relevant ICT innovations for Smart Industry and the technology readiness level we developed questions that are discussed with the field labs (see appendix B).

3 Context of the case study

This chapter describes the empirical cases under study. The Dutch field labs were initiated in 2014 with the Smart Industry Action Agenda. They often build on existing initiatives. Some Dutch field labs have a regional focus, others a national or a European focus. Currently there are 32 Smart Industry field labs active in the Netherlands and more are expected. These 32 field labs address various Smart Industry subjects and technologies such as flexible manufacturing, 3D printing, Robotics, 5G etc. of which we focus on the 10 earliest established. For new Smart Industry field labs an application procedure has been developed by the Smart Industry Program Office, with criteria such as: having a radical innovation objective, having a program of at least three years, with a program coordinator and a number of projects with various private and public partners, including financing. In addition, coordination with other field labs must take place.

In February 2018 the Smart Industry Implementation agenda was launched. The key objective of the Smart Industry Implementation Agenda 2018-2021 is "*to speed up digitization within Dutch businesses, so that by 2021 the Netherlands has developed the best and most flexible digitally connected production network in Europe".*[18] Based upon a SWOT as well as discussions in the regions - national and international - eight transformations (e.g. smart products, servitization etc.) are described in the Smart Industry Implementation agenda and the Smart Industry Roadmap 2018, that will make Dutch industry fit for the future (see Figure 3).[19] The transformations are described in more detail in section 2.3.1.

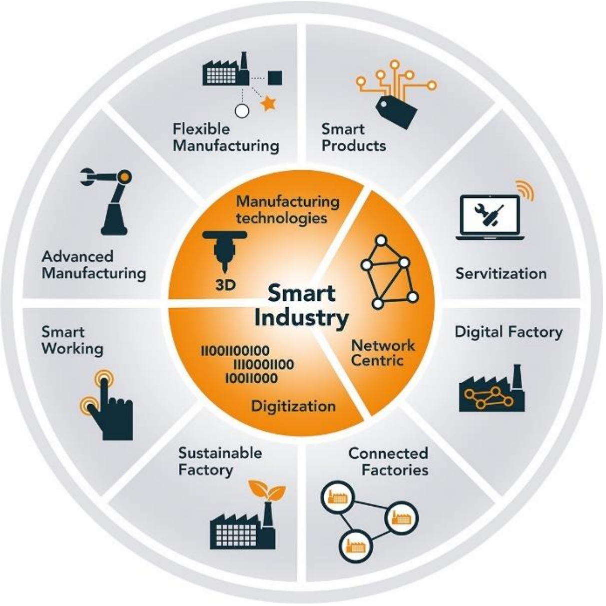

Figure 3 Transformations and core technologies for Smart Industry

Source: Smart Industry implementation agenda

---

[18] Smart Industry implementation agenda 2018: https://www.smartindustry.nl/wp-content/uploads/2018/03/SI-Implementation-Agenda-2018-English.compressed.pdf
[19] Smart Industry Roadmap 2018: https://www.smartindustry.nl/wp-content/uploads/2018/02/Smart-Industry-Roadmap-2018.pdf

3.1 Individual field lab cases

This chapter describes the content of the 10 field labs under study. It gives insights in the technologies and sectors of each of the field labs. Recent new field labs are out of the scope of this research (like the field lab that focuses on 5G).For and overview of all 32 Smart Industry field labs see appendix C.

3.1.1 Region of smart factories

The field lab “Region of Smart Factories” (RoSF) is a field lab based on a consortium of 32 companies (large and small) and knowledge institutes that jointly conduct research into a range of new technologies for the “Zero defect factory.” This consortium was established around the three main OEM companies (Philips, and Fokker). The foundations of Smart Factories are first reinforced with the help of a scientific program, after which various firm clusters develop and implement new technologies in 10 pilot projects. Examples of these pilot projects include the use of new factory automation for ‘zero defect’ production of electric shavers, the use of new sensors for the production of optical lenses and the development of dashboards for data visualization.

3.1.2 CAMPIONE

Field lab CAMPIONE is a facility where innovators can work in a lab environment to predict maintenance. The field lab focus on the chemical and process industry. In this sector maintenance is currently corrective or preventive. With advanced sensors and data analytics premature maintenance and unnecessary shutdown of a factory can be prevented. The firms involved make part of their plant available for testing purposes. There are +/- 35 participants involved, such as FUJIFILM, Ericsson, Tata Steel and Sitech Services.

3.1.3 FreshTeq

Field lab FreshTeq offers - worldwide - local value chain solutions for sufficient healthy and fresh food for consumers in large cities. FreshTeq unites different actors such as seed breeder, grower, supplier, retailer and transport experts. Main focus of the field lab is on the development of growth support systems (e.g. greenhouses). FreshTeq supports its partners in optimizing their performance through training and education. FreshTeq has 6 partners.

3.1.4 The Garden

Field lab The Garden focuses on security in the implementation of Industry 4.0. The partners experiment with existing and (where necessary) new products and services for secure, real-time and reliable data and information exchange. In the area of security some new technologies are being tested for encryption and controlled data sharing. Secure data exchange is an important precondition for connections in the entire value chain. E-PLM (Extended Product Life Cycle Management) is an important use case and project of the Garden. The field lab has approximately 35 consortiums partners. These are industrial actors, universities and supporting organizations.

3.1.5 *Smart Connected Supplier Network (SCSN)*

Field lab Smart Connected Supplier Network focuses on the development of a networked high-tech supply chain for easier data sharing, to provide quick access to product and design data. The involved partners collaborate on the following topics:

- Easy data sharing.
- Reliable data sharing.
- Interpretation of shared data.

The objective of this field lab is to enable an improved collaboration in the supply network of high-tech OEMs, making them more efficient and reliable as well as improving the time-to-market. This should increase the overall attractiveness of the Dutch high-tech supply cluster for high-complexity, high-mix, low volume manufacturing.

3.1.6 *Flexible Manufacturing*

Field lab Flexible Manufacturing works on the development of flexible and fully and partly automated small series production against low costs. The field lab focuses on the development of human-robot applications and other forms of next generation manufacturing automation, that contribute for instance to a decrease of the time required to program robots. As a result the competitiveness of the manufacturing industry could be improved and jobs can be created. There are 19 consortium partners involved.

3.1.7 *Smart Dairy Farming/JoinData*

Field lab Smart Dairy Farming/JoinData developed a data hub (Data broker) and uses sensor technology. This helps the farmers to make the right choices for cow care. Proper care contributes to better health and longer life expectancy of these animals. The field lab provides an infrastructure for the farming and agricultural sector. That means that a farm has access to its own information and to the information of other parties.

3.1.8 *Smart Bending Factory*

Field lab Smart Bending Factory wants to become a worldwide innovation model for the metal sector, by developing a production facility for small batches that are 25% cheaper and 5 times faster. The field lab develops the state of art factory for cutting and bending metal. Customers can order fully digitized products based on an electronic environment for digital designs. The costs of these products are the same as if it was a product from a series of 500 pieces. There are 9 partners involved in the field lab.

3.1.9 *Multi material 3D printing*

Field lab Multi material 3D printing aims to develop entirely new value chains, based on the next generation 3D printing technologies and the associated data management systems. The field lab focuses on the realization of new innovative value chains in which mono and multi-material 3D printing plays a key role. Required technologies are ICT solutions for the management of large data streams and integrating 3D printing into existing production systems. Main sectors involved are the medical sector and the high tech industry. The field lab brings complementary knowledge organizations and industrial partners together.

3.1.10 Ultra-Personalized Products and Services (UPPS)

UPPS stands for Ultra Personalized Products and Services and is a result of new technologies such as 3D scanning, internet and smart sensors. Field labs UPPS uses these technologies to process the data in the product so that it is optimally matched to the user. UPPS can be divided into two categories. (1) Products in which personal data is obtained before use - such as 3D scans - and (2) products in which the data is obtained during use - such as temperature and heart rate sensors. Field lab UPPS focus on the health and fashions sectors. There are 10 consortium partners involved.

4 Results

In this section we will highlight our key-finding with regards to the field lab as mechanism to accelerate research and innovation in ICT technologies.

4.1 Creation process of the field labs

This section describes various elements that are relevant for the creation process of the field labs such as: *the reasons to initiate a field lab, the field lab initiators, and field lab involvement in the coordination with other policy initiatives.*

4.1.1 Reasons to initiate a field lab

The results indicate that field labs are founded for various reasons such as the fact that some technology developments cannot be done by one single firm alone, or to solve business challenges together, to stay competitive or develop the region into a home for Smart Factories and prove or demonstrate the business case to the industry (See Table 2).

This means that there is not one single reason to start a field lab.

4.1.2 Field lab initiators

Various stakeholders initiated the creation of the field labs. 2 field labs are initiated by public parties, 2 field labs are initiated by knowledge institutes, 2 field labs are initiated by firms and 4 field labs are initiated by existing networks (like World Class Maintenance, Brainport Industries and ClickNL) that have a lot of private parties (see Table 2).

This means that the initiators of most field labs are existing networks.
However, each of the initiators involved his field lab partners in an early stage of the creation process.

Table 2 Creation of the field lab

Field labs	Main factors and background conditions that motivated the creation of the field lab	Stakeholders involved in its creation
Region of Smart Factories	The field lab was initiated to develop the Northern Netherlands into the home of Smart Factories, thereby laying the foundations for a strong manufacturing industry. The RoSF consortium was established around the main two original equipment manufacturing companies; Philips, and Fokker, but has since grown into a group of 32 partners (SMEs, knowledge institutes and education institutions).	The field lab was initiated by the NOM (the Northern regional development organization). This is a public organization.
Campione	The field lab was developed because asset owners needed a test facility to prove the business case of Condition Based Maintenance (CBM) in the process industry. CBM is struggling to become accepted in the process industry for a number of reasons (including security risks, outdated infrastructure, conservatism, organizational obstacles, financing) etc.	World Class Maintenance is the initiator of the field lab. World Class Maintenance is the network for smart maintenance in the Netherlands. The members of this network are mainly firms and some education institutes.
FreshTeq	The field lab was created because fully automated production, cultivation and distribution of fresh fruit and vegetables is complex and a single firm cannot do this alone.	InnovationQuarter (the regional development organization in South Holland) is the initiator of the field lab. This is a public organization.
The Garden	The field lab was created based on the wish to handle the technological, business and legal complexity of safe data exchange with relevant partners in the region.	The firm Thales is the initiator of the field lab.
Smart Connected Supplier Network	The wish to solve the following 3 business challenges with the involved partners motivated the creation of the field lab: 1. Acceleration and improvement of the design process, 2. Acceleration of the production chain, prevention of errors, 3. Better international positioning via a stronger network	Brainport Industries (the global open supply network for High-Tech companies, located in the South of the Netherlands) is the initiator of the field lab.
Flexible Manufacturing	Based on the wish to significantly increase productivity with robot support through direct CAD coupling, smart (vision) technology, more flexible production systems and human-robot collaboration a field lab was created to be able to test these technologies with the involved partners.	Brainport Industries (the global open supply network for High-Tech companies, located in the South of the Netherlands) is the initiator of the field lab.
Smart Dairy Farming / JoinData	Firms, knowledge institutes and farmers had the wish to get a more sustainable and efficient production in the dairy sector on the basis of real-time measuring based on sensors and information from models about young stock, fertility and transition (phase between stopping milk feeding and giving milk after giving a calf). To realize this firms knowledge institutes and farmers are brought together in the field lab.	The initiator of the field lab is the WUR (Wageningen University and Research) together with the NOM (the Northern regional development organization), , TNO, Royal FrieslandCampina, Agrifirm and CRV.
Smart Bending Factory	The wish to bring a large number of non-competitive OEMs in the region together to share knowledge, experiences, information and resources and to exploit manufacturing processes to remain competitive or increase the competitiveness of the region motivated the creation of the field lab.	247Tailorsteel (private firm) is the initiator of the field lab.
Multimateriaal 3D printing	The wish to have a demonstration platform as future factory for 3D printing to facilitate and transfer the technology and knowledge to the industry motivated the creation of the field lab.	The field labs was initiated by 2 knowledge institutes. The TU Eindhoven and TNO.
Ultra-Personalized Products and Services (UPPS)	The creative industry had the wish to apply the added value of the creative sector in the manufacturing sector by the development of radical new product propositions for the manufacturing industry (e.g. ultra personalized products and services such as the development of a specific foot brace). The field lab was created to test and experiment with these product propositions in a test facility.	ClickNL. Is the initiator of the field lab. ClickNL is a Dutch top consortium of knowledge and innovation (TKI), that makes a link between researchers and creative professionals.

4.1.3 *Field lab involvement in the coordination with other policy initiatives*

The 10 field labs are initiated in cooperation with the national Smart Industry Program (see Table 3). The Program bureau Smart Industry, in which the Ministry of Economic Affairs and Climate Policy is also represented provides the field labs their Smart Industry field lab status, if they meet the required criteria (for more details about the criteria see section 3). The Program bureau Smart Industry advices the field labs if needed and organizes regular field lab meetings so that field labs can exchange their expertise, best practises and lessons learned. Most field labs also have a link with the regional Smart Industry initiatives like BOOST in the east of the Netherlands (e.g. the Garden), or the field lab initiative in South Holland (e.g. FreshTeq). BOOST is the accelerator of Smart Industry in the east of the Netherlands, in which entrepreneurs, educational institutions, intermediaries and the government work as a unit in various projects to realize a competitive, strong and sustainable manufacturing industry in the eastern Netherlands. In South Holland 15 field labs are brought together for the Regional Investment Program to form a regional network that contribute to cross-sector cooperation and innovation. Another initiative is the BIC campus in the Brainport region were various field labs will be located in the near future (e.g. Smart Connected Supplier Network, Flexible Manufacturing).

This means that all field labs have a link with the national and in most cases also the regional Smart Industry initiatives to reinforce each other.

Table 3 Coordination with other (policy) initiatives

	Coordination with other (policy) initiatives
Region of Smart Factories	The field lab is part of the national Smart Industry imitative.
Campione	The field lab is part of the national Smart Industry initiative and is initiated by the network World Class Maintenance that initiated 5 other field labs (SMASH, Camino, Capella, Amici and Zephyros).
Fresh Teq	The field lab is part of the 15 field labs in South Holland that form a regional network for cross-sector cooperation and innovation in the region.
The Garden	Linked with the national and regional Smart Industry initiative called BOOST
Smart Connected Supplier Network	The field lab is part of the national Smart Industry Program and becomes part of the BIC campus in the south of the Netherlands
Flexible Manufacturing (South)	The field lab is part of the national Smart Industry initiative and becomes part of the BIC campus in the south of the Netherlands
Smart Dairy Farming / JoinData	Linked with the national Smart Industry initiative and the regional Smart Industry initiative called BOOST
Smart Bending Factory	The field lab is part of the national Smart Industry program and has a link with the regional Smart Industry initiative called BOOST.
Multimateriaal 3D printing	The field lab is part of the national Smart Industry program. The field lab also becomes part of the BIC campus in the south of the Netherlands and is part of the vanguard initiative. The Vanguard initiative aims to stimulate industrial modernization in its participating European regions through the more effective deployment of new technologies.
Ultra-Personalized Products and Services (UPPS)	Linked with the national Smart Industry initiative and the regional Smart Industry initiative called BOOST

4.2 Main features of the field labs

This section describes the main features of the field labs including the *field lab mandates and objectives, the main activities of the field lab, the sectors and* *technologies on which the field lab focuses, mechanisms to ensure interdisciplinary approaches to R&D, and the financial investments in field labs.*

4.2.1 Field lab mandates and objectives

Important decisions for the field labs are in general made in consultation with the partners. The field lab coordinator has in principle the mandate to represent the partners on national field lab meetings and in communications to the outside world.

The objectives of the field labs differ a lot, but have in common that they are radical in nature. They want for instance to develop complete new value chains, radical new product propositions or they have the ambition to become world leader (see Table 4).

That indicates that the 10 field labs have the same main features in terms of their decision making process, their mandate and the radical nature of their goals.

Table 4 Field lab objective

Field lab	**Field lab objectives**
Region of Smart Factories	Has two objectives: 1. Generate a successful demand-driven manufacturing industry via zero defect production and 'first time right' product and process development. 2. Growth of regional SME Smart Factory Solution Providers by development and validation of their new products and/or services.
Campione	Make maintenance for chemical firms 100% predictable, thereby significantly improving the productivity, availability and safety of production equipment at lower costs.
FreshTeq	Make Dutch industry the world leader in smart solutions for fully automated production, cultivation and distribution of fresh fruit and vegetables.
The Garden	Provide Smart Industry maximum secure data exchange in the complete value chain.
Smart Connected Supplier Network	Come to the best 'networked' high tech supply chain in the world, for easier data sharing, and to provide quick access to product and design data.
Flexible Manufacturing	Production of small series, flexible and fully automated by robots and without programming time.
Smart Dairy Farming / JoinData	Increasing the sustainability of dairy farming and agriculture by real-time monitoring of dairy cows and agriculture and the sharing of data in the chain.
Smart Bending Factory	Become a global showcase of innovation in customization for the metal industry to bring small series 25% cheaper and 5 times faster to the market.
Multimateriaal 3D printing	The development of completely new value chains, based on the next generation of 3D printing technologies and the associated data management systems.
Ultra-Personalized Products and Services (UPPS)	The development of radical new product propositions for the manufacturing industry through the innovative use of data and by making products fully customized.

4.2.2 Main activities of the field lab

All 10 investigated field labs are involved at least 5-6 activities per field lab. Field labs are mainly active in *collaborative research, development and innovation, concept validation and prototyping* and *testing and validation*. Other activities in which almost all field labs are active are *ecosystem building, scouting, brokerage and networking* and *education and skills development*. One field lab is involved in incubator and accelerator support and one field lab works on standardization. However, none of the field labs is involved in market intelligence IP and legal activities (see Table 5 for the most important activities mentioned by the field labs).

This means that the field labs are most active in non-commercial related activities.

Table 5 Main activities of the field lab

Field labs	**Awareness creation**	**Ecosystem building, scouting, brokerage, networking**	**Collaborative research, development and innovation**	**Concept validation and prototyping**	**Testing and validation**	**Pre-competitive series production**	**Incubator/ accelerator support**	**Market intelligence**	**Education and skills development**	**Legal framework**	**Standards and norms**	**IP**
Region of Smart Factories	x	x	x	x	x				x			
Campione	x	x	x	x	x	x			x			
FreshTeq	x	x	x	x	x				x			
The Garden	x	x	x	x	x				x			
Smart Connected Supplier Network			x	x	x						x	
Flexible Manufacturing	x	x	x	x	x				x			
Smart Dairy Farming / JoinData	x	x	x	x	x	x[20]			x			
Smart Bending Factory		x	x	x	x	x			x			
Multimateriaal 3D printing	x	x	x	x	x		x		x			
Ultra Personalized Products and Services (UPPS)	x	x	x	x	x				x			

---

[20] In this case it concerns precompetitive services instead of products.

4.2.3 Sectors and technologies on which the field labs focus

The 10 field labs focus together on more than 15 sectors (see Table 6) and develop and combine various ICT technologies. Most of them focus at least on 2 ICT technologies (see Appendix A).

The indicates that the investigated field labs together address a relative large landscape of sectors and ICT technologies.

Table 6 Sectors and technologies

Field labs	**Sectors / application fields**
Region of Smart Factories (ROSF)	Consumer electronics, shipbuilding, health, lenses
Campione	Chemical and process industry
Fresh Teq	Agricultural and food (cross-overs with other sectors are under investigation)
The Garden	Defense, generic
Smart Connected Supplier Network	High-tech
Flexible Manufacturing	Various
Smart Dairy Farming / JoinData	Farming and agricultural
Smart Bending Factory	Steel
Multimateriaal 3D printing	Health, dental, free form electronics and high-tech process equipment
Ultra-Personalized Products and Services	Health and fashion

4.2.4 Mechanisms to ensure interdisciplinary approaches to research and innovation

8 field labs ensure their interdisciplinary approaches to research and innovation via the involvement of a relative high diversity of partners from different disciplines (e.g. firms, knowledge institutes, education institutes) and the cooperation multiple stakeholder projects (see Table 7). Two field labs have a lower diversity of partners and one of these two field labs with a lower partner diversity is also not active in multi-stakeholder projects.

That means that most field labs use both mechanisms (a relative high diversity of partners and multi stakeholder projects) to ensure interdisciplinarity in research and innovation.

Table 7 Mechanisms to ensure interdisciplinary approaches to research and innovation

Field labs	**Mechanisms to ensure interdisciplinary approaches to research and innovation**	
	Diversity of the partners *	**Project based approach with multiple stakeholders**
Region of Smart Factories	3	x
Campione	3	x
Fresh Teq	3	x
The Garden	3	x
Smart Connected Supplier Network	2	x
Flexible Manufacturing	3	x
Smart Dairy Farming / JoinData	3	x
Smart Bending Factory	2	No
Multimateriaal 3D printing	3	x
Ultra-Personalized Products and Services	3	x

***(1=only firms involved, 2=firms and knowledge institutes involved, 3=firms, knowledge institutes and education involved)**

4.2.5 *Financial investments in field labs*

More than 72 million Euros have already been invested in the investigated field labs, of which 31 million Euros come from private investments.

This indicates that more than 40% of the budgets of the 10 field labs is funded by private financing and about 60% by public funding instruments like funding from the provincial government or the EU EFRO-program (see Table 8.1).

Table 8.1 Field lab budgets

This table shows the funding that the field labs have acquired since their start date (after 1 January 2015) up to and including today and which shortages they still have (Funding gap). The end date must be read as the end of a program period, not the end of the field labs.				**Total**	**Funding gap**	European funding sources			National sources					private		Loan	**Total (check)**
						EFRO (excluding "Rijksbijdrage")	Other European (like H2020)	National	Rijksbijdrage EFRO	Regional government (Province, municipality, etc.)	Knowledge institutes	TKI	Diverse (WBSO, RAAK, MIT, IPC)	Firms		(like "SI regeling")	
														Cash	In-kind		
nr	**Field lab**	**Start date**	**End date**	In K													
	Total incl funding gap	**2015**	**2020**	**73841**	**1800**	**9831**	**3528**	**2483**	**6089**	**10566**	**5258**	**3080**	**0**	**6705**	**24501**	**0**	**73841**
	Total minus funding gap			**72041**								**Total private**		**31206**			

The field lab budgets are based on various funding sources (see Table 8.2 below). Private financing is used by all field labs. Regional funding instruments are the most common public instrument for the 10 investigated field labs.

Table 8.2 Field lab funding sources

Field labs	**Sources of funding**					
	Regional	**Knowledge institutes**	**TKI**	**National**	**European**	**Private**
Region of Smart Factories	x			x	x	x
Campione	x				x	x
Fresh Teq	x	x			x	x
The Garden	x	x		x	x	x
Smart Connected Supplier Network	x		x	x		x
Flexible Manufacturing	x	x	x		x	x
Smart Dairy Farming		x	x			x
Smart Bending Factory	x				x	x
Multimateriaal 3D printing	x				x	x
Ultra-Personalized Products and Services		x	x			x

4.3 Field labs in practice

Field labs are consortia of organizations, that belong to the strategic public private partnerships, that focus on higher TRL levels and have an open and shared facility to provide mainly start-ups and SMEs the chance to do experiments on a platform.[21] At the same time, a field lab cannot be completely open, because participation requires a contribution and commitment.[22]

This section describes the field labs in practice and focus on the *organization of the field lab, difference with field labs without a digital focus, challenges during the implementation process.*

4.3.1 Organization of the field labs

Every field lab has one coordinating partner, which is in most cases the initiator of the field lab (see Table 2). Some of them have a firm as coordinator, while others have a network like Brainport Industries, a knowledge institute or a regional development organisation.

Of the assessed field labs the field lab Region of Smart Factories has a steering committee. This is a reflection of the type of participants in the field lab and consists of 7 members. A meeting is planned quarterly. The field lab Smart Dairy farming has a program board consisting of the founding fathers and an advisory board consisting of farmers. The assessed field labs do not have a scientific advisory body.

Most of them have a physical test location or will get that in the near future. Most field labs use a project based approach to develop their technologies and realize their activities.

---

[21] van der Zee F., Goetheer A., and Gijsbers G., (2017), *Staat van Nederland Innovatieland*, TNO.
[22] Gijsbers, G, Stolwijk C., van der Horst T., and Butter M. (2017), Typologie van fieldlabs, TNO: http://publications.tno.nl/publication/34625485/D5Io8n/TNO-2017-R10967.pdf

That means that the number of field labs with some kind of steering committee or advisory body is limited, as the governance is often organized within the projects.

4.3.2 Difference with field labs without a digital focus

The main difference between field labs with a digital focus and field labs without a digital focus has to do with the fact that some digital focused field labs do not necessarily need a physical location as they might also be virtual in nature like field lab Smart Dairy Farming / JoinData.

4.3.3 Challenges during the implementation process

The most important challenges that the assessed field labs needed to deal with during the implementation process of the field labs were financial challenges. However, this is not specific for field labs with a digital focus. The problem is that field labs first have to “prove their added value” to attract private financing, while they do not have such proof yet and also had to deal with a shortage of funding in the instruments for public private partnerships in R&D&I.[23] Another challenge mentioned by some field labs concerns the upscaling and business model development.

4.4 International dimension of the field labs

The international dimension for field labs is getting more and more important.

4.4.1 Most field labs have an international dimension

5 field labs cooperate with partners from other countries (see Table 9). Examples are cooperation in European projects (The Garden), cooperation with foreign research institutes (Flexible Manufacturing) or with for instance the German Industrial Data Space initiative (Smart Connected Supplier Network). 2 field labs aim to focus on the international market.

The field labs also have the opportunity to present itself as a Digital Innovation Hub at European level and to connect to the pan-European network.[24] Member States and regions play a key role in establishing DIHs that support Smart Industry in their regions. The role of the European Commission is to link them up in this-European network of DIHs. For this, the European Commission is investing €100 million per year between 2016 and 2020.[25] For this network a database called the ‘*Digital Innovation Hubs Catalogue*’ has been developed with extensive information about the DIHs in Europe. Some of these 10 field labs are included in this database like Smart Connected Supplier Network and Regions of Smart Factories.

Three field labs do not have any international dimension.

That means that most field labs have an international orientation.

---

[23] Stolwijk C. et al. 2017, Financing Field labs: file:///C:/Users/stolwijkccm/AppData/Local/Packages/Microsoft.MicrosoftEdge_8wekyb3d8bbwe/TempState/Downloads/TNO-2017-R10964.pdf

[24] https://www.smartindustry.nl/kansen-fieldlabs-pan-europees-digital-innovation-hubs-netwerk/

[25] https://ec.europa.eu/digital-single-market/en/digital-innovation-hubs

Table 9 International dimension of the field lab

Field labs	**International dimension / engage in cross-country collaborations for innovation or other mechanisms for international outreach**
Region of Smart factories	Yes via European projects
CAMPIONE	No
Fresh Teq	Yes, aims to provide an integrated 'growth support systems' proposition to the international market. The first hortisimulator will simulate climate conditions of Colombia in order to prove that Dutch greenhouse technology can improve yields compared to local growing standards.
The Garden	Yes, focus in one of the projects (EPLM2) is on the international market position. There are also partners involved from other countries like Fraunhofer
Smart Connected Supplier Network	Yes, based on cooperation with the German Industrial Data Space initiative.
Flexible manufacturing	Yes via European projects
Smart Dairy Farming 2.0 / JoinData	The aims is to provide the technology in the future to partners outside the country
Smart Bending Factory	No
Multimateriaal 3d printen	Yes via the involvement of international partners and its involvement in the vanguard initiative
Ultra Personalized Products and Services	No

4.5 Impact of the field labs

The impact of the field labs are monitored in the period 2016-2018.

4.5.1 The field labs made a lot of progress

The field labs have on average more than 20 partners per field lab, of which the majority consists of firms (on average >15). Field labs are on average active in 8 project in which they generated knowledge and develop new technologies (for more details about the technologies, see section 4.6). More and more field labs focus on education and training and 7 field labs have on average 27 students per field lab involved. 4 field labs have on average 6 PhD's per field lab involved. 5 field labs mention that their partners generated on average 79 jobs per field lab, which is partly caused by the field lab (e.g. Regions of Smart Factories) and 5 field labs have spin-offs (4 firms and 1 field lab) (see Table 10).

Table 10 Impact of the field labs

Field labs	**Partners**	**Partner firms**	**PhD's**	**Students**	**Projects**	**Jobs**	**EU projects**	**Spin-offs**
Region of Smart factories	32	24	4	10 per year	10	203[26]	1	1[27]
CAMPIONE	35	20	4	60	20	5	0	2
Fresh Teq	6	1 foundation with firms as members	0	0	5	80	0	0
The Garden	35	27	0	10	5	0	1	0
Smart Connected Supplier Network	27	25	0	0	3	0	0	1
Flexible manufacturing	19	14	0	0	12	0	1	0
Smart Dairy Farming 2.0	8	5	0	4	4	5	0	0
Smart Bending Factory	9	7	0	50+	0	100	0	1
Multimateriaal 3d printen	30	20	11	3	6	0	0	0
Ultra Personalized Products and Services	10	10	4	20	10	0	0	0

4.6 Overview of ICT development within field labs

In this section we will highlight our key-finding with regards to ICT related developments in the various field labs. ICT is a very important technology and each of the field labs already performed a lot of activities in this area.

4.6.1 Most transformations are covered by the field labs

The transformations are addressed by the field labs in the following ways[28]:

- Field lab Ultra Personalized Products & Services (UPPS) focus on Smart products.
- Field labs that develop technologies required to come to a servitization business model are Campione and Smart Dairy Farming/JoinData
- Field lab Region of Smart Factories is working on the realization of Digital Factory transformation.
- The field labs Smart Connected Suppliers Network, and the industrial security field lab the Garden are involved in the Connected Factories transformation.
- Field lab Ultra Personalized Products & Services (UPPS) has sustainability as design constraint.
- The field labs Region of Smart Factories and Flexible manufacturing are test environments with a focus on Advanced Manufacturing.
- Field lab Smart Bending Factory and field lab Smart Connected Supplier Network, provide prototype environments for the Flexible Manufacturing transformation.

---

[26] This number of new jobs is partly caused by the field lab

[27] This spin-off concerns a new field lab instead of a new firm

[28] Smart Industry Roadmap 2018: https://www.smartindustry.nl/wp-content/uploads/2018/02/Smart-Industry-Roadmap-2018.pdf

The only transformation with less emphasis is “smart working”. Based on the Dutch roadmap for smart industry all current field labs should include some form of skills lab for life-long learning and start discussions on the social impacts of the technologies.[29]

4.6.2 *Main focus on high-TRL*

Most field labs started with a focus on ICT technologies with a relatively high TRL level. This means that the field lab used existing/generic ICT solutions and (re-) used them in an industrial context ,driven by the specific needs of the industrial end-users of the field lab. Even though ICT companies were involved in the field labs, there were only a few examples of ICT companies using field labs to develop new technologies or evolve existing ones.

The combination and application of these existing technologies can be seen as a form of incremental innovation. Incremental innovation is the most common and a very relevant form of innovation. This is in line with previous research on the Apple cases which indicate that incremental technological innovations can sometimes have more influence than radical ones[30].

Many field labs indicate that their key-aim is to facilitate the collaboration between the stakeholders in the field lab and align business and ICT accordingly. For example: the field lab FreshTeq aims to provide an integrated ‘growth support systems’ proposition to the international market. To achieve this, they look for international market opportunities and ways for the individual vendors to collaborate. In the current status of the field lab they aim to use the existing underlying (ICT) technologies to achieve the required integration.

4.6.3 *Emerging need for new developments on medium level TRLs*

Since their establishment, several field labs have gone through several innovation cycles. In some cases, this has resulted in the notion that new technologies need to be developed on a medium level TRL. For instance: when existing (high level TRL) technologies proved not fit-for-purpose or were lack certain capabilities for scaling-up.

This has led to field labs innovating in new ICT technologies themselves and more fundamentally adapting new ICT technologies from other domains for industrial use.

Several field labs have applied for some form of public funding to enable these more fundamental innovations. Accordingly the field lab has a stronger focus on research. Examples include the use of semantic web technology in the Smart Connected Supplier Network field lab to enable large scale data sharing and the usage of linked data technologies in the Smart Dairy Farming/JoinData field lab.

---

[29] Smart Industry Roadmap 2018: https://www.smartindustry.nl/wp-content/uploads/2018/02/Smart-Industry-Roadmap-2018.pdf

[30] Rayna, T., & Striukova, L., (2009). The Curse of the First-Mover: When Incremental Innovation Leads to Radical Change, *International Journal of Collaborative Enterprise,* Vol. 1, No. 1, pp. 4–21.

4.6.4 *Main focus on AI-enabled data infrastructures & data spaces for network centric collaboration*

Where ICT plays an important role in a field lab the key focus is on either AI-enabled data infrastructures or data spaces for network centric collaboration

Often the focus is on the sharing of data between stakeholders and using this data for a new business proposition. In many cases a third party such as a platform provider or 'information value provider' is involved to integrate the data and to perform certain analytics functions. For example:

- The Smart Dairy Farming/JoinData field lab where sensor-data relating to the well-being of livestock is shared between farmers, equipment manufacturers and dairy companies through a so called 'information broker' (the Data hub).
- The CAMPIONE field lab where maintenance related data is shared between equipment manufacturers, service & maintenance companies and users of equipment. To do this an architecture called 'Daisy' is applied. This architecture was initially developed for offshore wind turbines and is now used in the chemical process industry.

In several other field labs the focus is on connecting the various stakeholders in a supply chain and supporting the exchange of designs, orders, logistics and product-usage data. For example:

- Field lab 'The Garden' focusing on extended product lifecycle management. This includes the sharing of designs and product data between an OEM and its suppliers to seek their involvement in the design and maintenance of a product.
- Smart Bending Factory, Multi material 3D printing and Ultra Personalized Products and Services (UPPS) focusing on the exchange of (3D) digital designs between customers and manufacturers in various contexts: metal cutting and bending, 3D printing and ultra-personalized products.

It is also within those two areas were the need for medium level TRL developments has emerged most strongly.

4.6.5 *Limited focus on next generation of factory automation in the current field labs*

There are several field labs which apply factory automation (e.g. the 'zero defect' pilot in RoSF). But very often this is in the context of seeking new business opportunities/collaborations for existing technology (e.g. the FreshTeq field lab) and not yet to enhance or develop the required underlying technologies. One could think of sensor technology (industrial 'internet of things') and subsystems with a much higher level of intelligence (e.g. the combination of big data analytics/machine learning and manufacturing execution systems (MES)).

Such topics are a clear priority in the German Industry 4.0 platform and became part of the trilateral Paris declaration on Smart Manufacturing.[31]

This relates in particular to the following technologies:

- **Industrial Internet of Things**. This typically includes:
  - the usage of sensors in the production environment to support flexible and zero defect manufacturing

---

[31] Paris Declaration of the Trilateral Group for Smart Manufacturing

  - the usage of sensors in products in use to support new value added services and maintenance – both of which are very important from the perspective of ‘servitization’ of manufacturing.

  There are just a few of these 10 field labs applying these technologies. Where they are applied they are not in the core of the scope of the field lab (but mostly a supporting technology).
- **Wireless communication technologies.** This typically includes the use of new protocols and technology to provide connectivity.
  - Commercial actors such as telecom operators are investing in technologies such as LoRa and narrowband LTE to support connecting to sensor devices. This development is however not yet included in any of the 10 field labs.
  - Similarly there is no focus on the next generation of wireless connectivity as part of the development of 5G in the 10 field labs. The European Union puts a lot of emphasis on its development. The 5G PPP (public-private partnership) recommended that its development should be driven by verticals such as the (manufacturing) industry. This is however not yet covered in any of the field labs under investigation.

We do however note that new field labs have been established which have a more specific focus on these technologies, e.g. on 5G wireless communication.

In addition, this is an area which is in focus for further follow-up of existing field labs. For instance the Flexible Manufacturing field lab and the Smart Connected Supplier Network are expected to move to a ‘Brainport Industries Campus’ building with several manufacturing companies under one roof[32]. As part of this new physical location of the field lab it is expected that the focus will also shift towards a joint data backbone for factory automation. This also links to the emerging need as identified in paragraph 4.6.3.

4.6.6 Some field labs have potential for further standardization

In some field labs there are certain aspects which have a potential for further standardization (mostly by adapting or extending existing standards). This includes:
- The information broker concept as was developed in the Smart Dairy Farming / JoinData field lab.
- Security requirements and frameworks which are part of the scope of field lab The Garden.
- The Daisy architecture for the sharing of maintenance related data (field lab Campione).
- Concepts for Flexible Manufacturing which relate to input and control mechanisms in a flexible production cell.

However, at present standardization is not at the core of any of the 10 field labs. Most field labs indicate that they either apply or combine existing standards. There are no formal linkages to international standardization initiatives yet.

A possible approach could be to include these developments as a use case in international platforms such as the Industrial Internet Consortium and the Industrial Data Space Association. These consortia aim to develop new standardized

---

[32] See: www.brainportindustriescampus.com/en/home

frameworks for data sharing and network centric collaboration. Both consortia are driven by specific use cases. There are currently some links between the German Industrial Data Space Association and the Smart Connected Supplier Network field lab.

In 2018 a national Smart Industry Standardization Platform[33] has been initiated to explore such opportunities in more detail.

An overview of the ICT developments per field lab is presented in Appendix A.

---

[33] See: https://smartindustry.nen.nl/

5 Conclusion and recommendations

5.1 Conclusion on field labs

Based on this investigation we come to the following main conclusions:

Creation process of the field labs

- **Most field labs were initiated by existing networks with many private parties (e.g. Brainport Industries, World Class Maintenance):**
  - to realize radical objectives, which require a cooperative setting (e.g. develop radical new product propositions or the ambition to become world leader).
  - and to cope with challenges that require an interdisciplinary approach such (e.g. technology developments that cannot be done by one single firm alone, to solve business challenges, stay competitive or develop the region into a home for Smart Factories).
- **All field labs are involved in the national Smart Industry related initiative and most of them are also involved in a regional initiative:**
  - to share knowledge and expertise between field labs and to discuss challenges and reinforce each other (e.g. via the field lab coordinator meetings of the National Smart Industry Program and regional initiatives like BOOST).

Main features of the field lab

- **The 10 field labs have comparable main features which makes them similar in the way they function:**
  - the coordinators have in principle the mandate to represent their partners on national field lab meetings and in outside communications.
  - the field labs involve their partners in important decisions.
  - all field labs have ambitious objectives.
- **Many activities and investments take place:**
  - they are on average involved in in 5-6 investigated activities per field lab that are crucial to accelerate research, development and innovation in digital technologies. Activities vary from activities such as awareness creation to collaborative research, development and innovation and education and skills development. Main activities of the field lab are *collaborative research, development and innovation, concept validation and prototyping* and *testing and validation.*
  - The 10 field labs together focus on more than 15 sectors.
  - More than 72 million Euros have been invested in the 10 investigated Smart Industry Field Labs since 2015, of which 31 million Euros were private investments.

Field labs in practice

- **The daily practice of the field labs is for most field labs organized in the same structured way:**
  - most field labs have a clear, but non-hierarchical organization structure (e.g. they often do not have and advisory board and they do not have a scientific board), and use a project based approach (e.g. via EFRO projects, European projects, TKI projects or projects).

  - most field labs have a physical test location to execute their activities.
- **The biggest challenge during the implementation of the field labs was their financing:**
  - due to initial difficulties to attract private financing and a shortage of public funding instruments.

International dimension

- **Since Smart Industry is an international development which require international cooperation 7 of the 10 field labs have an international dimension:**
  - the international dimension is for most field labs based on their cooperation with foreign partners, often via projects (5 out of 10) (e.g. German partners).
  - for some others the international dimension is based on their ambition to approach foreign markets (2 out of 10).

Impact of the field labs

- **The 10 field labs have been able to generate a relatively high impact on various indicators since 2015:**
  - they have been able to involve on average 20 partners per field lab, of which more than 15 involved firms.
  - they have on average on 8 projects per field lab.
  - 7 field labs have on average 27 students per field lab involved.
  - 4 field labs have on average 6 PhD’s per field lab involved.
  - 5 field labs mention that their partners generated on average 79 jobs per field lab, which is partly caused by the field lab.
  - 5 field labs have spin-offs (of which 4 spin-offs concern new firms and 1 spin-off is a field lab).

5.2 Conclusions on ICT developments in field labs

- The **10 field labs mainly apply ICT technologies on a high-TRL level.**
- There is an **emerging need for new ICT developments** on medium level TRL levels, e.g. to reduce barriers for large scale adoption of Smart Industry concepts.
- **The technology developments of the investigated field labs contribute to most transformations** (7 out of 8)**.** In each of the following transformations are 1 or 2 assessed field labs involved:
  1. Smart products
  2. Servitization
  3. Digital Factory
  4. Connected Factories
  5. Sustainable Factory
  6. Advanced Manufacturing
  7. Flexible Manufacturing
- The **“Smart working” transformation is addressed in a limited way only by the 10 field labs investigated.** More emphasis might be needed on this transformation in the future.

- **Most enabling ICT innovations are addressed** by the field labs, in particular AI-enabled digital infrastructures and Data spaces for network centric collaboration.

- **There is less focus on the enabling ICT innovation "next generation of factory automation"** in the field labs assessed and the underlying technologies such as Industrial Internet of Things and Wireless communication technologies. Most field labs using the innovation focus on the integration of a particular production capability or sensor in an existing production environment, instead of looking at the overall future of factory automation. Underlying ICT technologies such as wireless communication technologies and industrial internet of things are applied where necessary, but all on a high TRL level.

- **Most ICT technologies** (6 out of 8) are covered within the field labs:
  1. Distributed Data Infrastructures
  2. Secure and trusted connectivity
  3. Semantic Interoperability
  4. Distributed data infrastructures
  5. Visualization and human machine interaction
  6. Digital designs and product data

- Some field labs have certain aspects (e.g. information broker concept, security requirements and frameworks, architecture for the sharing of maintenance related data, concepts for flexible manufacturing and flexible production cells) which have a future **potential for further standardization**, most likely by adapting or extending existing standards. The national Smart Industry standardisation platform is exploring these opportunities in more detail.

5.3 Recommendations for further ICT acceleration by field labs

Based on these conclusions we have the following recommendations for different stakeholders:

5.3.1 For the Programme Bureau Smart Industry

- When selecting new field labs, **focus on one or more of the following topics** since they are relevant for Smart Industry and currently not addressed in 10 investigated field labs:
  - ICT developments on medium TRL level to accelerate more fundamental and radical developments such as large scale data sharing technologies and large scale industrial internet-of-things.
  - On the enabling ICT innovation 'next generation of factory automation': the new IT setup of the factory of the future. This is for instance a key priority in the German Industry 4.0 platform. It relates in particular to Internet of Things in an industrial context and Wireless Communication Technologies
- It should be noted that **only 10 of the 32 initiated new Smart Industry field labs are in the scope of this research**. The ICT developments in 22 other Smart Industry field labs need to be analysed as well to be able to get a complete picture of the whole field lab portfolio and the TRL levels of all 32 field labs in order to say something about topics that are not yet included in the portfolio. 5G wireless communication technology is for instance part of one of the more recent field labs, which is not part of this investigation.

5.3.2 *For policy makers in general*

- **Stimulate the use of field labs** to fosters the Smart Industry developments as it is a useful mechanism to accelerate ICT development and contribute to a diverse impact.
- Public R&D funding with a strong ICT / KET focus are likely to stimulate **an increase in ICT developments on medium TRL-level** both within existing as well as in new field labs.

5.3.3 *For the Smart Industry programme bureau in cooperation with individual field labs and other stakeholders*

- Increase cooperation between field labs by organizing **workshops** on practical issues (financing, contracts, IP) and technology-related topics such as large scale data sharing and industrial internet of things.
- **Increase awareness on standardization** via the Smart Industry Standardization platform.
- **Stimulate standardization** by including potential standardisation developments of field labs as a use case in international platforms such as the Industrial Internet Consortium and the Industrial Data Space Association.

A Overview of findings per field lab

The table below highlights the various enabling ICT innovations and underlying ICT technologies and indicates their use in the various field labs. For each of the field labs and technologies several characteristics are highlighted in the table:
The **technology readiness level** (TRL). We differentiate between:
☑ **-** High TRL: Use of technology which is currently available on the market. The field lab applies this technology.
❋ **-** Medium TRL: Development of new technology or adaptation of existing technology for a new market/use case. The field lab is actively adapting or developing the technology.

The extent to which the field lab is **focused on the use of ICT**:

- Marked **GREY** – the technology is used as generic enabler: ICT is used to achieve the overall objective, but it is not considered to be part of the core developments of the field lab.
- Marked **BLACK** – the technology is considered to be at the heart of the field lab and is crucial to its success.

	Enabling ICT innovations			**ICT technologies**						
	Next generation factory automation & connected products	**AI-enabled data infrastructures**	**Data spaces for network centric collaboration**	**Industrial IoT**	**Wireless Communication Technologies**	**Secure and trusted connectivity**	**Semantic Interoperability & Machine learning**	**Distributed data infrastructures**	**Visualization and human machine interaction**	**Digital designs and product data**
Region of smart factories	☑	☑	☑	☑	☑		☑		☑	☑
	The Region of Smart Factories field lab consists of various sub cases; as a result all enabling ICT innovations are applied to a certain extent.			Connected devices for consumer electronics; application of IoT in end-user products; realtime data collection in production processes for zero defect manufacturing	Antenna development for wireless communication for consumer electronics and IoT applications		Analytics are used to develop self-learning algorithms for zero defect manufacturing and to analyze product designs. Both are applied in a consumer electronics case during design (analyses of product models) and manufacturing (analysis of manufacturing data).		Design of user-friendly dashboards for both IoT end-user products and operators .	Integration of CAD/CAM and PDM (product data) systems – used in a shipbuilding case for 'first time right' and in a metal-polymer-case for process optimization and virtual testing. The field lab calls this 'model based product design'
	▨	▨	▨	▨	▨		■		▨	■
CAMPIONE		☑		☑		☑	☑	☑		
		DAISY system for the exchange of maintenance related data		Application of IoT (LoRa) to monitor production equipment (Ericsson and other suppliers)		IoT cloud environment	Data analysis to define maintenance requirements (business intelligence and analytics; dashboards/reporting)	Architecture for sharing sensor data between vendors of industrial equipment and maintenance companies (DAISY architecture)		
		■		▨		▨	▨	▨		

	Enabling ICT innovations			**ICT technologies**						
	Next generation factory automation & connected products	**AI-enabled data infrastructures**	**Data spaces for network centric collaboration**	**Industrial IoT**	**Wireless Communication Technologies**	**Secure and trusted connectivity**	**Semantic Interoperability & Machine learning**	**Distributed data infrastructures**	**Visualization and human machine interaction**	**Digital designs and product data**
FreshTeq	☑ Growth support systems in the agricultural sector (e.g. greenhouses) ▨			☑ Connecting growth support systems of different vendors. These systems control the operation of greenhouses (climate, energy, robotics, etc.) ▨						
The Garden			☑ ✱ Extended PLM solutions for collaboration between OEM and suppliers + technology for secure data sharing ■			✱ ☑ Advanced encryption and data protection technology for intercompany use without the need for centralized servers (Thales DPIF/Martello) ■		☑ Application of PLM portals for intercompany data sharing (product designs, product data) – focus on requirements and business processes ■		☑ The field lab performs experiments around security of the Digital designs and product data aspects in the project Extended Product Life Cycle management ■

	Enabling ICT innovations			**ICT technologies**						
	Next generation factory automation & connected products	**AI-enabled data infrastructures**	**Data spaces for network centric collaboration**	**Industrial IoT**	**Wireless Communication Technologies**	**Secure and trusted connectivity**	**Semantic Interoperability & Machine learning**	**Distributed data infrastructures**	**Visualization and human machine interaction**	**Digital designs and product data**
Smart Connected Supplier Network			☑ ❋ Connecting ERP/MRP systems of different suppliers ■			☑ Usage of core technologies from Industrial Data Space to enable trust and data sovereignty ▨	❋ Semantic web technologies and the use of ontologies/domain models for easier interoperability (vs. existing EDI/XML systems) ■	❋ Development of a 4-corner model based on Industrial Data Space for data exchange ■		
Flexible Manufacturing	❋ New technology for supporting production cells for flexible manufacturing ■						☑ Development of semantic models for smart production cells ▨		❋ Human-machine interaction in semi-automated production - e.g. an operator working together with a robot with work instructions being projected on the product, the bins and/or the desk/product carrier ■	

	Enabling ICT innovations			**ICT technologies**						
	Next generation factory automation & connected products	**AI-enabled data infrastructures**	**Data spaces for network centric collaboration**	**Industrial IoT**	**Wireless Communication Technologies**	**Secure and trusted connectivity**	**Semantic Interoperability & Machine learning**	**Distributed data infrastructures**	**Visualization and human machine interaction**	**Digital designs and product data**
Smart Dairy Farming / JoinData		☑ ✱				☑ ✱	☑ ✱		✱	
		Sharing of sensor data related to cows to optimize livestock conditions (health, milk production)				Data broker for the trusted sharing of sensor data: the broker keeps track of data providers and data users. It allows for data governance by farmers (data owner) and suppliers in case they have IP on the data	The field lab worked on semantic interoperability and machine learning to link data sources.		Application of data analytics technology for visualization: used to analyze data shared through the data broker. UX-model was further developed and applied for authorization of JoinData	
		■				■	▓		░	
Smart Bending Factory	☑		☑							☑
	Integration with the production environment (feeding digital designs to metal processing production equipment – cutting and bending)		Online environment SOPHIA for digital designs, used to reduce the time to market for tailor-made sheet metal products							SOPHIA web-tool for analyzing digital designs (design optimization, quotations, production preparation) – used for value chain integration.
	░		■							■

	Enabling ICT innovations			**ICT technologies**						
	Next generation factory automation & connected products	**AI-enabled data infrastructures**	**Data spaces for network centric collaboration**	**Industrial IoT**	**Wireless Communication Technologies**	**Secure and trusted connectivity**	**Semantic Interoperability & Machine learning**	**Distributed data infrastructures**	**Visualization and human machine interaction**	**Digital designs and product data**
Multimateriaal 3D printing	☑ Integrating multiple 3D printers in a production line, supporting different 3D printing technologies for different materials		☑ Digital designs for 3D printing are used as an input for the printing-line; the field lab uses market-standards for this.						☑ Improvement of input and control interfaces for 3D printers	☑ 3D models are used as input
Ultra Personalized Products and Services (UPPS)			☑ Sharing of digital designs						☑ Visualization of product designs	☑ Digital models of personalized products
Conclusions	Focus is mostly on the integration of new equipment in a production environment. Less focus on the overall architecture for future factory automation.	AI is mostly focused on the usage of semantic web technology to link different data sources. It is however at the core of several field labs.	Controlled datasharing is a critical enabler for many field labs. Most fieldlabs deploy high-TRL technologies. Some initiatives (e.g. SCSN) have recognized the need to go beyond the state-of-the-art and also explore new technological concepts .	Some fieldlabs deploy available IoT and wireless communication technologies as an enabler. Advancing these technologies is not a specific focus of the fieldlabs involved.		There several fieldlabs using a range of technologies for trusted connectivity. This is also an area where fieldlabs are pushing new technologies.	Several fieldlabs have used semantic interoperability technology to describe data sources and ensure the linking of data. Some field labs are actively deploying new technologies for this.	Some fieldlabs are using high-TRL technologies (e.g. portals and centralized platforms) for data sharing. Others, such as CAMPIONE and SCSN explore novel architectures and new – more distributed – approaches.	Several fieldlabs use visualization technologies to display 3D models or to provide operators support.	Digital design (e.g. STEP files) are used as a basis for novel manufacturing concepts. Some field labs (e.g. The Garden) enrich these design with lifecycle data.

B Questions used for the investigation

Questions about the field lab as mechanism to accelerate research and innovation in ICT technologies

The process of creation of the field labs

1. What are the main factors and background conditions that motivated the creation of the centre/network of centres/platform?
2. What stakeholders were involved in its creation? (e.g. Did the private sector play a leading role in its creation?)
3. Did the creation of the centre(s)/platform involve co-ordination with other policy areas (e.g. co-ordination with other ministries or agencies)? What mechanisms facilitate such co-ordination?

Main features of the field labs

4. What is the mandate and the specific objectives of the centre(s)/platform?
5. What are the centre(s)/platform's main areas of action? (e.g. Research and innovation, legal framework, standards and norms, intellectual property, education and training, etc.)
6. Are the activities of the centre(s)/platform focused on specific sectors or technologies? If so, which ones? Are there mechanisms in place to ensure interdisciplinary approaches to research and innovation?
7. What is the annual budget allocated to the centre(s)/platform?
8. What are the sources of funding? Please describe its funding model.

The field labs in practice

9. How is the centre(s)/platform structured? How does it operate in order to achieve its objectives? (e.g. Does it have a steering committee? Does it have a scientific advisory body?)
10. In what ways does the centre(s)/platform differ from others (if any) that do not have a digital focus?
11. What challenges have been faced during the process of design and/or implementation of the centre(s)/platform (if any) and how are these being (or planning to be) addressed? To what extent do these differ from challenges faced by centres/platforms that do not have a digital focus?
12. Are other policy initiatives (also in other policy areas) in line with the objectives of the centre(s)/platform? In what ways do they reinforce each other?

International dimension

13. Does the centre(s)/platform have an international dimension? (e.g. Does it engage in cross-country collaborations for innovation or other mechanisms for international outreach?)
14. In what ways did experiences from other countries inform the development of the centre(s)/platform? Has this experience motivated the implementation of similar centres/platforms in other countries?

Impact of the field labs

15. Has the institution's/platform's impact already been evaluated? If so, what have been the outcomes? If not, how and when are impacts planned to be evaluated?

Questions about the ICT developments within the field labs

ICT developments

1. Do you recognize the enabling ICT innovations and ICT technologies in the overview we provided?
2. Which one is most relevant in your field lab?
3. Which ICT technologies are developed/or do you plan to develop within your field lab?
4. What is the current stage of the ICT development (R&D, scaling up, applications, close to the market/TRL)?
5. What are the most important bottlenecks related to your ICT development?
6. What are the needs to solve this in terms of funding resources etc.?
7. What is the role of standards in these ICT developments?

Do you develop/apply/combine standards (different domains) (with a main focus on ICT)?

C Overview of the 32 Smart Industry field labs in the Netherlands

	Field Lab
1	Ultra Personalized Products and Services
2	Region of Smart Factories
3	Smart Dairy Farming 3.0
4	Smart Bending Factory
5	The Garden
6	FreshTeq
7	MultiMateriaal 3D Printen
8	Smart Connected Supplier Network
9	CAMPIONE
10	Flexible Manufacturing
11	Digital Factory Composites
12	ACM3
13	RAMLAB
14	3D Makers Zone
15	Smart Welding Factory
16	Praktijkcentrum voor Precisielandbouw
17	De Duurzaamheidsfabriek
18	3D Medical
19	Composieten Onderhoud en Reparatie
20	ThermoPlastic Composites Nederland (TPC NL)
21	CAMINO
22	SMASH
23	Smart Base
24	5G
25	Industrial Robotics
26	Technologies Added
27	Dutch Optics Centre
28	RoboHouse
29	High Tech Software Competence Center
30	Blocklab
31	Dutch Growth Factory
32	Techport