D 3.1
Initial Scouting Collection and fine-tuned mapping methodology

Action acronym	ConnectedFactories 2
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Grant Agreement Number	873086
Instrument	CSA: Coordination and Support Action
Project coordinator	VTT

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Actual submission date	03/07/2020

[1] PU: Public, CO: Confidential, only for members of the consortium (including the Commission Services)
[2] RE: Report, OT: Other; ORDP: Open Research Data Pilot

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Abbreviations and acronyms

TERMS, ABBREVIATIONS AND ACRONYMS	
WPL	Work Package Leader
GA	Grant Agreement / General Assembly
EB	Executive Board
CO	Coordinator
DoA	Description of Action
EC	European Commission
WP	Work package
QM	Quality Manager
DPO	Data Protection Officer
QMP	Quality Management Plan
CA	Consortium agreement
SyGMa	System for Grant Management
ORDP	Open Research Data Pilot

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Executive Summary

This document reports about the initial work of WP3 regarding the fine-tuning of the mapping methodology and the scouting of cases to be mapped. The objective of this deliverable is double: first, to describe the methodology inherited from the ConnectedFactories 1 project, and how this is a living methodology that is being refined as WP1 goes deeper into the key enablers and cross-cutting factors and also the new pathways are being defined in WP2; second, to identify the main sources of the cases that will become a part of the portfolio of cases, and that will go beyond DT-ICT-07 projects, including cases from regional/national initiatives.

The overall objective of ConnectedFactories2 WP3 is to collect and catalogue the main results of the Research an Innovation projects funded by the Commission as well as those funded by other national and regional initiatives. In parallel, these cases will be mapped to help European Industries to progressively and harmoniously move forward on aligned digital manufacturing transformation pathways, to inspire and encourage them to invest in digital transformation platform deployment and smart connected services and application projects.

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1 Introduction

The main goal of this deliverable is to describe the methodology that is used to map cases in the context of the ConnectedFactories 2 CSA, and to identify the main sources of demonstrators and cases to be analysed and mapped.

This methodology allows the systematic analysis of many specific aspects, such as the coverage of demonstrators in the different pathways, the gaps between the real market and the innovation projects, and many other. The methodology is supported by the general methodology applied by EFFRA, supported by the EFFRA Innovation Portal and, therefore, it is applied across the whole project portfolio of the Factories of the Future PPP and beyond.

An important component in the methodology are the *structured lists*, including cross-cutting factors and enablers, as well as pathways to digitalisation. These structured lists were enhanced considerably by the ConnectedFactories1 CSA (carried out in 2016-2019), and has been successfully used since then.

In ConnectedFactories2 one of the objectives is to increase the number of cases collected but, even more important, perform a deeper analysis of the whole portfolio of cases, platforms and demo centers to detect the areas in which the implementation of the new technologies is more widespread, and to identify the challenges that will have to be addressed by future initiatives. Also, the identification of the most illustrative and inspiring cases in particular for SMEs is an important goal of the mapping exercise.

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2 The mapping methodology

2.1 The general approach and the role of the EFFRA Innovation Portal

The mapping of cases is supported by the EFFRA Innovation Portal. This means also that the mapping can be applied to any projects and the associated cases (use cases, demonstrators, pilots) that are included on the EFFRA Innovation Portal.

General guidance to the mapping is available on the EFFRA website, in particular on the pages https://www.effra.eu/promote-your-projects-results-and-demonstrators-effra-innovation-portal

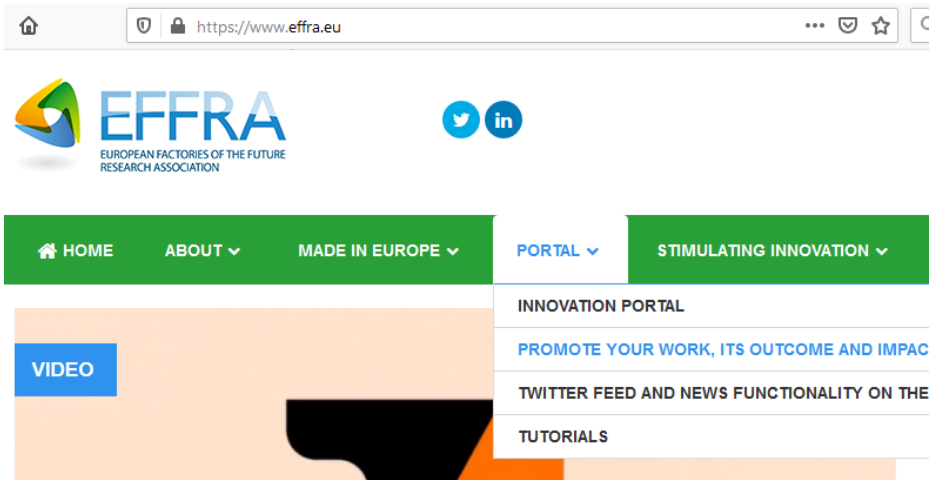

Figure 1- EFFRA website capture

In order to promote the usage of the EFFRA Innovation Portal, video-tutorials (https://www.effra.eu/tutorials) have been made available to make it easier for the users to contribute and to navigate through the huge amount of information that it contains.

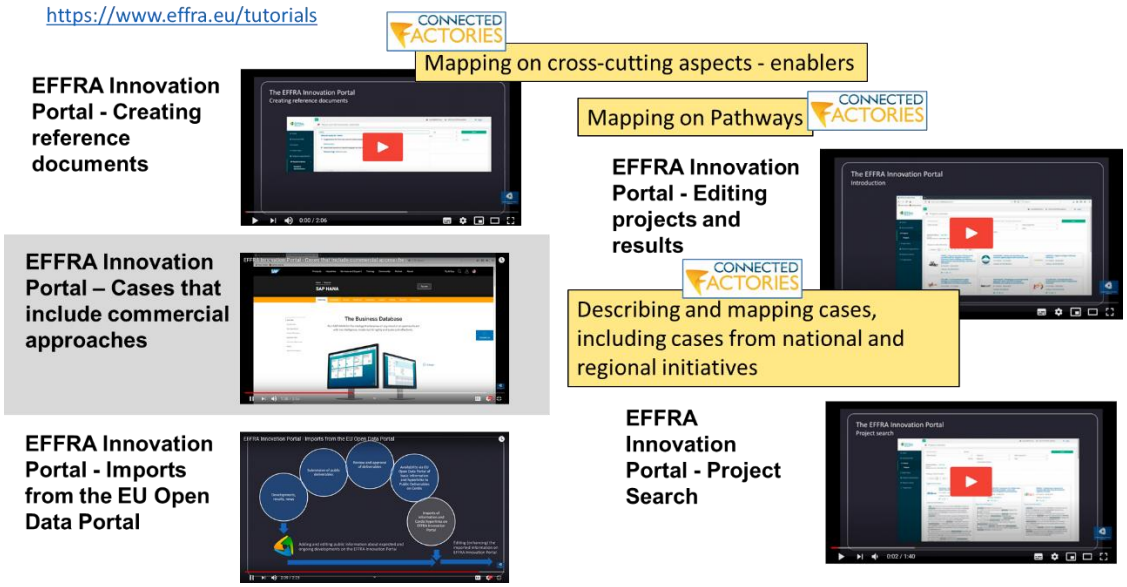

Figure 2: Tutorials about the EFFRA Innovation Portal and their relation to key activities in the ConnectedFactories CSA

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The list below included the tutorials that were published in April 2020:

1) Editing projects and results: https://youtu.be/xcyWz__8oNY
2) Project search: https://youtu.be/xW_vK3emKXM
3) Imports from the EU Open Data Portal: https://youtu.be/VxBVEvJucd0
4) Creating reference documents: https://youtu.be/wCsJFG2UK10

A dedicated video tutorial about the description of case that include commercial approaches was also produced: https://www.youtube.com/watch?v=8Die1vQwP4U .

2.2 Including cases in the EFFRA Innovation Portal

Herewith some extracts of this guidance taken from the EFFRA website in April 2020.

Any user with editing permission for a specific project can edit the information and/or add project results and demonstrators.

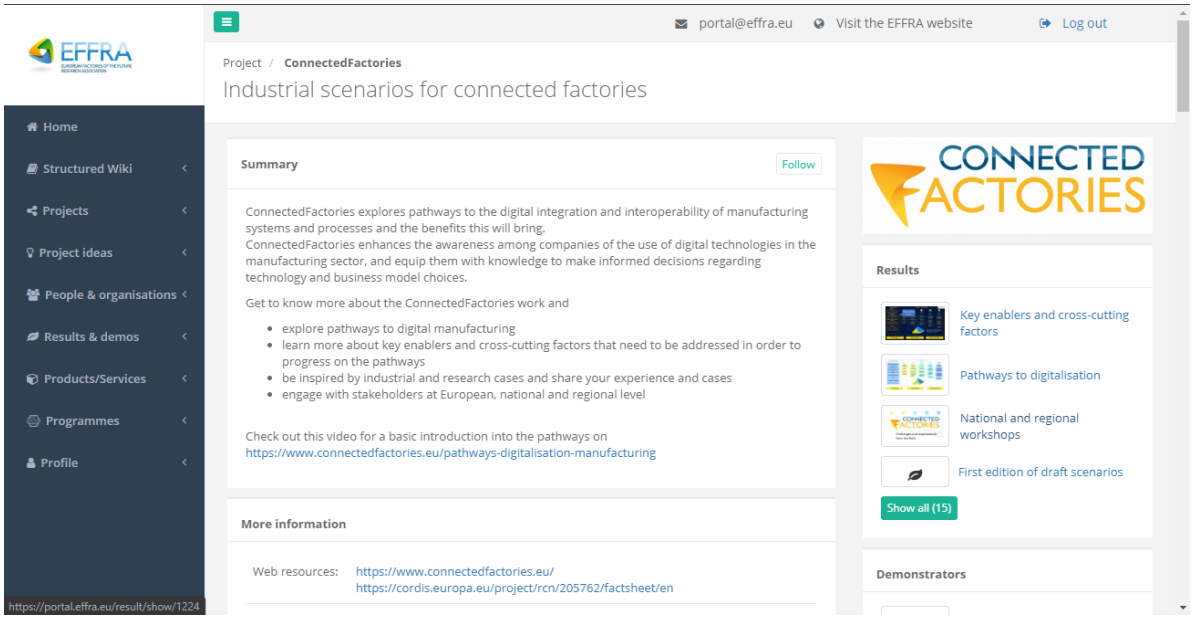

Figure 3: The ConnectedFactories project information in the EFFRA Innovation Portal

The user can describe the general features and the overall status of the project and update the project summary whenever is indicated. Also, new results and/or demonstrators can be included (and will be shown in the project information page, as shown in Figure 3). Note that any item can be marked both as a result and a demonstrator at the same time or any of them individually.

It is important to indicate a contact person for each of the results and demonstrators. The contact person must be registered in the EFFRA Innovation Portal. Also, including pictures and images for illustrative purposes of the use cases is very recommended.

In case of having a use case that includes commercial approaches, this can also be included in the Innovation Portal. As it is shown in Figure 4, which is a screen capture of a demonstrator that is related to some

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commercial products and services, these are indicated in the right hand side, in a section that lists the *Associated products/services*.

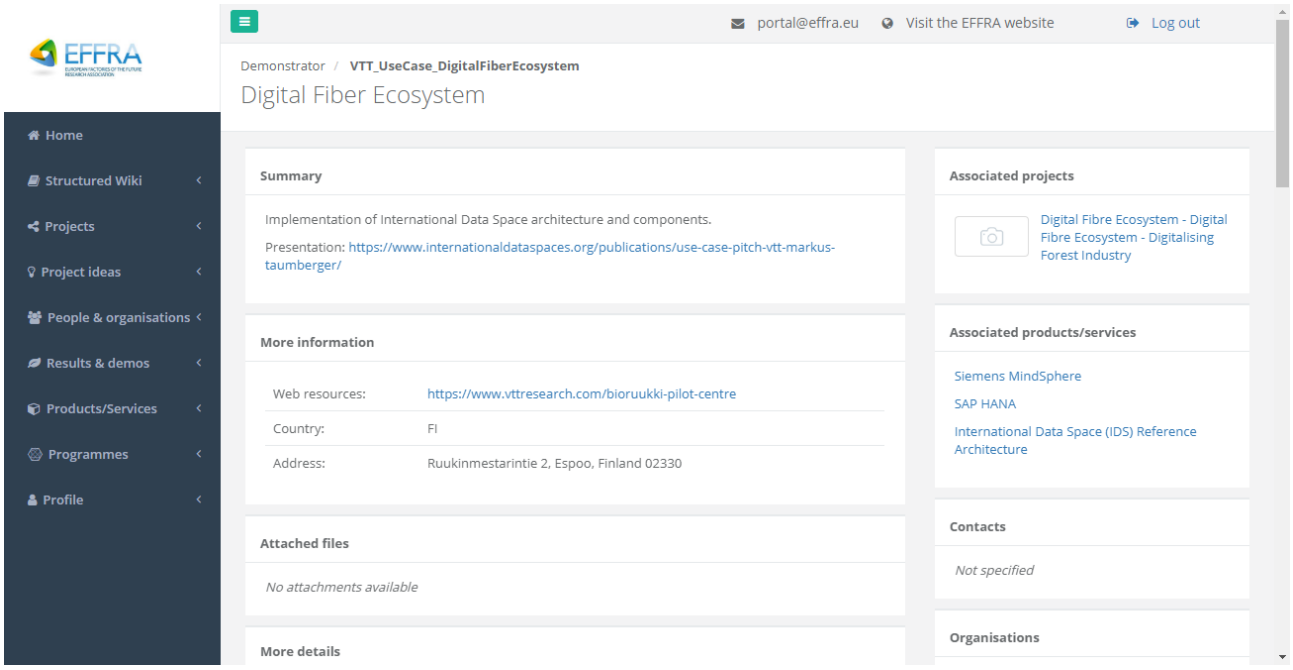

Figure 4: Use case with commercial approaches in the EFFRA Portal

When clicking the link of any of the associated products/services, we will see a description of the product/service with a link to the product/service's website, the demonstrators related, and also, additional files and even a contact if assigned.

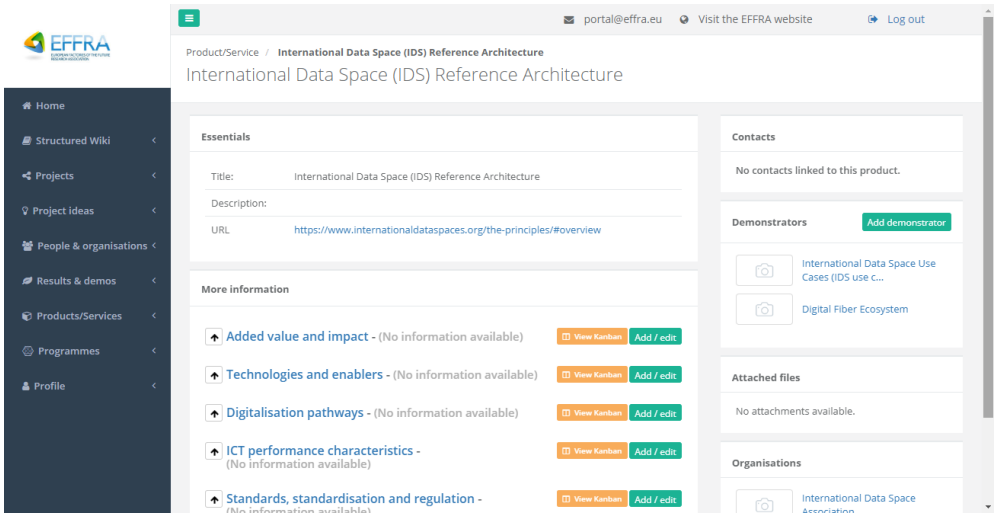

Figure 5: A Product/Service example

2.3 Searching cases in the EFFRA Innovation Portal

There are several ways to search and find the use cases in the portal: directly, through the Results & demos section of the menu, or indirectly, through the Project sections, for example. The portal is equipped with a

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highly powerful search engine, that supports free-text index-based searches. When searching for a specific term, the search engine retrieves the results and demonstrators that term is relevant and the page displays where the term is encountered. This can be in the title, the description, the structured list items and the associated comments of the result/demonstrator, but also in the associated project title or in the name of the associated products/services.

See for instance this search action on Human and robots in manufacturing (and the associated screenshot below).

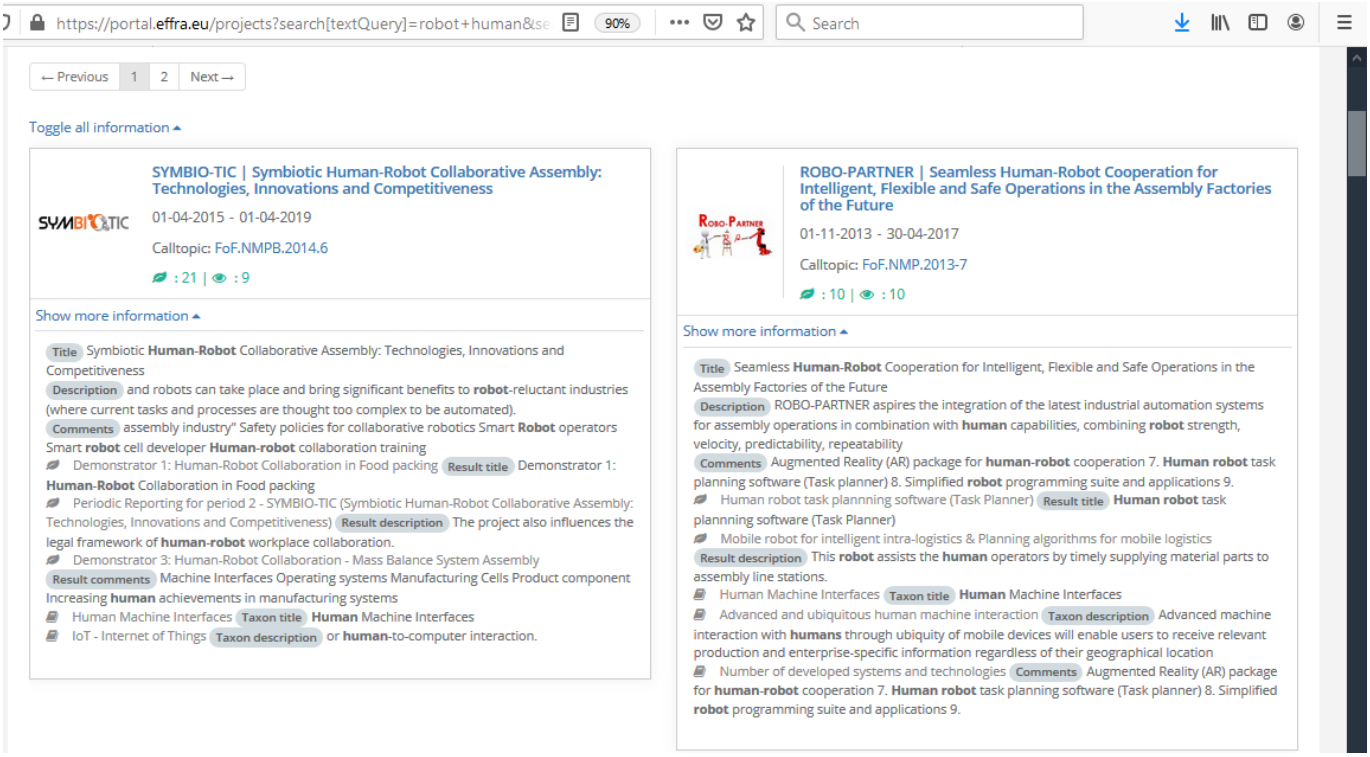

Figure 6- Screenshot of the search action Human and Robots in Manufacturing

The quality of the search and the returned information is dependent on the quality of the short descriptions of the projects and the associated results and demonstrators. The quality can also be significantly raised by providing specific information via the structured lists (also accessible via the structured wiki see section 2.4).

Here follows a short explanation on how to search directly in the results and demonstrators' section, although the indirect search is pretty similar.

Once the Results & Demos menu item is selected, a list of all the results/demos that are in the portal is shown, with the search interface (Figure 7) on top. The simple search interphase allows a free-text search and also to set some filters to the search: type of item (result or demo), call topic and call programme and project. An advanced search is also available by clicking on the link "Show additional filters", that allows to set several additional filters, associated to the structured list items.

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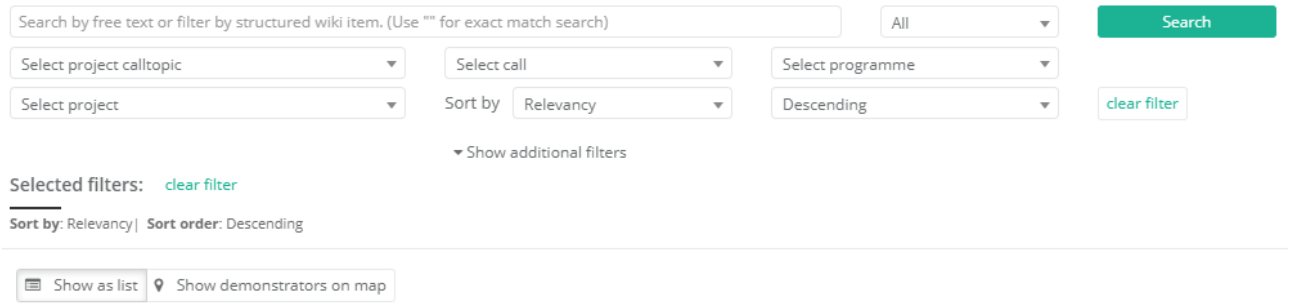

Figure 7: Simple search interface of the Results & demos section

The free-text search interface also proposes the structured lists items (see section 2.4) that include the searched term. By clicking those items, the results page will show only the results/demonstrators that have been directly mapped on this specific structured list items, as Figure 8 shows.

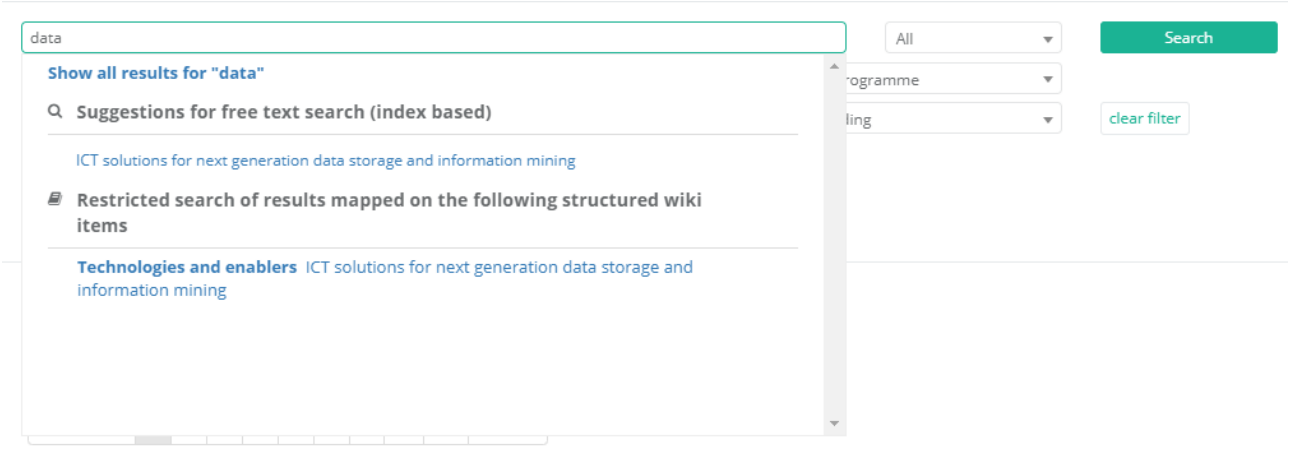

Figure 8: The search interface proposes the structured lists items

The following links lead to search results on project level and result-demonstrator level on the EFFRA Innovation Portal for a number of aspects that are key to the development and deployment of digitalisation in manufacturing:

- Cybersecurity – **project search** – **results and demonstrator search**
- Interoperability – **project search** – **results and demonstrator search**
- Business model aspects – **project search** – **results and demonstrator search**
- Humans and digitalisation aspects – **project search** – **results and demonstrator search**
- Architectures – **project search** – **results and demonstrator search**

2.4 The role of structured lists (including pathways) for mapping projects and their cases

On the EFFRA Innovation Portal projects and cases can be described using structured lists, which also feature on the EFFRA Innovation Portal as a structured wiki. This is the backbone of the structured mapping and it

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also serves as a stand-alone structure wiki about aspects that matter in the context of manufacturing and manufacturing innovation in particular. During ConnectedFactories1, the sections in this structured wiki that cover digitalisation have been considerably enhanced. In addition, ConnectedFactories2 will revise, enhance and fine-tune the structured wiki on a continuous basis (See section 3 of this document).

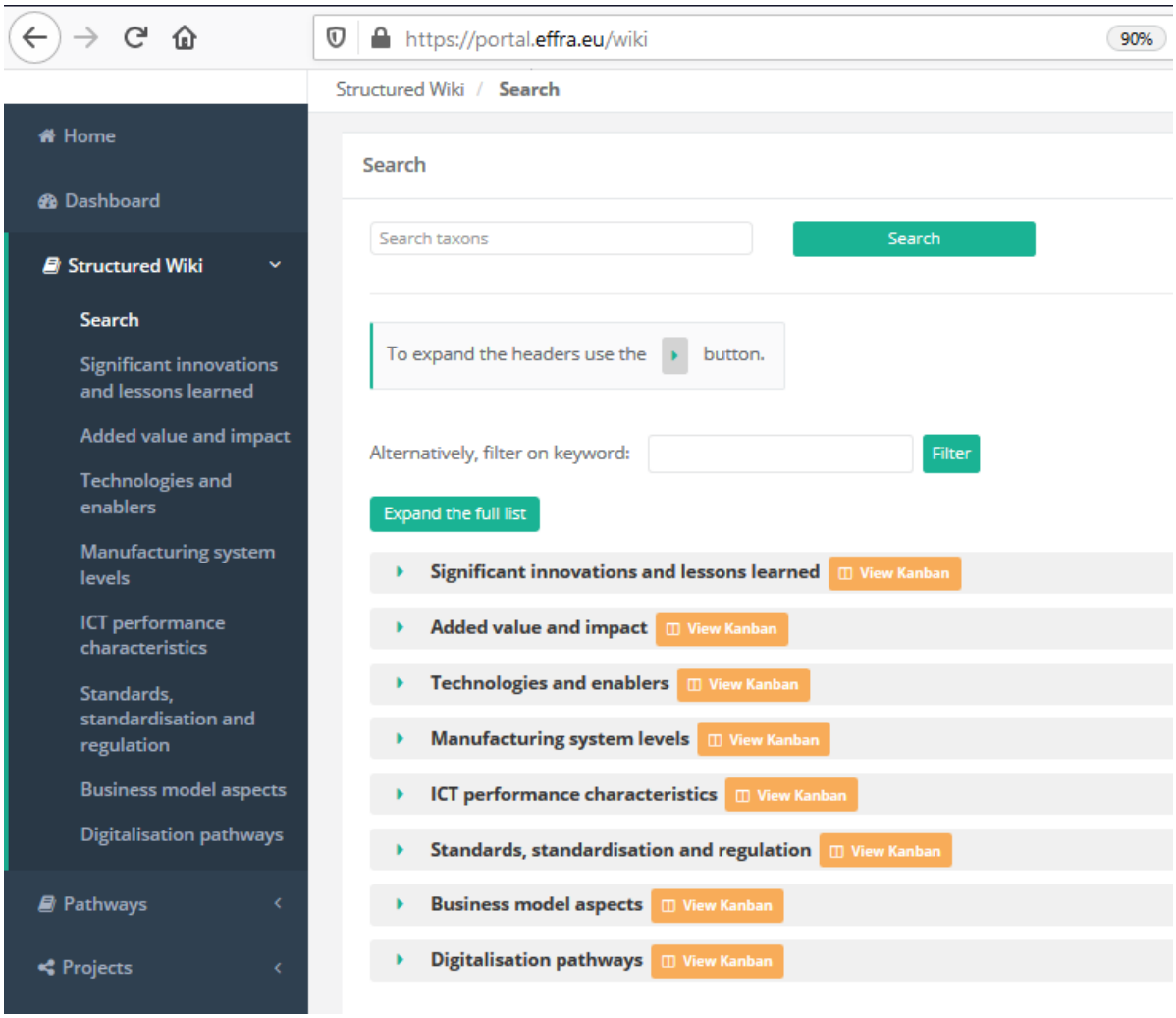

Figure 9- Screenshot of the structured lists in the EFFRA Innovation Portal

A complete snapshot extracted from the portal database of the structure lists is included in the Annex (in chapter 6 of this document).

A particular set of structured lists: pathways

Pathways to digitalisation of manufacturing reflect how digitalisation and eventually the deployment of digital platforms can bring value within different kinds of manufacturing perspectives, such as factory automation, value networks or product-service development. The pathways enhance the awareness among different stakeholders about the actual and future use of digital technologies in manufacturing and facilitate the migration from legacy situations towards innovative approaches.

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Three pathways with a particular scope within the overall context of manufacturing have been developed during the ConnectedFactories 1 project (2016-2019):

- **Autonomous Smart Factories** (more on this page, see also the video here below)
- **Hyperconnected Factories** (more on this page, including a video)
- **Collaborative Product-Service Factories** (more on this page ; a video will be available soon)

Also, during ConnectedFactories 1, a pathway on **cybersecurity for manufacturing** has been drafted. It was presented at the Cybersecurity for manufacturing workshop in October 2018. (See this presentation on slide 27).

Deliverable 4.7 reflects a snapshot at the end of December 2019 of the progress and outlook of the development of the pathways. It is available for download here.

In the meantime, work is underway for the development of **two new pathways within Connected Factories 2**:

- **Circular economy for manufacturing**. A recent presentation can be found here. See also section 3.3 in this deliverable.
- **Data spaces for manufacturing**. A recent presentation can be found here. See also section 3.2 in this deliverable.

2.5 ConnectedFactories mapping and information sharing and analysis

The use of the EFFRA Innovation Portal for the mapping and analysis work in the ConnectedFactories CSA is explained on https://www.connectedfactories.eu/connectedfactories-information-sharing-and-analysis (the work was started under the first ConnectedFactories CSA that was carried in out in 2016-2019)

The following is based on an extraction of that web page from April 2020.

You can download here Connected Factories 1 Deliverable 3.2 that reflects the mapping of projects and project cases (produced at the end of 2019), which is mainly composed of extractions from the EFFRA Innovation Portal.

Projects, solutions and demonstrators are characterised and positioned using this structured approach.

This video (https://youtu.be/Jtk6Nx9n_54) explains how the digitalisation pathways and the digital mapping framework/cross-cutting factors are used to characterise and put into context cases or examples digitalisation of manufacturing:

Figure 10- Screenshot of the YouTube video: Introduction to Pathways

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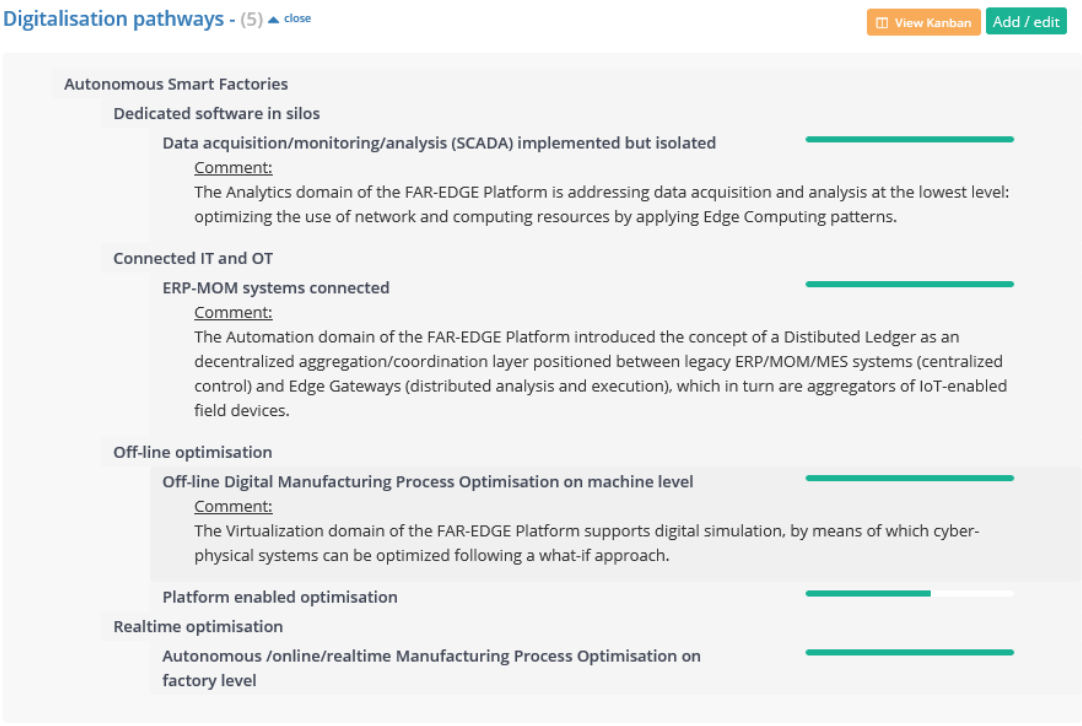
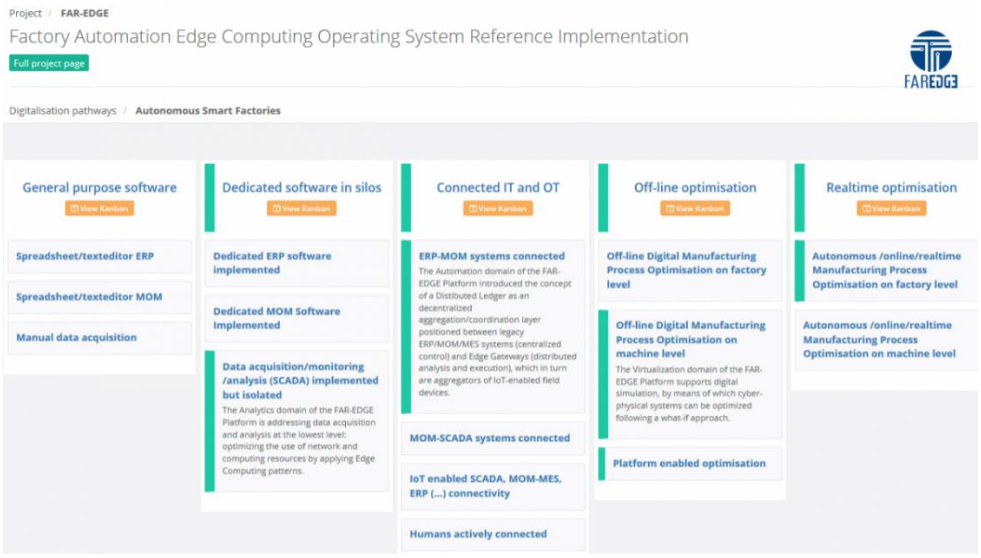
See below how the project FAR-EDGE is currently positioned on the pathways 'Autonomous Smart Factories'

First in the 'List' view:



In the 'Kanban' view (https://portal.effra.eu/project/1628/taxonomy-list-taxon/911):



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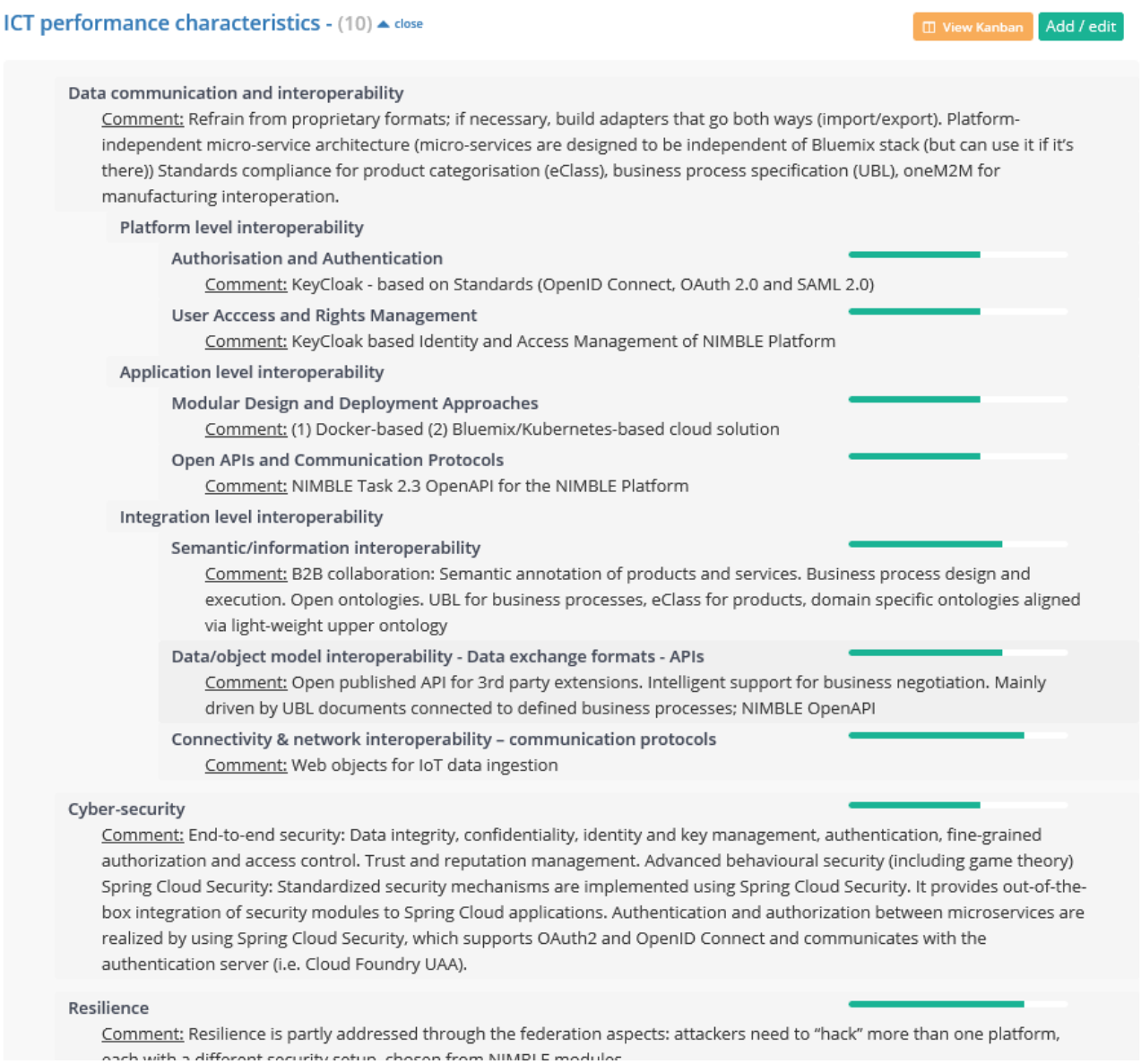
See here an example from the NIMBLE project and how this projects is mapped on some of the key enablers and cross-cutting factors, in this case in the section 'ICT Performance Requirements - Data communication and interoperability'.

In 'List view:



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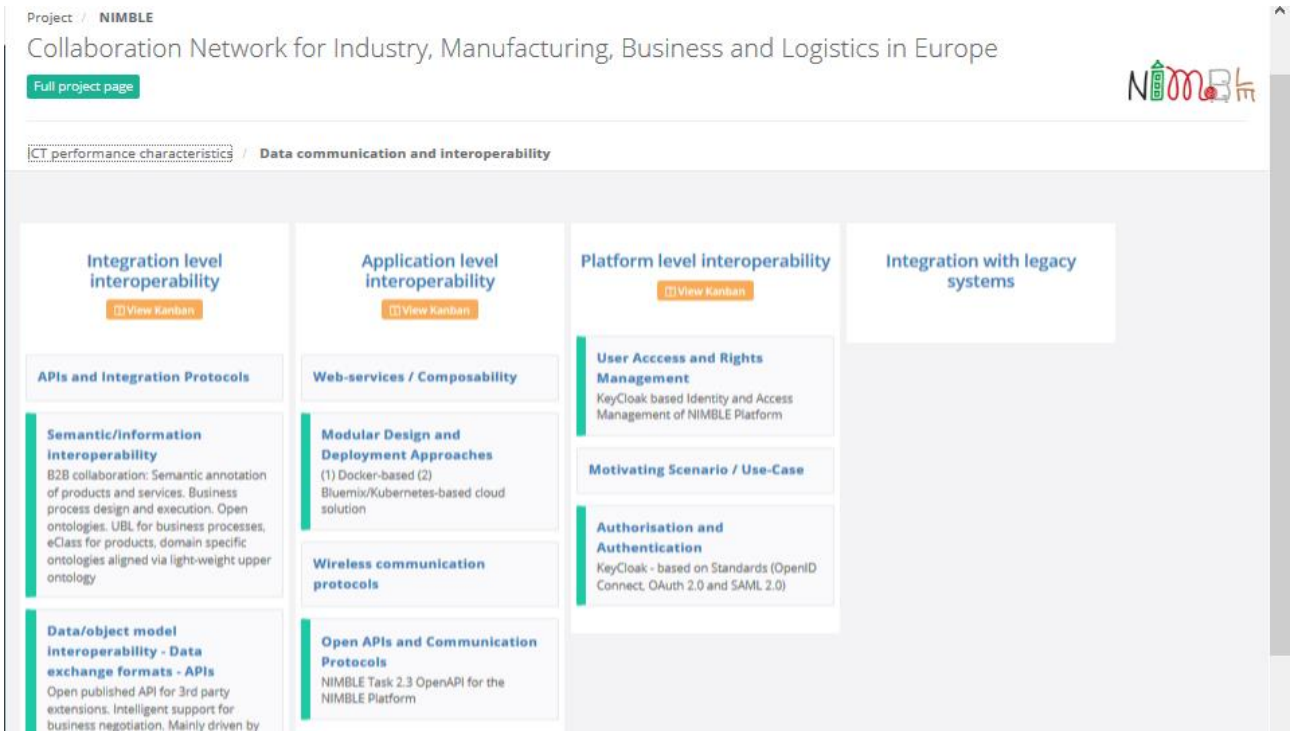
In 'Kanban' view (https://portal.effra.eu/kanban/project/1641/taxonomy-list/1030):



2.6 ConnectedFactories related deliverables

The starting point for the ConnectefFactories 2 project are the results of the ConnectedFactories project. In the case of WP3, the main results associated to the mapping of projects and associated cases and demonstrators are gathered in the following public Connected Factories deliverables:

1) Deliverable 4.7 – Revised set of consolidated pathways, available in https://cloud.effra.eu/index.php/s/k16YJOsSjkoilmR
2) Deliverable 5.1 – Report on cross-cutting factors, available in https://cloud.effra.eu/index.php/s/im0tadtYf8KrYwV
3) Deliverable 3.2 – Second report on the mapping of research activities, available in https://cloud.effra.eu/index.php/s/Zn569w2NbqBrwYJ

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3 Fine-tuning of the methodology

In section 2 of this document, the mapping method and tools as it was available in May 2020 is described. This section describes examples of the ongoing fine-tuning and enhancements of the structured lists (associated to WP1 of the ConnectedFactories2 CSA), including the 'pathways' (associated to WP2 of the ConnectedFactories2 CSA), that serves as a mapping framework for the mapping of projects and use case, pilots, demonstrators (as well as other resources, such as reference documents or other interesting resources). Other sections will be revised as the work of the associated WP progress and both the structured lists and the pathways are refined.

3.1 The section on standards and standardisation

The section on standards and standardisation will be subject to a revision. At the time of the submission of this deliverable, the section on standards includes a section that was set-up in consultation with CEN-CENELEC (see below)

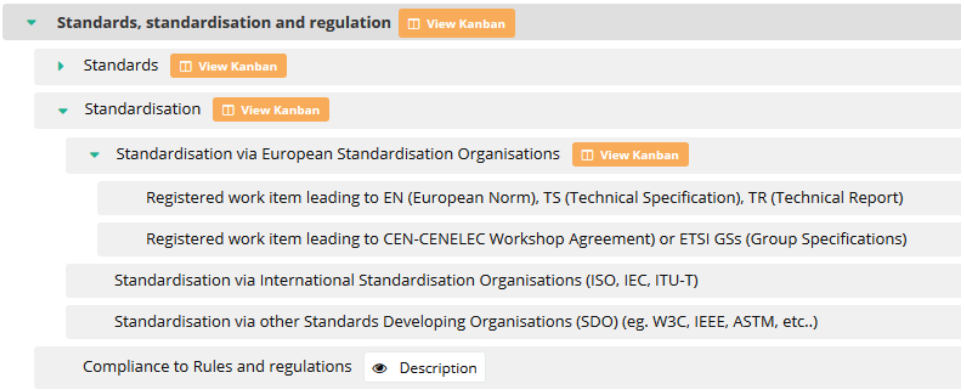

Figure 11- Section of stardards and standarization in the Structured Lists

The sub-section of standards however just provides some pointers to standards of associated initiatives (such as OPC-UA):

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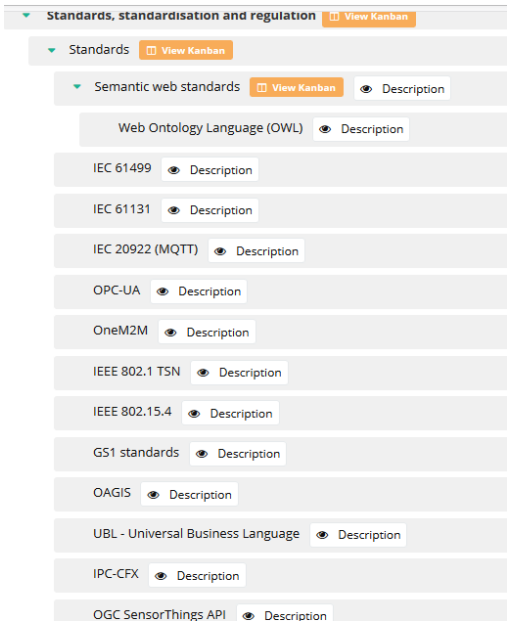
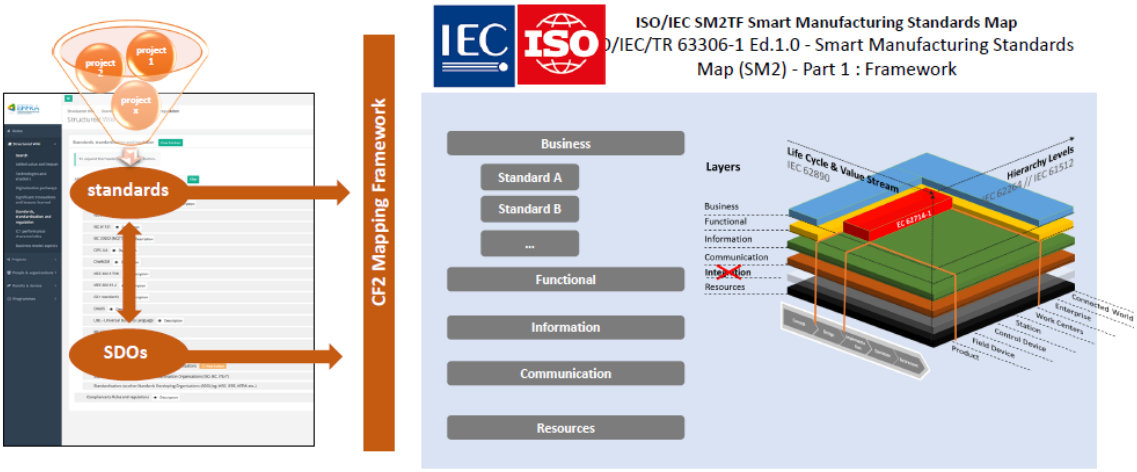


Figure 12- Subsection of standards details

It is envisaged to include a set of categories of standards according to ongoing work that is taking place at ISO level: the ISO/IEC CD TR 63306-1 Smart manufacturing standards map — Part 1: Framework (See also https://www.iso.org/standard/81277.html). There, a common framework is being established that is also in line with the vertical dimension (layers) in the RAMI 4.0 Reference Model Architecture.



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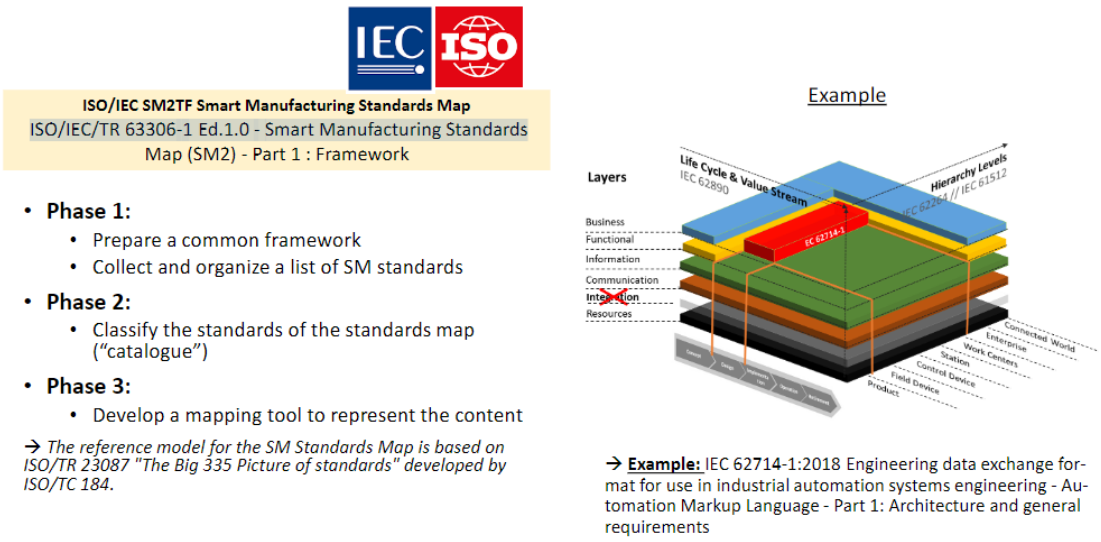
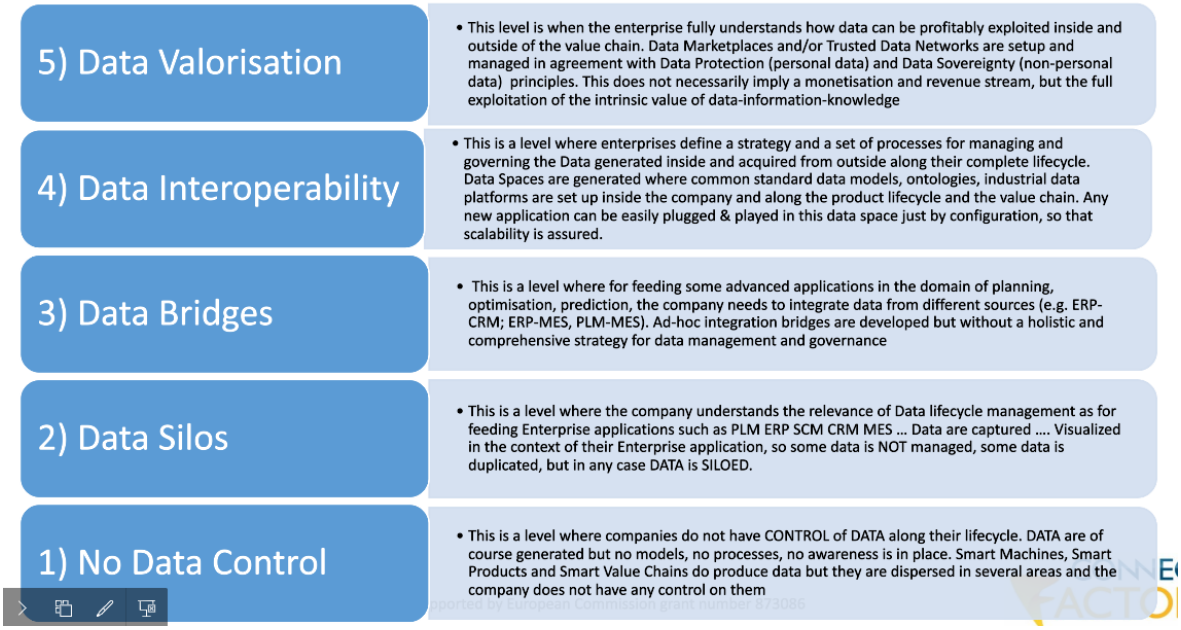


Figure 13: Structure update and refinement according to ISO/IEC/TR 63306. See also https://www.iso.org/standard/81277.html

One option is that in the structured wiki these categories include a set of key standards, such that the experts that coordinate the development of use cases can be requested to indicate and comment about the standards that are applied in their use cases. This process will be further fine-tuned in a progressive way.

3.2 The pathway 'Data spaces in Manufacturing'

In addition to existing pathways (see section 2.4 in this document), a pathway with a focus on **Data spaces for manufacturing** is being developed. At the time of submission of this deliverable, the high-level pathway looks like this.



A recent presentation can be found online (https://cloud.effra.eu/index.php/s/rrHQ0JbKIFeelk2).

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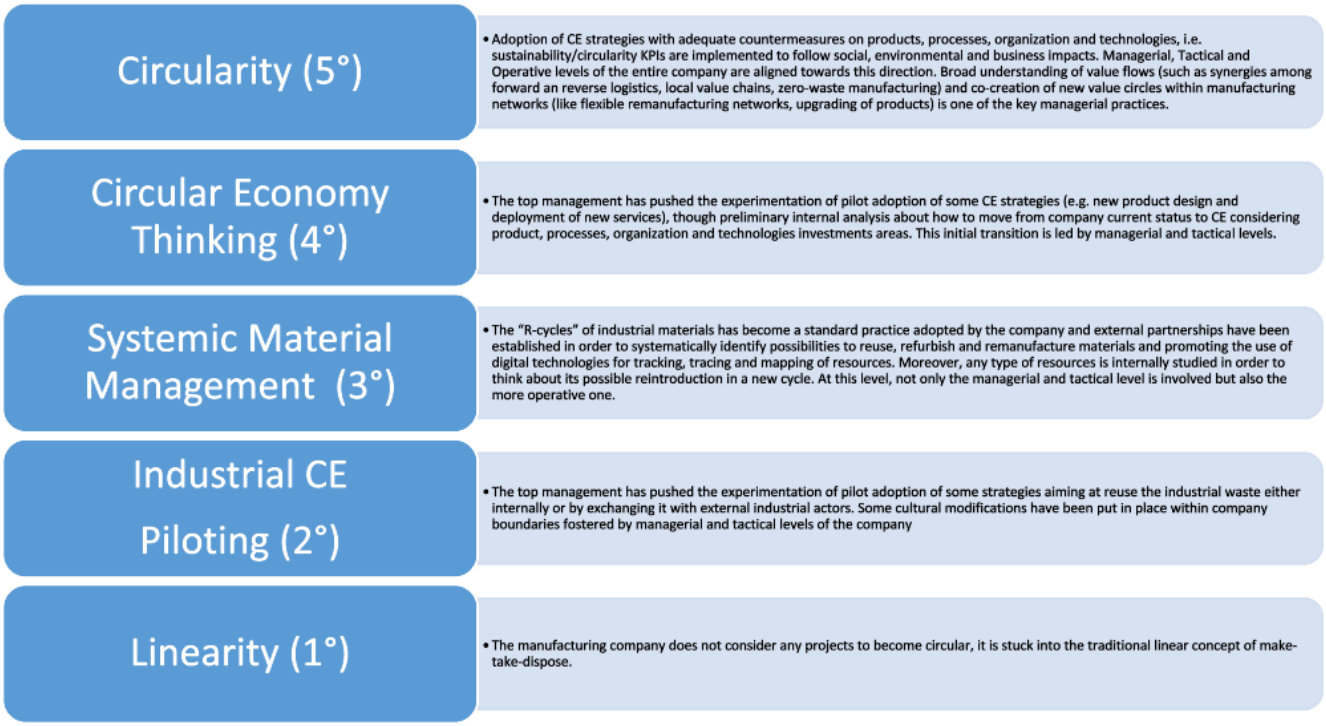
3.3 The pathway 'Circular economy in Manufacturing'

Similar to existing pathways (see section 2.4 in this document) a pathway to **Circular economy for manufacturing** is being developed. At the time of submission of this deliverable, the high-level pathway looks like this.



A recent presentation can be found here.

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4 Scouting portfolio of cases

This section of the deliverable intends to specify the initial collection of cases that will be analysed and mapped into the pathways in the coming months. However, as mentioned before, this portfolio will be extended with cases coming from other initiatives and sources. Future deliverables D3.2 (in M18) and D3.4 (in M34) will provide a more exhaustive collection, including the mapping of the demonstrators into the pathways.

4.1 DT-ICT-07-18-19 project demonstrators

Presentations of the associated projects, including video recordings, from a webinar organised by ConnectedFactories on 11 March 2020 are available on:

https://www.connectedfactories.eu/news/digitalisation-and-digital-platform-webinar-presentations-and-video-recordings-are-available

See also:

DT-ICT-07-2018 **- Digital Manufacturing Platforms for Connected Smart Factories_1 Associated projects**

- QU4LITY - Digital Reality in Zero Defect Manufacturing
- eFactory - European Connected Factory Platform for Agile Manufacturing
- ZDMP - Zero Defect Manufacturing Platform

DT-ICT-07-2019 **- Digital Manufacturing Platforms for Connected Smart Factories_2 Associated projects**

- KYKLOS 4.0 - An Advanced Circular and Agile Manufacturing Ecosystem based on rapid reconfigurable manufacturing process and individualized consumer preferences
- SHOP4CF - Smart Human Oriented Platform for Connected Factories
- DigiPrime - Digital Platform for Circular Economy in Cross-sectorial Sustainable Value Networks
- ConnectedFactories 2 - Global-leading smart manufacturing through digital platforms, cross-cutting factors and skilled workforce

The use cases for the first call (DT-ICT-07-2018) are listed below. The ones for the second call, that started earlier this year, are still not totally defined.

4.1.1 eFactory Pilots -

- Ad-hoc Supplier Network in the Avitation Domain
- Lot size 1 Furniture Manufacturing Pilot
- Lot size 1 in Closed-Loop Supply Chain

4.1.2 Qu4lity Pilots

- Pilots related with the *Autonomous Smart Factories Pathway*:
  - PHILIPS OneBlade shaving unit production line
  - SIEMENS SIMATIC Products Quality Improvements
  - WHR Dryer Factory Holistic Quality Platform
  - KOL's Real-time injection moulding process monitoring-control

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- THYS Quality Management of Steering Gear based on Acoustic control
- AIRBUS Trade space framework for Autonomous Quality Manufacturing Systems' Design
- RiaStone Autonomous Quality ZDM for "Ceramic tableware Single-firing
- PRIMA Additive Manufacturing Pilot Adaptive Control Technology
- Danobat Digital Machine for zero-defects at high precision cutting/grinding
- GF Digital machine and part twins for zero defect manufacturing
- GHI Real-time cognitive hot stamping furnace 4.0

- Pilots related with the *Hyperconnected Factories Pathway*:
  - CONTI Autonomous Quality in PCB Production for Future Mobility
  - WHR Dryer Factory Holistic Quality
  - Zero defect and Autonomous Quality in Machinery Building for Capital Goods
  - PRIMA Additive Manufacturing Pilot Adaptive Control
  - FAGOR Zero-Defects Manufacturing Digital Press Machine

- Pilots related with the *Collaborative Product-Service Factories Pathway*:
  - Zero defect and Autonomous Quality in Machinery Building for Capital Goods sector

4.1.3 ZDMP Pilots

- Automotive Sector: Engine Block Manufacturing
  - Defects detection and prediction in aluminium injection operations
  - Defect detection and prediction in machining operations
  - Defects reduction by optimization of the machining process
- Machine Tool Sector: Moulds Manufacturing
  - Process alert system for machine tool failure prevention
  - Smart process parameter tuning
  - In-line 3D modelling
- Electronic Sector: Electronic Components Manufacturing
  - Component inspection
  - Assembly line: AI-supported optical defects detection
  - Assembly line: Monitoring and control system
- Construction Sector: Construction Sites and Supply
  - Steel Tubes: Production/Quality Monitor
  - Sone Tiles: Equipment Wear Detection
  - Quality Control at Construction Site
  - Quality Traceability

4.2 Other relevant projects and associated cases.

There are many projects that will provide very interesting cases that will provide additional perspectives about many of the key factors and pathways covered by the ConnectedFactories CSA:

ICT-08-2019 - Security and resilience for collaborative manufacturing environments

Associated projects

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 873086.

- SeCoIIA - Secure Collaborative Intelligent Industrial Assets
- COLLABS - A COmprehensive cyber-intelligence framework for resilient coLLABorative manufacturing Systems

DT-FOF-08-2019 - Pilot lines for modular factories (IA 50%)

Associated projects

- DIMOFAC - Digital Intelligent MOdular FACtories
- AVANGARD - Advanced manufacturing solutions tightly aligned with business needs

ICT-38-2020 - Artificial intelligence for manufacturing

Associated projects are in grant preparation phase at the time of submission of this deliverable.

FoF.2016.03 - Zero-defect strategies at system level for multi-stage manufacturing in production lines

Associated projects

- ForZDM - Integrated Zero Defect Manufacturing Solution for High Value Adding Multi-stage Manufacturing systems
- GO0D MAN - aGent Oriented Zero Defect Multi-stage mANufacturing
- STREAM-0D - Simulation in Real Time for Manufacturing with Zero Defects
- Z-Fact0r - Zero-defect manufacturing strategies towards on-line production management for European factories
- ZAero - Zero-defect manufacturing of composite parts in the aerospace industry

DT-FOF-06-2019 - Refurbishment and re-manufacturing of large industrial equipment (IA)

Associated projects

- RECLAIM - RE-manufaCturing and Refurbishment LArge Industrial equipMent
- LEVEL-UP - Protocols and Strategies for extending the useful Life of major capital investments and Large Industrial Equipment

FoF.2017.09 - Novel design and predictive maintenance technologies for increased operating life of production systems

Associated projects

- PROPHESY - Platform for rapid deployment of self-configuring and optimized predictive maintenance services
- PROGRAMS - PROGnostics based Reliability Analysis for Maintenance Scheduling
- SERENA - VerSatilE plug-and-play platform enabling remote pREdictive mainteNAnce
- PreCoM - Predictive Cognitive Maintenance Decision Support System
- UPTIME - UNIFIED PREDICTIVE MAINTENANCE SYSTEM

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 873086.

- Z-BRE4K - Strategies and Predictive Maintenance models wrapped around physical systems for Zero-unexpected-Breakdowns and increased operating life of Factories

FoF.2017.12 - ICT Innovation for Manufacturing SMEs (I4MS)

Associated projects

- MIDIH - Manufacturing Industry Digital Innovation Hubs
- L4MS - Logistics for Manufacturing SMEs
- I4MS-Go - I4MS Going to Market Alliance
- AMable - AdditiveManufacturABLE
- CloudiFacturing - Cloudification of Production Engineering for Predictive Digital Manufacturing

DT-ICT-03-2020 - I4MS (phase 4) - uptake of digital game changers

Associated projects are in grant preparation phase at the time of submission of this deliverable.

Cases from national-regional projects

Such cases include:

- Digital Manufacturing on a Shoestring (UK)
- RebootIoTFactory (Finland)
- Future Work Lab (Germany)
  Including: https://futureworklab.de/en/demonstrator-environment.html

Cases from EIT-Manufacturing

EIT Manufacturing www.eitmanufacturing.eu is on the first year of operation. A number of projects/activities http://eitmanufacturing.eu/activities/eit-projects/ are expected to conclude by end of 2020. These projects could provide additional cases for analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 873086.

5 Conclusions – next steps

The ConnectedFactories2 project deploys very powerful tools for projects to provide visibility to the pilots that are being deployed, and not only to the European projects, but also for those that are being developed through the national and regional initiatives.

This deliverable intends, on one side, to be a guide for projects to take the maximum profit of the tools and methods that the CSA is providing, and, on the other side, to show the work that ConnectedFactories2 is planning to address during the duration of the project in relation with the mapping of the demonstrators on the pathways.

Therefore, the next step of WP3 will be to work together with the DT-ICT-07-18/19 projects to deeply analyse the different use cases to have a clear view of the mapping in the pathways. This will include not only the main pilots, but also the open call use cases. In parallel, the national/regional workshops organised in WP5, use cases coming from any other source will also be analysed and mapped, in order to get a broader vision of the current Innovation trends in Europe.

All this information will be continuously analysed and will allow to identify, together with WP1 and WP2, the areas in which the implementation of the new technologies is more widespread, in order to provide guidance and inspiration for the stakeholders that wish to advance towards digital manufacturing and also enabling the identification of challenges that will have to be addressed in future initiatives.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 873086.

6 Annex - Snapshot of structured WIKI in June 2020

Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 873086.

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6.1 Significant innovations and lessons learned

- Significant innovations and achievements
- Significance of the results for SMEs
- Specific use case requirements
- Lessons learned

6.2 Added value and impact

- Manufacturing the products of the future
  - Complex structures, geometries and scale
  - Novel materials
  - Customised products
  - Resource efficient, sustainable products
- Economic sustainability
  - Flexibility

    Flexibility in manufacturing means the ability to deal with slightly or greatly mixed parts, to allow variation in parts assembly and variations in process sequence, change the production volume and change the design of certain product being manufactured.

    (from https://en.wikipedia.org/wiki/Flexible_manufacturing_system)

  - Lead time

    A lead time is the latency between the initiation and execution of a process. For example, the lead time between the placement of an order and delivery of a new car from a manufacturer (from https://en.wikipedia.org/wiki/Lead_time)

  - Product quality - Quality assurance

    In business, engineering, and manufacturing, quality has a pragmatic interpretation as the non-inferiority or superiority of something; it's also defined as being suitable for its intended purpose (fitness for purpose) while satisfying customer expectations. (from https://en.wikipedia.org/wiki/Quality_(business))

    Quality assurance (QA) is a way of preventing mistakes and defects in manufactured products and avoiding problems when delivering solutions or services to customers; which ISO 9000 defines as "part of quality management focused on providing confidence that quality requirements will be fulfilled". This defect prevention in quality assurance differs subtly from defect detection and rejection in quality

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control, and has been referred to as a shift left as it focuses on quality earlier in the process i.e. to the left of a linear process diagram reading left to right. (from https://en.wikipedia.org/wiki/Quality_control)

- Supply chain and value network efficiency

  Optimisation challenges must be faced along the entire supply chain or value network, involving OEMs, components suppliers, service providers and SMEs.

- Productivity

  Productivity describes various measures of the efficiency of production. A productivity measure is expressed as the ratio of output to inputs used in a production process, i.e. output per unit of input. Productivity is a crucial factor in production performance of firms and nations. (from https://en.wikipedia.org/wiki/Productivity)

- Process reliability - dependability

  In systems engineering, dependability is a measure of a system's availability, reliability, and its maintainability, and maintenance support performance, and, in some cases, other characteristics such as durability, safety and security. In software engineering, dependability is the ability to provide services that can defensibly be trusted within a time-period. This may also encompass mechanisms designed to increase and maintain the dependability of a system or software. (from https://en.wikipedia.org/wiki/Dependability)

- Business development - Access to new markets

  Business development entails tasks and processes to develop and implement growth opportunities within and between organizations. It is a subset of the fields of business, commerce and organizational theory. Business development is the creation of long-term value for an organization from customers, markets, and relationships. (from https://en.wikipedia.org/wiki/Business_development)

- Social sustainability

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- Human aspects
  - Human-machine interaction
- Safe and attractive workplaces
- Skills, training, new job profiles
- Increasing human achievements in manufacturing systems
- Occupational safety and health

Occupational safety and health (OSH), also commonly referred to as occupational health and safety (OHS), occupational health or workplace health and safety (WHS), is a multidisciplinary field concerned with the safety, health, and welfare of people at work. (from https://en.wikipedia.org/wiki/Occupational_safety_and_health)

- Environmental sustainability
  - Reducing the consumption of energy, while increasing the usage of renewable energy

*Efficient energy use, sometimes simply called **energy efficiency**, is the goal to reduce the amount of energy required to provide products and services. (from https://en.wikipedia.org/wiki/Efficient_energy_use)*

    - Reduction of energy consumption (in %)
  - Reducing the consumption of water and other process resources.

Reduction of resources other than energy (materials, water, etc.)

    - Reduction of water consumption (in %)
  - Reducing emissions in manufacturing processes
    - Reduction of CO2 emissions (in %)
  - Towards circular economy
    - Material efficiency

Material efficiency is a description or metric which expresses the degree in which raw materials are consumed, incorporated, or wasted, as compared to previous measures in construction / manufacturing projects or physical processes. Making a usable item out of thinner stock than a prior version increases the material efficiency of the manufacturing process. (from https://en.wikipedia.org/wiki/Material_efficiency)

      - Reduction of material consumption (in %)
    - Waste minimisation - old

Waste minimisation is a set of processes and practices intended to reduce the amount of waste produced. By reducing or eliminating the generation of harmful and persistent wastes, waste minimisation supports efforts to

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promote a more sustainable society. Waste minimisation involves redesigning products and processes and/or changing societal patterns of consumption and production. (from https://en.wikipedia.org/wiki/Waste_minimisation)

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  - Reduction of waste (in %)
- Co-evolution of products-processes-production systems
  Co-evolution of products-processes-production systems or 'industrial symbiosis' with minimum need of new resources
- Innovative re-use of equipment

6.3 Technologies and enablers

- Advanced manufacturing processes
  The efficiency and sustainability of both the manufacturing of actual and future products is still very much determined by the processes that shape and assemble the components of these products. Innovative products and advanced materials (including nano-materials) are emerging but are not yet developing to their full advantage since robust manufacturing methods to deliver these products and materials are not developed for large scale. Research is needed to ensure that novel manufacturing processes can efficiently exploit the potential of novel products for a wide range of applications.
  - Additive manufacturing

    Also referred to as 3D printing.

  - Innovative physical, chemical and physicochemical processes
  - Photonics-based materials processing technologies
  - Shaping technology for difficult to shape materials
    Shaping technology such as forming and machining, to address challenges related to "difficult to shape" materials and to explore new processing methods to achieve nano-sized microstructure components.
  - Replication, Equipment for flexible scalable prod/Assembly , Coatings

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- Methods for handling of parts, metrology and inspection
  Methods for handling of parts, metrology and inspection require development also to ensure ability to manufacture at scale (volume) with high reliability.
- Integration of non-conventional technologies and conventional technologies

  Integration of non-conventional technologies (e.g. laser, ultrasonic) towards the development of new multifunctional manufacturing processes (including in process concept: inspection, thermal treatment, stress relieving, machining, joining

- High productivity and "self assembly" technologies development of conventional (joining, forming, machining) and new micro/nano-manufacturing processes
- Flexible Sheet-to-Sheet (S2S) and Roll-to-Roll (R2R)
  Flexible Sheet-to-Sheet (S2S) and Roll-to-Roll (R2R), building in plastics electronics, large volume patterning at nanoscale (photolithography) and new materials and greater use of space on CMOS.
- Recycling processes

- Mechatronics

  Mechatronics, which is also called mechatronic engineering, is a multidisciplinary branch of engineering that focuses on the engineering of both electrical and mechanical systems, and also includes a combination of robotics, electronics, computer, telecommunications, systems, control, and product engineering. (From https://en.wikipedia.org/wiki/Mechatronics)

  - Control technologies

    https://en.wikipedia.org/wiki/Control_system

    Control technologies will be further exploiting the increasing computational power and intelligence in order to come forward to the demands of increased speed and precision in manufacturing. Advanced control strategies will allow the use of lighter actuators and structural elements for obtaining very rigid and accurate solutions, replacing slower and more energy-intensive approaches. Learning controllers adapt the behaviour of systems to changing environments or system degradation, taking into account constraints and considering alternatives, hereby relying on robust industrial real-time communication technologies, system modelling approaches and distributed intelligence architectures.

  - Condition and performance monitoring technologies

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Continuous monitoring of the condition and performance of the manufacturing system on component and machine level, enables sustainable and competive manufacturing, also by introducing autonomous diagnosis capabilities and context-awareness. Detecting, measuring and monitoring the variables, events and situations will increase the performance and reliability of manufacturing systems. This involves advanced metrology, calibration and sensing, signal processing and model-based virtual sensing for a wide range of applications, e.g. event pattern detection, diagnostics, anomaly detection, prognostics and predictive maintenance.

- Intelligent machinery components, actuators and end-effectors

  Intelligent components enable the deployment of safe, energy-efficient, accurate and flexible or reconfigurable products and production systems. This includes the introduction of smart actuators and the use of advanced end-effectors composed of passive and active materials. Energy technologies are gaining importance, such as (super)capacitors, pneumatic storage devices, batteries and energy harvesting technologies.

- Energy technologies
- Advanced materials in manufacturing systems

  Production equipment does not yet take full advantage of the benefits that new and advanced materials offer, and factories of the future will need more advanced equipment to meet the requirements for energy efficiency and environmental targets and to meet new demands for a connected world. The future will therefore see modern, lightweight, long-lasting/flexible and smart equipment able to produce current and future products for existing and new markets. There will be a step change in the construction of such equipment, leading to a sustainable manufacturing base able to deliver high added value products and customised production. Increased smartness in the manufacturing equipment also enables a systems approach with machines able to learn from each other and impacting on the human-machine interface.

  - Smart and functional materials

    Smarter equipment and manufacturing systems with self-diagnosis (temperature, vibrations, noise) and embedded sensing, memory or active architecture, with functional materials allowing them to adjust work processes and operations to variances in structure, shape and material composition (right first time manufacture).. Capture of machine data through this inherent 'smartness' for communication between machines (for M2M), at factory level and through supply chains for a systems approach to manufacturing and meeting customer demand. New equipment components taking advantage of new designs and advanced materials (e.g. gears and transmissions providing longer lifetime of equipment, active surfaces that can embed and release lubricant when needed (higher pressures or temperatures))

- Information and communication technologies

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- Digital manufacturing platforms

  See https://www.effra.eu/digital-manufacturing-platforms

- IoT - Internet of Things

  The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. (from https://en.wikipedia.org/wiki/Internet_of_things)

- Human Machine Interfaces
  - Augmented reality

    https://en.wikipedia.org/wiki/Augmented_reality

  - Virtual reality

    https://en.wikipedia.org/wiki/Virtual_reality

  - Advanced and ubiquitous human machine interaction

    Advanced machine interaction with humans through ubiquity of mobile devices will enable users to receive relevant production and enterprise-specific information regardless of their geographical location and tailored to the context and the skills/responsibilities they own. Interactions with ICT infrastructures and equipment will be natural language-like

  - Data visualisation

    https://en.wikipedia.org/wiki/Data_visualization ; http://www.visual-analytics.eu/faq

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- Data collection, storage, analytics, processing and AI
  - Data acquisition

Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems, abbreviated by the acronyms DAS or DAQ, typically convert analog waveforms into digital values for processing. The components of data acquisition systems include:

- *Sensors, to convert physical parameters to electrical signals.*
- *Signal conditioning circuitry, to convert sensor signals into a form that can be converted to digital values.*
- *Analog-to-digital converters, to convert conditioned sensor signals to digital values.*

Data acquisition applications are usually controlled by software programs developed using various general purpose programming languages
So, as a summary, Data acquisition is in itself a vast group of protocols, technologies, sensors, hardware and software…

(from https://en.wikipedia.org/wiki/Data_acquisition)

  - Data storage

Data storage is the recording (storing) of information (data) in a storage medium. DNA and RNA, handwriting, phonographic recording, magnetic tape, and optical discs are all examples of storage media. (from https://en.wikipedia.org/wiki/Database)

    - ICT solutions for next generation data storage and information mining
      - Non-relational database (NoSQL)

https://en.wikipedia.org/wiki/NoSQL

    - Dataspaces

Dataspaces are an abstraction in data management that aim to overcome some of the problems encountered in data integration system. The aim is to reduce the effort required to set up a data

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integration system by relying on existing matching and mapping generation techniques, and to improve the system in "pay-as-you-go" fashion as it is used. (From https://en.wikipedia.org/wiki/Dataspaces)

- Relational databases

  https://en.wikipedia.org/wiki/Relational_database_management_system

- Data processing

  Data processing is, generally, the collection and manipulation of items of data to produce meaningful information (https://en.wikipedia.org/wiki/Data_processing)

  - Cloud computing, edge computing
    - Cloud computing

      https://en.wikipedia.org/wiki/Cloud_computing

      Cloud computing can be deployed as private cloud, public cloud, hybrid cloud

      Digital Manufacturing Platforms can be ran into IaaS, PaaS or SaaS.
      Considerations need to be made to security measures in the cloud (kubernetes, container security), identity & access, or carefully considering the security measures by the respective cloud services providers.

    - Edge computing

      https://en.wikipedia.org/wiki/Edge_computing

      https://ecconsortium.eu/

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European Edge Computing Consortium is working on a reference architecture in line with RAMI.

A security architecture is being worked upon.

- Data analytics
- Data modelling

Data modeling in software engineering is the process of creating a data model for an information system by applying certain formal techniques. (from https://en.wikipedia.org/wiki/Data_modeling)

- Cognitive and artificial intelligence (AI) technologies - machine learning

In computer science, artificial intelligence (AI), sometimes called machine intelligence, is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and animals. Computer science defines AI research as the study of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. Colloquially, the term "artificial intelligence" is used to describe machines that mimic "cognitive" functions that humans associate with other human minds, such as "learning" and "problem solving" (from https://en.wikipedia.org/wiki/Artificial_intelligence)

- Fuzzy logic

Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1 inclusive. It is employed to handle the concept of partial truth, where the truth value may range between completely true and completely false (from https://en.wikipedia.org/wiki/Fuzzy_logic)

- Neural networks

Artificial neural networks (ANN) or connectionist systems are computing systems vaguely inspired by the biological neural networks and astrocytes that constitute animal brains. The neural network itself

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is not an algorithm, but rather a framework for many different machine learning algorithms to work together and process complex data inputs.[4] Such systems "learn" to perform tasks by considering examples, generally without being programmed with any task-specific rules. (from https://en.wikipedia.org/wiki/Artificial_neural_network)

- Genetic algorithms

  In computer science and operations research, a genetic algorithm (GA) is a metaheuristic inspired by the process of natural selection that belongs to the larger class of evolutionary algorithms (EA). Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by relying on bio-inspired operators such as mutation, crossover and selection. (https://en.wikipedia.org/wiki/Genetic_algorithm)

- Heuristics

  A heuristic function, also called simply a heuristic, is a function that ranks alternatives in search algorithms at each branching step based on available information to decide which branch to follow. (from https://en.wikipedia.org/wiki/Heuristic_(computer_science))

- System modelling, simulation and forecasting

  Simulation (often referred to as digital twins) is the imitation of the operation of a real-world process or system. The act of simulating something first requires that a model be developed; this model represents the key characteristics, behaviors and functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time. (from https://en.wikipedia.org/wiki/Simulation)

  - CAE models interoperability to allow fast and complete complex process of virtual verification
  - Integrated knowledge based systems
    Integrated knowledge based systems supporting the product and process archetypes approach, with self-learning capabilities for semi-automatic design rules update

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- ICT solutions for modelling and simulation tools
  Complex environments need to be consistently described by semantic models in order to correlate information, describe the dynamics, and forecast their behaviour. Knowledge from different sources (e.g. human, experience, research) will be made available and fully exploited by dedicated modelling and simulation tools.
- MDO (Multidisciplinary Design Optimization)
  Integration of the modelling and simulation methods of manufacturing processes in a MDO (Multidisciplinary Design Optimization) to permit an holistic approach and to guarantee fast and costless results
- Modelling and simulation for the (co-)design and management of integrated product-process-production systems
  Achieving the goal of sustainable manufacturing requires methods and tools for modelling, simulating and forecasting the behaviour of production processes, resources, systems, and factories during their life-cycle phases. New methods and tools are needed for the design and management of integrated product-process-production system that are well embedded into their social, environmental and economical context.
- Virtual models spanning all levels of the factory life and its life-cycle
  A holistic and coherent virtual model of the factory and its production machinery will result from the contribution and integration of modelling, simulation and forecasting methods and tools that can strategically support the manufacturing-related activities during all the phases of the real factory life-cycle (e.g. site and network planning, conceptual design, technology selection and process planning, resource design and component selection, layout planning, implementation, ramp-up, operation/execution, maintenance, end-of-life). Virtual factory models need to be created before the real factory is implemented to better explore different design options, evaluate their performance and virtually commission the automation systems, thus saving time-to-production. Furthermore, virtual factory models will be maintained throughout the lifetime of the production to guarantee an effective and efficient connection with the shop floor. On the one hand, reconfiguration options need to be tested in the virtual factory thanks to modelling and simulation tools and then, after validation, implemented into the real factory in a shorter time. On the other hand, the evolution of the real factory will be reflected and stored into the virtual models of the factory. Modelling, simulation and forecasting methods and tools for manufacturing may have a great impact on the whole factory hierarchy. At the low level of the hierarchy, methods and tools can improve the design and management of production machinery and processes to support advanced and sustainable manufacturing. Then, methods and tools are required to properly design and manage production systems that are becoming more and more complex. Finally, at the high level of the hierarchy, modelling and forecasting are needed to support long-term strategic decisions.
- Modelling and simulation methods of manufacturing processes involving mechanical, energetic, fluidic and chemical phenomena

- Programming Frameworks – Software Development Kits (SDKs)
  - FIWARE

    See https://www.fiware.org/

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- Smart Industry Context Information Management and Persistence
  - The Orion Context Broker Generic Enabler

    The Orion Context Broker Generic Enabler is the core and mandatory component of any "Powered by FIWARE" platform or solution. It enables to manage context information in a highly decentralized and large-scale manner. It provides the FIWARE NGSIv2 API which is a simple yet powerful Restful API enabling to perform updates, queries or subscribe to changes on context information.

  - The STH Comet Generic Enabler

    The STH Comet Generic Enabler brings the means for storing a short-term history of context data (typically months) on MongoDB.

  - The Cygnus Generic Enabler

    The Cygnus Generic Enabler brings the means for managing the history of context that is created as a stream of data which can be injected into multiple data sinks, including some popular databases like PostgreSQL, MySQL, MongoDB or AWS DynamoDB as well as BigData platforms like Hadoop, Storm, Spark or Flink.

- Smart Industry NGSI Agents Framework to Real World
  - The IDAS Generic Enabler
  - The Fast RTPS Incubated Generic Enabler
  - The OpenMTC Incubated Generic Enabler
- Smart Industry Information Processing
  - The Wirecloud Generic Enabler
  - The Knowage Generic Enabler
  - The Kurento Generic Enabler
  - The Cosmos Generic Enabler
  - The FogFlow Incubated Generic Enabler
  - The AEON Incubated Generic Enabler
  - The Domibus Incubated Generic Enabler
  - PROTON

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        - PERSEO
        - CEPHEUS
        - XML3D
        - Augmented Reality (FIWARE)
        - Quantum Leap
      - Smart Industry Context Data/API Management, Publication and Monetization
        - The CKAN extensions Generic Enabler
        - The Keyrock Identity Management Generic Enabler
        - The Wilma proxy Generic Enabler
        - The AuthZForce PDP/PAP Generic Enabler
        - The Biz Framework Generic Enabler
    - Programming Languages
    - Operating systems
    - ICT Architectures
      - Collaborative and decentralized application architectures and development tools
- Manufacturing strategies
    - From Product/Services Systems (product centric approach) to Services through Product (solution oriented approach)

      The "servitization wave" of manufacturing has already spread out to the advanced countries and many leading high-capital investment sectors (e.g. aerospace and automotive) are already competing in the international markets providing to their customers a composition of services for product operation (e.g. maintenance, reliability, upgrades), and end-of-life use (e.g. re-manufacturing, recycling, disposal). Especially SMEs are trying to compete in the international markets with their niche solutions, adding innovative services to their value propositions. Such innovative business models are based on a dynamic network of companies, continuously moving and changing in order to afford more and more complex compositions of services. In such a context, there is a strong need to create distributed, adaptive, and interoperable virtual enterprise environments supporting these undergoing processes. In order to do so, new tools must be provided for enabling and fostering the dynamic composition of enterprise networks. In particular, SMEs call for tools and instruments which follow them in their continuously re-shaping process, enabling collaboration and communication among the different actors of the product-service value chains. New IPR methods are also needed.
    - From delocalisation to Globalisation 2.0 (re-shoring)

      The rise of the transport cost, the need for higher efficiency and productivity, the customer demand for greener product, the higher instability of raw material and energy prices and the shortening of the lead-time production will push for a more critical assessment of the delocalisation strategy towards low cost countries. Service-led personalised products will require a new paradigm for western countries re-industrialisation (Globalisation 2.0), moving back (re-shoring) manufacturing of selected products.

    - Innovation

      Finally, innovation should become a business model in itself and a continuously run business

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process (the factory innovation): increasing the competitiveness through the design of a new product requires the development of a company strategy where product and process innovation is seen as a permanent, widely distributed, multi level, social oriented and user centric activity. Collaboration among companies of different sectors to exploit multi-disciplinary cross fertilisation is also envisaged. New tools, methodology and approaches for the user experience intelligence (i.e. social networks, crowd sourcing, social science methods, qualitative and quantitative, to generate insights, models and demonstrations, etc.) need to be addressed and explored.

- From User-centric design to user well-being design
  According to the new paradigm of sustainability, the importance of the user is increasing. The user is at the same time a customer, a citizen and a worker. The well-being of the user could therefore become a winning strategy both for B2B as well as B2C companies. More detailed modelling behaviour can help the development of innovative solutions, aiming at user comfort, safety, performance, style; this requires new competitive focus for the development of these innovative solutions and new business models to support a quick and dynamic response to market changes.
- Virtualisation and digitalisation of the interrelation between manufacturing and new business models
  As products are today virtually designed and tested before being engineered for production, new business models need also to have tools to support the company to design and test them before they are implemented through products, services and manufacturing processes. The complexity of these tools is higher than that of tools for product development, due the need for holistic modelling of product and processes.

- Skills - Knowledge-workers

The European Factories of the Future are expected to provide global manufacturing competitiveness, but also to create a large amount of work opportunities for the European population. Future factory workers are therefore key resources for industrial competitiveness as well as important consumers. However, as previously stated, the changing demographics and high skill requirements faced by European industry pose new challenges. Workers with high knowledge and skills ("knowledge workers") will be scarce resources. Research efforts within Horizon 2020 must address ways to increase the number of people available for, and interested in, manufacturing tasks. This includes the following important aspects of the human resources: - New technology-based approaches to accommodate age-related limitations, through ICT and automation - New technical, educational, and organisational ways to increase the attractiveness of factory work to the young potential workforce, the existing workforce, the potential immigrant workforce, and the older workforce - New approaches to skill- and competence development, as well as skill and knowledge management, to increase competitiveness and be part of the global knowledge society - New ways to organise and compensate factory knowledge workers - New factory human-centric work-environments based on safety and comfort - Ways to integrate future factory work in global and local societal agendas and social patterns

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6.4 Manufacturing system levels

- Manufacturing system levels
  - Factory Equipment/Field Device
  - Manufacturing Cells
  - Production lines
  - Enterprise - Factory
  - Connected Enterprises - Factories
    - Connecting factories from different enterprises
- Manufacturing system levels and life-cycle stages
  - Manufacturing system life-cycle stages
    - Design/development
    - Production engineering of mftg equipment/techn
    - Production of manufacturing equipment/technologies
    - Integration/ configuration of manufacturing systems
    - Use-phase of manufacturing system (producing products)
    - After-use phase of manufacturing systems
- Product levels and life-cycle stages
  - Product life-cycle stages
    - Product design/development
    - Production engineering of product
    - Production of product
    - Product distribution
    - Product use phase
    - After-use phase of product
  - Product levels
    - Product component
    - Product module
    - Product
    - Connected Products

6.5 ICT performance characteristics

- Data communication and interoperability
  - Integration with legacy systems
  - Platform level interoperability
    - AAA - Access, Authorisation and Authentication

Authorisation is the process of allowing an entity (humans, systems or devices) to access information systems or facilities where information and processing capabilities are being stored. More practical in an industrial setting for Digital Manufacturing Platforms, an authorized person can get access to an operational machine in order to update it, or investigate its contents. Unauthorized access could be someone who has been able to access the network from the outside, performing actions that have not been authorized and cannot be justified.

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Authentication is a means to assess the authorization rules of an entity by means of a set of instruments. In the case of Digital Manufacturing Platforms it would be the instruments like user name and password, and in addition a second factor such as a physical token or a mobile phone that can authenticate the person accessing the platform. The physical token connects the person to something he has, the password to something he knows.

A third A in the AAA-architecture is related to Access. Once authorized, and authenticated, access can be granted to the location, system, application, and / or information. Access control levels can thus be set up on different layers. These can be physical (access to the country, to the plant, to the building, the room and the environment where the system is located), and logical (using authentication technologies). In Digital Manufacturing Platforms this means the systems could be accessible only on premise, in the factory or for instance in the (private or public) cloud. As a result different access mechanisms needs to be considered, depending on the risk and intended security levels and controls.

https://en.wikipedia.org/wiki/AAA_(computer_security) ;
https://en.wikipedia.org/wiki/Authorization

- User Acccess and Rights Management
- Motivating Scenario / Use-Case

- Application level interoperability
  - Web-services / Composability
  - Modular Design and Deployment Approaches
  - Open APIs and Communication Protocols
    - Wireless communication protocols
- Integration level interoperability

Standardisation to Support Cross Platform Integration

- Semantic/information interoperability
- Data/object model interoperability - Data exchange formats - APIs
- Connectivity & network interoperability – communication protocols
- APIs and Integration Protocols

API's (and REST API's) need to be carefully protected through mechanisms limiting access on the basis of identity and authorizing and authenticating

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through managed and controlled mechanisms. Usually certificates and IP-addresses are being used to restrict access to API's, but a more granular approach is advisable from a Security Architecture perspective. Other architectures being used as Integratio Protocols in Digital Manufacturing Platforms are JSON (for its near real time capabilities) and MQ (message bus architectures). The letter being less secure, since it provides a continuous stream of information which is being sent to a destination.

- Cybersecurity

  Security for information and infrastructure related to digital systems

  - Risks addressed by security
  - Risk or security assessment
  - Trustworthy Systems in Platform Lifetime
  - A Security Architecture for Digital Manufacturing Platforms

    *A Security Architecture is a **conceptual design** that addresses **various aspects of security** in a system and resulting application, set of applications and components that make up the system. It is being used to support the design, development, implementation and operation of these systems, which can include Manufacturing Platforms. For Digital Manufacturing Platforms it addresses necessities and potential risks identified following potential scenario's or within a specific environment. It tries to present a comprehensive perspective of various security concepts on the conceived OT and IT architecture which includes networks, systems and equipment connected to these networks, the communication protocols and operating systems being used, the application development and operational process and recommends the use of security measures using security controls. Having a Security Architecture also helps both the design and integration process, supports identification of incidents and the security monitoring, speeds up discussions with partners for a level play field and best practices and is generally reproducible. Digital Manufacturing Platforms tend to try to bridge operational systems with information technology, such as the use of analytics, data collection and distribution and visualization that can lead to automated actions by these systems on the basis of unattended and unsupervised decisions and control implementations. To avoid physical harm, collateral damage other safety or cybersecurity issues, having a Security Architecture supporting the Digital Manufacturing Platforms should allow developers and companies at least to consider the various aspects and challenges of security in an organized and comprehensible manner. Architectures can follow standards such as IEC62443, ISO27k or NIST800.16, or any alternative scheme, but that needs to complete towards the digital and operational platforms.*

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  - Specific security standard(s) addressed and impact on implementation
  - Used guidelines and specific frameworks for security and/or privacy by design
  - Security mechanisms and technologies
    - Distributed ledger technology

      Example: blockchain

      https://en.wikipedia.org/wiki/Distributed_ledger

- Real-time communication capability
- Services
- Performance characteristics
- Safety
- Privacy
- Scalability
- Data communication infrastructure
- Data integrity

  Data Integrity is the reliability and the trustworthiness of the data being provided. Manipulated data by means of intentional or unintentional means can have been corrupted, causing the data not to be reliable any longer. The data integrity is particularly important in Manufacturing environments because of its large volumes of unsupervised data streams, coming from operational machines. If data acquirers such as sensors have been manipulated, the data representation is no longer correct and loses its integrity.

  Protection of integrity is a difficult and challenging task, and has been for a long team not been considered as a key challenge related to information security. Usually it is being handled by authentication mechanisms, trying to prove the authenticity of the source and therefor accepting that the data integrity has not been compromised.

  In Digital Manufacturing Platforms a lot of attention needs to be paid to ensuring the data integrity throughout the platform, especially during the software development process and the integration layers. In transactional systems, a small change in the system can cause a major discrepancy, in manufacturing leading to major losses, defects and even environmental and safety issues.

- Resilience

6.6 Standards, standardisation and regulation

- Standards
  - Semantic web standards

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The Semantic Web is an extension of the World Wide Web through standards by the World Wide Web Consortium (W3C). (From https://en.wikipedia.org/wiki/Semantic_Web)

See also https://www.w3.org/standards/semanticweb/

- Web Ontology Language (OWL)

  The W3C Web Ontology Language (OWL) is a Semantic Web language designed to represent rich and complex knowledge about things, groups of things, and relations between things. (from https://www.w3.org/OWL/)

- IEC 61499

  The international standard IEC 61499, addressing the topic of function blocks for industrial process measurement and control systems, was initially published in 2005. The specification of IEC 61499 defines a generic model for distributed control systems and is based on the IEC 61131 standard. (see https://en.wikipedia.org/wiki/IEC_61499 and IEC 61499 - International Electrotechnical Commission.

- IEC 61131

  IEC 61131 is an IEC standard for programmable controllers. (see also https://en.wikipedia.org/wiki/IEC_61131, https://webstore.iec.ch/searchform&q=61131)

- IEC 20922 (MQTT)

  MQTT (MQ Telemetry Transport) is an open OASIS and ISO standard (ISO/IEC PRF 20922) lightweight, publish-subscribe network protocol that transports messages between devices. (From https://en.wikipedia.org/wiki/MQTT)

- OPC-UA

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OPC Unified Architecture (OPC UA) is a machine to machine communication protocol for industrial automation developed by the OPC Foundation.
(see https://en.wikipedia.org/wiki/OPC_Unified_Architecture)

- OneM2M

  http://www.onem2m.org/

- IEEE 802.1 TSN

  Time-Sensitive Networking (TSN) is a set of standards under development by the Time-Sensitive Networking task group of the IEEE 802.1 working group. The standards define mechanisms for the time-sensitive transmission of data over Ethernet networks. (See https://en.wikipedia.org/wiki/Time-Sensitive_Networking

- IEEE 802.15.4

  IEEE 802.15.4 is a technical standard which defines the operation of low-rate wireless personal area networks (LR-WPANs). (from https://en.wikipedia.org/wiki/IEEE_802.15.4)

- GS1 standards

  https://www.gs1.org/

- OAGIS

  Canonical object messaging standard (see https://oagi.org/)

- UBL - Universal Business Language

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Universal Business Language (UBL) is an open library of standard electronic XML business documents for procurement and transportation such as purchase orders, invoices, transport logistics and waybills. UBL was developed by an OASIS Technical Committee with participation from a variety of industry data standards organizations. Version 2.1 was approved as an OASIS Standard in November 2013 and an ISO Standard (ISO/IEC 19845:2015) in December 2015

(From https://en.wikipedia.org/wiki/Universal_Business_Language)

- IPC-CFX

IPC-CFX is an electronics manufacturing industry developed standard forming the foundation/backbone of Industry 4.0 Applications. (From: http://www.ipc-cfx.org/)

- OGC SensorThings API

SensorThings API is an Open Geospatial Consortium (OGC) standard providing an open and unified framework to interconnect IoT sensing devices, data, and applications over the Web. It is an open standard addressing the syntactic interoperability and semantic interoperability of the Internet of Things. It complements the existing IoT networking protocols such CoAP, MQTT, HTTP, 6LowPAN. While the above-mentioned IoT networking protocols are addressing the ability for different IoT systems to exchange information, OGC SensorThings API is addressing the ability for different IoT systems to use and understand the exchanged information. As an OGC standard, SensorThings API also allows easy integration into existing Spatial Data Infrastructures or Geographic Information Systems.

(from https://en.wikipedia.org/wiki/SensorThings_API)

- Mechatronics standards

- Standardisation
  - Standardisation via European Standardisation Organisations
    - Registered work item leading to EN (European Norm), TS (Technical Specification), TR (Technical Report)
    - Registered work item leading to CEN-CENELEC Workshop Agreement) or ETSI GSs (Group Specifications)
  - Standardisation via International Standardisation Organisations (ISO, IEC, ITU-T)
  - Standardisation via other Standards Developing Organisations (SDO) (eg. W3C, IEEE, ASTM, etc..)
- Mechanical standards
- Compliance to Rules and regulations

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In general, compliance means conforming to a rule, such as a specification, policy, standard or law. Regulatory compliance describes the goal that organizations aspire to achieve in their efforts to ensure that they are aware of and take steps to comply with relevant laws, policies, and regulations. (from https://en.wikipedia.org/wiki/Regulatory_compliance)

- Standards General

6.7 Business model aspects

- Business model aspects of digital platform deployment

Here the term "business models" is used in a wide sense, complementing the technological and organisation aspects of digital platforms.

One proven tool for analysing and shaping business model is the "Business Model Canvas". When trying to apply this tool to platforms, it appears that some elements apply to platform-based business models (e.g. the "value proposition") and that tools as the "canvas" can provide a first inspiration.

However, for digital platforms the traditional business models view in the narrow sense falls short of describing the business and relationship aspects of platforms. In particular, the strict "partner" and "customer"- view has to be replaced by an ecosystem-perspective. In addition, this ecosystem can be highly dynamic, which means that platforms can move into new user groups, change their features and might have the typical effects. Another difference is the central role of data for platforms, meaning that data governance is one of the essential elements of the value proposition of platforms.

  - Business ecosystem

By definition, by bringing together actors from different sides, platforms are defined by their stakeholders. There are core stakeholders (target customers, core suppliers, value chain partners), but it should not be forgotten that there are also actors with an indirect or external interest in the activities in the platform (competitors, existing customers not addressed through the platform). A platform also defines the relationship with and the channels with the different user groups.

    - Target clients

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Which are the target groups? Which new markets and users will be connected?

- Interaction with other (commercial) digital platforms

  Interactions with other (commercial) digital platforms indicate how developed solutions are interoperable with legacy systems or how future interaction with other solutions is anticipated.

- Other eco-system aspects

  Other eco-system aspects can be:

  - *What are the value chain implications?*
  - *Is the network open or closed? Is there an intention to expand?*
  - *Is it a vertical, sectorial platform or a cross-cutting, horizontal platform?*
  - *How are the relationships defined?*

- Service model

In order to be sustainable, the value proposition must be mirrored by a revenue stream, which is orchestrated by the platform. This value streams can be direct (pay-per-use, subscription, sales etc.), but could also be indirect (increasing price of products, increasing market share).

- Platform as a Service (PaaS)

  Platform as a Service (PaaS) or application platform as a Service (aPaaS) or platform base service is a category of cloud computing services that provides a platform allowing customers to develop, run, and manage applications without the complexity of building and maintaining the infrastructure typically associated with developing and launching an app. (from https://en.wikipedia.org/wiki/Platform_as_a_service)

- Software as a Service (SaaS)

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Software as a service (SaaS /sæs/) is a software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted. It is sometimes referred to as "on-demand software". (from https://en.wikipedia.org/wiki/Software_as_a_service)

- Infrastructure as a Service (IaaS)

  https://nl.wikipedia.org/wiki/Infrastructure_as_a_service

- Payment modalities
  - Pay per use - Pay per duration of use

    Pay-per-use or pay-per-duration-of-use implies that users are charged pro-rata of how much they used the service (in terms of consumed resources, computing power,... or in terms of the duration of the use of the service)

  - Pay per saved unit of X - pay per added value

    Pay-per-saved-unit-of-X or pay-per-added-value implies that the user pays pro-rate the added value that the service is generating

- Data ownership - data governance

At the core of all potential industrial use case scenarios of platforms are data. When formerly isolated data are shared, suddenly a new set of factors arises, both in terms of new external factors, but also in terms of business/microeconomic implications. Therefore, at the core of every digital platform must be a legally, organizationally and commercially viable concept for data sharing/trading/exchange.
When shaping this model, the following questions must be answered:

- *What is the legal arrangement for data "ownership"? Can users classify their data, is staggered approach possible (closed, traded or open data)? What are legal means that the platform uses to ensure the confidentiality of data ? (Trade Secrets, data base directive)*
- *Transparency: Can users monitor/control the sharing of data with third parties? Are there "expiration dates" for data use?*
- *Is the legal setting a fixed standards ("general conditions") or is it a flexible, individual approach? Are model contracts available?*
- *Are there sectorial regulatory requirements concerning data?*

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- *How far is portability and change of platform possible?*
- *Who is responsible in the case of breaches of confidentiality?*
- *How is fairness/ a level playing field between the platform and smaller players ensured ?*

- Added Value from user perspective

Digital platforms will be successful if they provide a clear value proposition to the user groups involved. In general, digital platforms offer added-value basd upon three main mechanisms:

- *Reduction of transaction costs*
- *Network effects*
- *Use of data integration for new services (mainly optimisation) and business models*

Based upon these mechanisms, added-value can be created in a variety of perspectives, such as the process perspective (what process or activity is optimised?) or the KPI perspective (what KPI is the focus of the optimisation). This added value enables the financing of the digital processes through e.g.increased price margins, market shares or reduced costs.

- Business requirements
- Data Liability
- Software ownership
  - Proprietary software

Proprietary software is non-free computer software for which the software's publisher or another person retains intellectual property rights—usually copyright of the source code, but sometimes patent rights. (from https://en.wikipedia.org/wiki/Proprietary_software)

  - Open source

Open-source software (OSS) is a type of computer software whose source code is released under a license in which the copyright holder grants users the rights to study, change, and distribute the software to anyone and for any purpose. Open-source software may be developed in a collaborative public manner. According to scientists who studied it, open-source software is a prominent example of open collaboration. (from https://en.wikipedia.org/wiki/Open-source_software)

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- Infrastructure ownership

In the same way that software can be developed and commercialized using different business models according to the software ownership, digital platforms could be developed and commercialized using different business models according to the infrastructure ownership. Different infrastructure ownerships can be identified in this chapter and also their business models (like renting, pay per use…)

6.8 Digitalisation pathways

- Autonomous Smart Factories
  - General purpose software
    - Spreadsheet/texteditor ERP
    - Spreadsheet/texteditor MOM
    - Manual data acquisition
  - Dedicated software in silos
    - Dedicated ERP software implemented
    - Dedicated MOM Software Implemented
    - Data acquisition/monitoring/analysis (SCADA) implemented but isolated
  - Connected IT and OT
    - ERP-MOM systems connected
    - MOM-SCADA systems connected
    - IoT enabled SCADA, MOM-MES, ERP (…) connectivity
    - Humans actively connected
  - Off-line optimisation
    - Off-line Digital Manufacturing Process Optimisation on factory level
    - Off-line Digital Manufacturing Process Optimisation on machine level
    - Platform enabled optimisation

Digital platforms will be successful if they provide a clear value proposition to the user groups involved. In general, digital platforms offer added-value basd upon three main mechanisms:

- *Reduction of transaction costs*
- *Network effects*
- *Use of data integration for new services (mainly optimisation) and business models*

Based upon these mechanisms, added-value can be created in a variety of perspectives (see for instance here)

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    - Realtime optimisation
        - Autonomous /online/realtime Manufacturing Process Optimisation on factory level
        - Autonomous /online/realtime Manufacturing Process Optimisation on machine level
- Hyperconnected Factories
    - General purpose software
        - Spreadsheet and text editor based SCM, CRM

          SCM: Supply Chain Management ; CRM: Customer Relationship Management

        - Spreadsheet/texteditor ERP
        - Administrative transactions digitalised
    - Dedicated software in silos
        - ERP implemented

          Dedicated ERP software implemented

        - SCM implemented

          Supply chain management system implemented

    - Basic internal connectivity
        - ERP and SCM connected
    - Dedicated IT connection to some supply chain partners
        - SCM - MES - ERP Software connected to SCM - MES - ERP software of suppliers or customers
        - Forecasting of required capabilities

          Forecasting of required capabilities (link with Autonomous Smart Factories)

        - High level planning using dedicated digital connections
    - Dynamic IT connections to new supply chain partners
        - Common digital platform used for tenders and bidding

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Common digital platform used for tenders and bidding (dynamically connecting to new suppliers/customers)

- Visibility of work in progress
- Dynamic detailed scheduling and rescheduling

- Collaborative Product-Service Factories
  - Product, no Service

    Product-Oriented Organizations based on highly qualified professional knowledge for design-manufacturing

    - Use of CAD systems
    - Use of PDM systems

      Product Data management Systems

  - Product and disjoint Service

    Products are considered along their own lifecycle. Complex Interactions between Lifecycles considered.

    - PLM Systems (integrating CAD and PDM)

      Product Life Cycle systems integrating Computer Aided Design and Product Data Management systems.

    - Use of CRM Systems

      Customer Relationship Management systems

  - Service-enabled Product Design

    Product-Service-System Design Engineering open to customers and final users. Advanced services integrated.

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        - Voice of suppliers Customers / Users
        - Service orient. Product Design (integration of PLM and CRM)
    - Product-Service Innovation

      Manufacturing companies integrate innovative services in their value proposition

        - Closed loop PSS Design (Connected to users data)
        - Service Innovation and new Business Models
    - Product-Service Symbiotic Evolution

      Product Service Systems induce digital transformations at all levels: technical organizational and procedural. Collaborative PS Factories.

        - Digital Platforms for next generation PS Systems lifecycle management
- Cybersecurity

  Security for information and infrastructure related to digital systems

    - Security level 1
        - Physical and logical password

          Physical and logical password should be considered from the overall taxonomy and as part of one of the Digital Pathways, as Physical and Logical Access provisioning. Physical passwords here are types of authentication technologies and can be voice commands, fingerprints, or simple presence (by means of an electronic token that an operator carries). Logical passwords here are both pincodes, passphrases or even certificates or hash keys, that support the specific levels of security. Both are considering the mechanism of access control for security in this pathway.

          Access control is a key component of security and cybersecurity to any system, being it a physical (gates, doors, equipment, ...) or logical (application, service, activity, ...) one.

          Under this heading, the purpose is to clarify that access control should be mandatory for every system being operated in a manufacturing environment. Access control levels can be very low, by providing everybody access to an application on the factory floor. But at least it has considered that only people on the factory floor should be getting access. That physical constraint

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can be taken into account. This means that from a risk perspective, unaccompanied visitors or subcontractors without oversight could also get access to this system.

By considering access control as a fundamental security mechanism, based upon a risk approach, controls can be further built in, relating back to the types of users, or moments of intervention. Least access principles should be applied, in order to only provide access after a specific given thought. For instance, the system can have a regular user (an operator), a floormanager or head of production (being capable to override a decision from an operator), a service engineer (maintainance) and an administrator.

These roles should allow different levels of access to the systems and can be related to specific risks related to them, and to the overall risk consideration. Physical passwords can be considered into the application as additional means to identify the specfic roles.

As an example, to enhance the security of an application in a manufacturing environment from Level 1 to Level 3, there will be administrator access needed to operate a specific machine or function, instead of simply pushing the button to power up a specific machine. This can be trivial, as a sawing machine that can only be used by an operator qualified to use it, up until ensuring only oversight happens when a maintenance engineer updates the machine via a usb-token and leaves additional malware on the machines.

- Malware (including Ransomware, APT, Virus, ...) protection

Malware is a broad term that describes a computer program (software) that was intentionally developed to cause damage to a computer system, mainly with the intention in financial gains - but more frequently to cause business interruptions, being held hostage or to simply steal information.

For over two decades malwares have existed, specifically written to exploit vulnerabilities in computer systems, that can be used for personal gains. It is a form of cybercrime to use them, to break into someone else system. In most countries in the world, it is not a crime to develop malware - only to exploit it against someone else.

Malwares exist in many different forms. What used to be viruses, that were sent generally via email in the past, have transformed into specifically engineered pieces of software for specific purposes - the most infamous one today being Stuxnet. For viruses, security software and firewalls have been equipped to detect them and quarantaine them before they can even be seen by the destination email address. But through phising attacks (emails with a malicious hyperlink - URL) or man in the middle attacks (website that have

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been compromised and redirect traffic) users are still being exposed to malware.

Malware can also enter by means of USB-sticks, pieces of software that don't belong on an industrial control systems or manufacturing system (games, apps, ...) which can sometimes contain malware of pieces of them.

Ransomware is a form of malware that typically starts encrypting data, once it has been activated. To decrypt a ransom has to be paid. Ransomware can be avoided by 1) frequently upgrading the underlying software to avoid exploitation of vulnerabilities, 2) isolating the industrial systems from office and other types of systems, 3) restricting access to the systems by means of physical and logical limitations.

APTs (Advanced Persistent Threats) usually are a combination of multiple attacks and threats, intended towards a specific target. APT's will combine the detection of vulnerabilities with the exploitation of malware and ransomware. APT's are typically being coordinated by nation state actors or organized crime.

Digital Manufacturing Platforms should be concerned about the abuse of their platforms by malicious users, and should prevent by all means available man in the middle attacks or similar attacks where redirects of the platform end up on the download of malwares. By running the Digital Manufacturing Platforms in the cloud, additional security measures can be put in place specifically monitoring the activities of specific containers for unexpected calls or actions. Manufacturing companies should further give notice to the continuous protection of end point devices and active monitoring of network traffic on top of the detection of malicious activities.

- Logging and monitoring, machine learning and AI - Cybersecurity Controls

The process of recording activities happening on an IT system, including OT systems operated via IT. Monitoring and logging typically occurs on network level, where packages are being sent over TCP/IP (internet protocol) and captured at the edges, in the controlling entities (routers and gateways) or as an in-line device (such as a firewall, ids or ips). Network traffic typically records origin and destination IP address, the type of application, and contents. Some of the traffic could have been encrypted.

Network traffic can be captured via a monitoring port on network devices. This results in the recording of all events that have been instructed to be

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logged. During the monitoring phase, this near real time data can be evaluated and analyzed. On the basis of the traffic patterns can be detected that allow the understanding of how applications (such as ransomware) arrives inside the organization or on how confidential data might leave the organization.

Logging also happens on the device level, allowing to identify the activities taking place on the device (types of applications being used and identities of people accessing the devices). This allows to identify a user with a certain transaction, or allows better for the detection of data manipulation or data theft to take place. With Machine Learning techniques some behavioral actions on a network will be detected prior to the malicious action of theft or abuse taking place. On the basis of patterns and pattern recognition, actions and events which are being used by criminals can be detected and indicating that an incident is taking place.

By utilising similar data from the outside, incidents happening in other locations, in other factories and companies can be recorded and similar patterns (signatures) can be signaled amongst trusted partners. This allows for preventative instructions inside the intrusion prevention systems, which will be able to block IP addresses, block users and applications.

Finally the monitoring and logging is important for forensics. Once an incident has happened, the recorded sessions allow to understand what exactly happened, collect evidence and use as a means for future preventive actions.

In Digital Manufacturing Platforms a logging facitlity should be enabled allowing to record the manipulations and transactions that have happened inside the platform itself, and recording the access and identity of the persons who have been controlling the platform itself.

- (Systemic) Penetration Testing

Penetration Testing (Pentesting) is a term used by Cybersecurity practitioners to describe the process of diligently assessing potential vulnerabilities in the information security infrastructure, including in the case of Manufacturing and Industrial environments also operational technology infrastructures. It typically uses a series of tools to automate the process, but will make use of the expert experiences focusing on known tricks

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and vulnerabilities. The goal for the pentester is to detect and report the leaks, but not to exploit them. It is also refered to as ethical hacking, in the perspective of not intentionally manipulating equipment, data, stealing data or leaving exploitable software behind. Pentesting is the ultimate means to demonstrate both the capabilities of the security infrastructure, as it is the way to identify the shortcomings upfront. A pentesting report will allow security managers to support their activities by indicating risks, threats, vulnerabilities and indicating the needs for a risk management process. Companies with a higher level of maturity will organize a systemic approach, allowing for pentesting to take place periodically, or following specific changes happening inside the infrastructure. This can also take place in the form of contests, having for instance red teams (the attackers) playing against the defenders (blue team); both utilizing their experiences of pentesting. With a Responsible Disclosure, organizatoins and individuals can call upon the community of ethical hackers (white hats) to help identifying vulnerabilities. These will be reported sometimes in return for a small bonus. Large hacking contests can be organized to test complete platforms. When vulnerabilities are found in technologies, including Platforms which are being sold, they are being reported as CVE's after a grace period of the reporting for about 3 to 6 months. For Digital Manufacturing Platforms pentesting should also take place in the platform itself, by performing software testing and testing the Platform being put into an operational environment, as it uses web and internet technologies making it susceptible for exploitation.

- Security level 2
  - Transmission data protection

    Transmission data protection is the description of the security used for the communication of the data.

    This can be Tranmission Layer Protocol (TLP) when considering two or more systems communicating directly communicating with each other over the internet, and securing the communication itself by means of encryption and decryption on either end.

    Other means can be by using (other) VPN technologies, where usually an encryption layer between devices and applications running VPN-type services and applications are being used.

    Public operators such as Internet Services Providers, Mobile Operators, ... in most cases use encryption technologies to protect the data transmssion over the public network, when providing specific business to business services. In 3G, 4G and the up and coming 5G mobile data provisioning transmission data protection has been enabled.

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However, operators and platform providers should assure themselves about which transmission data has been facilitated, or should require a security baseline for it. Additionally, digital platform can start providing transmission security as part of the platform. This will be especially necessary when working with edge devices transmitting and cloud platforms receiving data.

Transmission data protection should also be considered for machines and equipment on site, or nearby. Many robot instructions and their commands for instance, are being transmitted in clear text. Many technologies exist today to prevent this from happening, even at high speeds.

The tranmission data itself should also be protected and prevented from leaking. The transmission data can also be used as a control protocol, checking the transmission for arrival and audit.

- Password policy

Following a risk analysis, and upon the choice of a risk framework and definition of security policies, a password policy can be derived.

The password policy is to be set up by organizations, both end user organizations manufacturers and digital platform and system providers.

Password policies should at least include :
- strong passwords or passphrases
- users to regularly update their passwords
- advise the use of multifactor (use an additional authentication device)

Digital Platform providers should provide a mechanism for single sign on or federated authentication, allowing for passwords not to be stored into the platform itself, but by accepting tokens from third party suppliers.

- Physical security

Physical Security refers to the part of physical access control, borders, gates, identity verfication, passport control, manned guard services, videosurveillance, biometrics and related components. Physical security also considers physical attacks such as terrorist and criminal attacks, fire and water challenges.

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- Multi-factor authentication

  Multi-factor authentication describes the necessity for using more than 1 token as a proof of identity. As an example, when a user logs on to to a digital platform the basic means of authentication are user name and password.

  In addition to the password (single authentication), the user can be asked for a physical token (RFID-key, ID-card, ...). This can also be a mobile phone, an authenticator app token, a SecurID or Digipass token, or biometric (fingerprint, facial recognition, ...) elements.

  In security terminology this related to the concept on assuring someone's identity by something the user knows (password) and something he/she has (physical token). Additional layers can be built into this concept in order to further improve and strenghten the security levels.

  When proving someone's identity at the front gate on the basis of an ID-card, Driver License or verifiable photo-ID, it can be enhanced with a log into the system that the person has reached the premise. With his personal RFID-token, he will be able to access his office. Meanwhile video surveillance camera's might have identified him in the building. Finally when logging on to his system on the network, he can be asked for an authentication code coming from his company mobile phone.

  These additional levels of authentication harden the security and can be continuously expanded, depending on the security levels required.

- Security level 3
  - Security training and awareness

    Security training and awareness entails awareness creation, security information sessions an materials, education, educational programs, certification of people and all related formats and programs designed to inform and support people in understanding about cybersecurity.

    Training & education

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Security training programs will need to be an integrated part of a security strategy and policy. Next to the definition of risk, design of security policies describing how people should be getting or not getting access to specific environments, the people operating these environment should be instructed properly.
Security training and education can be system and operation specific, but needs also to accompany the company and plant specific guidelines in security.

Training and education should be a continuous activity, including repetition of elements of importance and strategic relevance.

Security education programs should be adapted to specific departments, or groups of people, depending on their levels of maturity, systems access and responsibilities.

Security education can be educational programs outside of the organizations, at specific dedicated educational organizations (private, high schools, universities, ...) or within the organization itself. Some companies organize a one day educational course on cybersecurity, while others provide access to courses online.

These educational programs can be followed by assessments, and can lead to the provision of certificates of attendance or qualification.

Programs related to Cybersecurity can be CISSP (Certified Information Security Professional), CISM (Certified Information Security Manager), CISA (Certified Informatio Security Auditor).

Other Cybersecurity educational programs will relate to specific components in the Cybersecurity architecture, such as Firewall, Monitoring, Identity & Access expert.

Organizations can provide educational programs from within their internal organizations (own developments or licensed from educational organizations), or can develop a specific cybersecurity program dedicated to a specific application or service which has been developed.

Awareness

Cybersecurity awareness programs are more informative than educational programs, typically less attention demanding, less lengthy, but aimed to a

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specific series of rules, or oriented to relate to a specific behavior instead of knowledge transfer.

The awareness program can indicate that the company is concerned over cybersecurity and draws attention to its employees how to handle incoming emails, watch out for suspicious behavior, means to detect that it is suspicious and what NOT to do with it. It can indicate the impact by means of a short movie, without going into detail on the whole architecture behind it.

- Peronnel vetting procedures
- User account management
- Token management

- Security level 4
  - Privileged account control
  - Database integrity
  - Software integrity
  - Back Office data flow security
  - Intrusion detection
- Security level 5
  - Digital platform environment segregation
  - CyberSecurity incident response capability - CSIRT

Cyber incident reponse capability is referred to as the means of an organization to cope with a cyber incident. Usually organized in a dedicated CSIRT (CyberSecurity Incident Response Team) or a CERT (Cyber Emergency Response Team) has developed a procedure for dealing with incidents (leakages, break-ins, attacks, ...) being detected in the organization and taking the necessary measures to mitigate, prevent and respond. This dedicated team should be empowered to be in control to prevent additional loss, and to fight an attack as it happens. That means that they are required to have a good understanding of the infrastructure and have the necessary means to deflect, increase security, limit access and ensure forensic means to collect during an incident. They should be in direct response and interaction with the crisis management team. During normal operations they will support the organization Security Operations (SOC) Team onsite or remote in coping with day to day alarms, investigating their threat levels and managing with the investigation of minor incidents.

More information on th organization of CSIRTS can be find with various sources such as

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: *https://resources.sei.cmu.edu/asset_files/Handbook/2003_002_001_14102.pdf*

A dedicated organization is working with different developments and challenges of the CSIRT and CERT teams moving forwards, called FIRST https://www.first.org/

- User session integrity
- Critical activity outsourcing
- Transaction controls

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