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Pathways cross-fertilisation with Digital Technologies- Second Iteration

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Abbreviations and acronyms

TERMS, ABBREVIATIONS AND ACRONYMS	
AI	Artificial Intelligence
B2B	Business-To-Business
DEP	Digital Europe Program
CF	Connected Factories
DGA	Data Governance Act
DFA	Digital Factory Alliance for Digital Manufacturing Platforms
IDSA	International Data Spaces Association
HEP	Horizon Europe Program
PPP	Public Private Partnership

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Executive Summary

Deliverable D2.6 (M34) "**Pathways cross-fertilisation with Digital Technologies - Second Iteration**" is the final release of Connect Factories 2 (CF2) cross-fertilisation with new trends and roadmaps from the domain of Digital Technologies. In the spirit of WP2 "Pathways to digitalisation of manufacturing" this means to take inspiration from Digital Technologies to develop new pathways for Manufacturing industry which could measure the readiness of enterprises with respect to the full adoption and implementation of such technologies.

More in particular, Task 2.2 Pathways cross-fertilisation with Digital Technologies, says. "*Using a commonly adopted metaphor, manufacturing systems and digital technologies can be regarded as the two sides of the same Industry 4.0 coin. This task will materialise or explicate the coin metal between the CF pathways side and the enabling and emerging digital technologies side, by identifying, supporting and implementing osmosis processes between the two domains. More in particular, digital innovations, such as in the AI or Cybersecurity domains, will be progressively and selectively (osmosis) transferred to the manufacturing domain, by enhancing and extending the current pathways by such new technologies. Conversely, new features of the manufacturing domain pathways could indicate new requirements and specifications for the digital technology side, as for instance required by the circular economy principles, humans in the loop factors and non-hierarchical manufacturing ecosystems*".

In the first release of D2.2 deliverable, we concentrated on the so-called "**Data Revolution**", i.e. how Data Economy could affect and influence the business of Manufacturing companies and how the Manufacturing industry is ready to fully adopt the potential benefits of this revolution. In the present, second release, we are focusing especially on Artificial Intelligence and Cybersecurity, in line with the main technologies at the basis of next 2021-2027 Digital Europe Programme.

The CF2 **AI for Manufacturing** pathway includes five maturity levels:

- **Level_1.** **Humans in Control**. AI systems (although sometimes present) do not influence the decisional processes which are firmly in the hands of the Humans.
- **Level_2.** **AI Assistance**. AI is able to provide additional information to the user (e.g. hidden knowledge discovery, clustering of cases, anomaly detection), who is then taking his/her decisions in autonomy
- **Level_3.** **AI Recommendation**. AI is able to suggest some decisional options, which are then assessed and evaluated by the Humans
- **Level_4.** **Collaborative AI**. Virtuous mixed teams of Humans and AI systems are set up and decisions are taken in a collaborative way thanks to train-explain-sustain interactive patterns
- **Level_5.** **AI in Control**. AI is taking decisions autonomously especially under real time constraints which do not allow a human intervention

Digital Manufacturing Platforms (DMP) clusters use cases (especially AI REGIO SMEs experiments) have been positioned in the five levels, while further validation and discussion has been held on June 13th 2022 interactive workshop.

Regarding AI, the five levels of the pathway have been put in relation with seven obstacles / barriers which currently prevent the adoption of AI solutions in Manufacturing (SMEs). **LACK of EVIDENCE** of BUSINESS BENEFITS is the main obstacle for the first levels of the pathway, when companies have to be convinced

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about the economic impact of AI solutions. **SKILLS and COMPETENCIES** come immediately after when companies need to develop their own AI literacy (independent or externalised to e.g. DIHs). **TRUST and SECURITY** have been proved to be the main barrier along the most mature levels of the pathway, when important and critical data and document need to be exchanged in the value chain. Reducing the **COMPLEXITY** of the AI solutions and improving the train-explain-sustain interaction cycle between humans and AI is the most fundamental barrier to be removed and it is valid for all the levels of the pathway.

The **CyberSecurity pathway** evolved from the Connected Factories project (FoF-11-CSA) from a perspective on digital manufacturing in five different maturing stages to include additional components and technologies such as AI and centralizing data. The CyberSecurity pathway takes into account regulatory requirements, up and coming standardization and indicates the sense of an incremental approach, similar to building expertise, skills and competences and increasing complexity of the manufacturing environment. This pathway continues to be a guidance that allows both Digital Manufacturing platform researchers, designers and developers but equally operators, system integrators and vendors to ensure to consider the different building blocks using its guidance to continue to further harden their environment. The pathway used the DMP cluster use cases, but also considered other related projects and activities under the Horizon2020 and Horizon Europe activities such as the DT-ICT-08 (CyberSecurity for Manufacturing), DT-ICT-02 (Digital Innovation Hubs) and Critical Infrastructure projects. Further validation happened during January 2021 and April 2022 interactive online workshops. Additional bilateral discussions took place to further enhance the approach.

As an outlook into the future, next Digital Technologies to be included in possible pathways are in our opinion **Digital Twins and HPC/cloud** (edge-to-cloud continuum), which have been subject of many topics in the Horizon Europe 2022 work programme (**TWIN-TRANSITION-01-06: ICT Innovation for Manufacturing Sustainability in SMEs (I4MS2)** and **HORIZON-CL4-2022-TWIN-TRANSITION-01-07: Digital tools to support the engineering of a Circular Economy**) and which will see the awarded projects (currently in Grant Preparation) starting beginning of 2023.

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1 Introduction

Deliverable D2.6 (M34) "Pathways cross-fertilisation with Digital Technologies - Second Iteration" is the final release of CF2 cross-fertilisation with new trends and roadmaps from the domain of Digital Technologies. In the spirit of WP2 "Pathways to digitalisation of manufacturing" this means to take inspiration from Digital Technologies to develop new pathways for Manufacturing Industry which could measure the readiness of enterprises with respect to the full adoption and implementation of such technologies.

In particular, T2.2 Pathways cross-fertilisation with Digital Technologies, says. "*Using a commonly adopted metaphor, manufacturing systems and digital technologies can be regarded as the two sides of the same Industry 4.0 coin. This task will materialise or explicate the coin metal between the CF pathways side and the enabling and emerging digital technologies side, by identifying, supporting and implementing osmosis processes between the two domains. More in particular, digital innovations, such as in the AI or Cybersecurity domains, will be progressively and selectively (osmosis) transferred to the manufacturing domain, by enhancing and extending the current pathways by such new technologies. Conversely, new features of the manufacturing domain pathways could indicate new requirements and specifications for the digital technology side, as for instance required by the circular economy principles, humans in the loop factors and non-hierarchical manufacturing ecosystems*".

In this final release of D2.6 deliverable, we concentrate on the so-called "**AI Revolution**", i.e. how Intelligent AI-based applications could affect and influence the business of Manufacturing companies and how the Manufacturing industry is ready to fully adopt the potential benefits of this revolution. Moreover, we will be focusing on Cyber-security and Data Confidentiality in line with the main technologies at the basis of next 2021-2027 Digital Europe Programme.

At any rate, Data Technologies (addressed in D2.2) are at the basis of any Digital Transformation both at technological and at business level: let's think for instance at the collaborative product-service pathway in CF1 (see §1.1) and the servitisation business models deriving from it.

In this introductory chapter, we will make a synthesis of the whole document and a reminder of the CF1 pathways which as reference North Stars will drive all the CF2 activities (§1.1).

Chapter 2 aims at firstly describing the EU policy landscape around Artificial Intelligence. As part of the EU Digital Decade 2030 and its Digital Compass (§2.1) we will briefly analyse the AI Strategy for Europe and the AI Package (AI Act §2.2) with the lenses of Manufacturing Industry, which is one of the nine critical sectors where the EC sees the most relevant advantages for EU Business and Society. Further paragraphs in Chapter 2 will be moreover devoted to EU initiatives in the implementation of AI in Manufacturing: the Smart Manufacturing Industry (SMI) working group and its white papers in BDVA (Big Data Value Association) and ADRA (AI Data and Robotics) partnerships (§2.3); finally in §2.4 the AI4Europe portal, experimentation facility and its relevance for Manufacturing will be presented.

Chapter 3 will start analysing the H2020, HEP and Digital Europe Program (DEP) initiatives relevant to AI for the Manufacturing Industry. In particular, in the H2020 work programme nine projects have been founded as Research and Innovation Actions in the ICT38 cluster (§3.1.1, including a CSA for establishing bridges between Europe and Japan, as well as the two Innovation Actions (AI REGIO and KITT4SME §3.1.2) realising SME-driven experiments (open calls) and developing a network of EU DIHs specialised in AI for Manufacturing (see DIH 4 Industry portal). Finally, a first analysis of HEP joint topics for Made in Europe and ADRA has revealed the presence of six new Innovation Actions which are going to enrich the DMP ecosystem, while in

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the DEP program, the AI TEF (Testing and Experimentation Facilities) for Manufacturing have been analysed (§3.2).

Chapter 4 is the core for the AI for Manufacturing pathway. In §4.1 a brief description of a strategic-level maturity model for Manufacturing Enterprises (SMEs) is described. The description of the 5 levels is in §4.2 leveraging on the Plattform 4.0 automation levels and with specific focus on MAL4 (level 4). Finally, the validation of the model is reported in §4.3, especially focussing on the interactive workshop held in Brussels c/o EFFRA offices on June 13th 2022 before the General Assembly.

Chapter 5 is fully devoted to the CyberSecurity Pathway II description and validation. Starting from the Connected Factories CyberSecurity Pathway which was focusing on five levels of maturity improvements. In Pathway II additional hardening has been explored for additional challenges and opportunities from both Societal (digitalization, sovereignty, climate change and global challenges) and Technological perspectives (data value streams, AI, cloud and edge, …). Validated against existing and ongoing projects and regulatory frameworks, the CyberSecurity Pathway II provides an approach allowing to further harden CyberSecurity accordingly.

Finally, **Chapter 6** will summarise some conclusions and envisage further Digital Technologies (namely Digital Twins and Edge-to-Cloud continuum) where further pathways could be developed, taking advantage of the positive experience of CF2 CSA and its Digital Technology pathways.

1.1 The CF1 Pathways and the future of Connected Factories

ConnectedFactories CSA[3] has been conducted along 2017-2019. In this section, the latest evolution of the three Big Data Technologies adoption pathways will be reported. Pathways to the digitalisation of manufacturing reflect how digitalisation (data driven in particular) and eventually the deployment of digital platforms (industrial data platforms) can bring value within different kinds of manufacturing areas, such as factory automation, value networks or product-service development. The pathways enhance 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.

Three generic pathways with a particular focus have been developed:

- The **Hyper-connected Factories pathway:** towards networked enterprises in complex, dynamic supply chains and value networks
- The **Autonomous Smart Factories pathway:** towards optimised and sustainable manufacturing including advanced human-in-the-loop workspaces
- The **Collaborative Product-Service Factories pathway:** towards data-driven product-service engineering in knowledge intensive factories

The **pathways** and in particular the associated examples (or cases) also reflect how different digitalisation approaches will or can be implemented and co-exist in a concrete business environment. The pathways developed **indicate how research and innovation projects contribute to the future deployment of digital platforms** for manufacturing and will **facilitate and stimulate the discussion and identification of more company-specific innovation strategies**.

[3] https://www.connectedfactories.eu/project-news/connectedfactories-csa-publishes-key-deliverables

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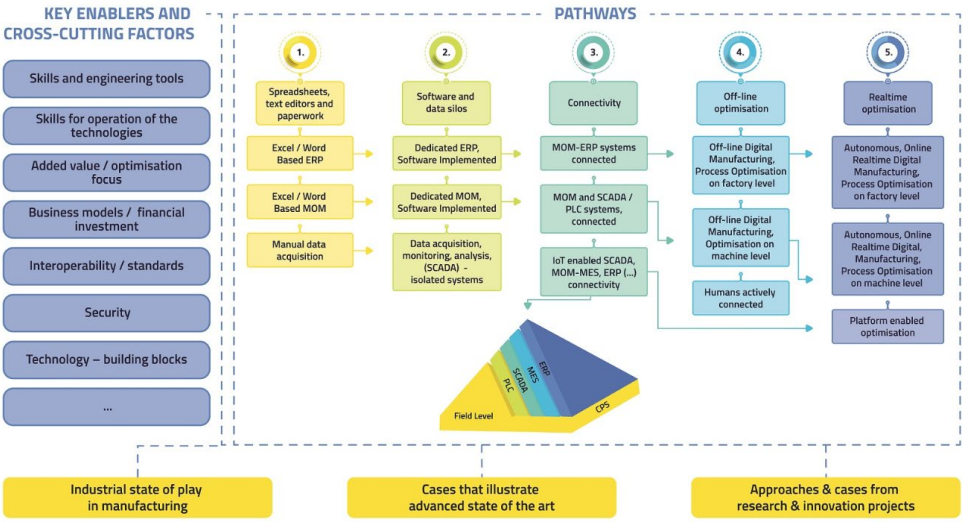


Figure 1 - Autonomous and Smart Factory Pathway and Key Enablers

Moreover, there are many **key enablers and cross-cutting factors** that empower progression along the pathways, such as engineering skills and tools and also the skills that are required for operating and managing the digital systems and tools. Another example is the many technological building blocks that need to be put into place and need to be integrated: from data communication infrastructure such as fieldbuses, industrial wireless or cabled networks to data storage, simulation tools, high performance computing, big data technologies, artificial intelligence, etc. The ConnectedFactories project endeavours to cover all, or at least the most important, of these different aspects, which are referenced as a self-standing **structured glossary** (available from the structured wiki[4] of the EFFRA Innovation Portal).

Every pathway involves the interaction of many stakeholders: one or more manufacturing companies, technology suppliers, system integrators, etc. The **pathways are also co-existing and non-exclusive**. In other words: the same manufacturing company can associate itself to different pathways and might be positioned on a more advanced level within one pathway compared to another. In addition, the same digital tools (for instance, digital platforms) may be applicable within different pathways and hence the suppliers of digital solutions, or system integrators, may be associated to more pathways as well. **Different people within companies will look at the pathways from their particular viewpoint**. A production manager would probably focus on manufacturing operations, a supply chain manager would look at value networks and a customer service manager would look at product service issues. Typically, the CEO (or CIO) of the company would, or should, look at all aspects related to their company strategy.

The most advanced level in the pathways is not necessarily the desired level for every manufacturing company. The pathways are not developed in order to distinguish 'good' manufacturing companies from 'bad' manufacturing companies.

On the contrary, it is of particular importance that **within each and every pathway, the perspective of the small scale (SME) manufacturing companies should be highlighted**. It should be noted however that large manufacturing is also facing challenges in making their way along the pathways.

[4] https://portal.effra.eu/wiki

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The ConnectedFactories CSA has concluded its journey at the end of 2019, and the latest evolution of the three pathways in the perspective of Big Data Technologies adoption can be seen in the Figures below. With respect to value creation resulting from big data, the **Autonomous & Smart Factories pathway** (see picture below) provides fundamental milestones that need to be reached in order to generate the data (in particular on level 3). Big amounts of data can then be used for the optimisation of manufacturing processes within the factory (still within the Smart & Autonomous Factories pathway).

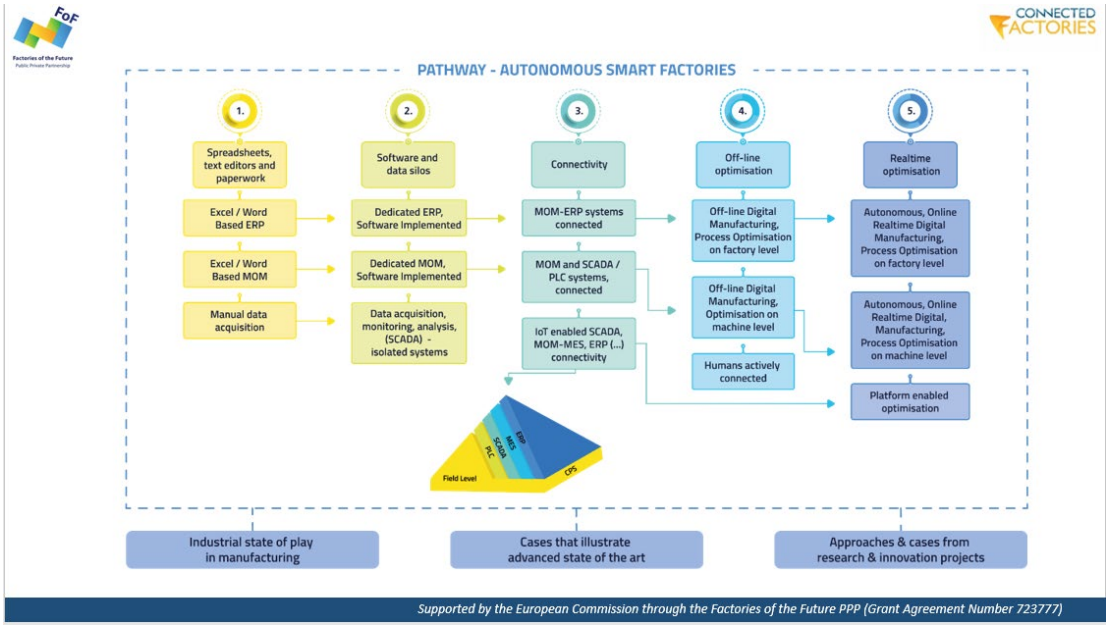


Figure 2 - Autonomous and Smart Factory Pathway

However, this optimisation will increasingly involve services that are provided by the suppliers of manufacturing systems or specialised third parties and described in the **Collaborative Product-Service Factories** pathway (depicted below).

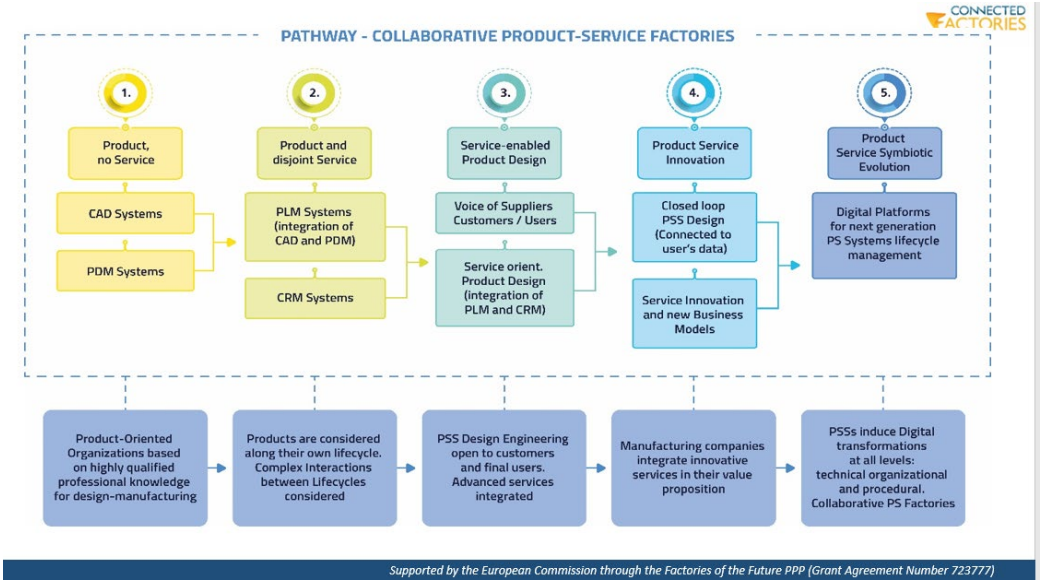


Figure 3 - Collaborative Product-Service Factories Pathway

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The **Hyperconnected Factories pathway** is perhaps less directly associated with big data, unless large amounts of data are used to establish advanced brokerage process (hence supporting the engagement with existing and new value network partners).

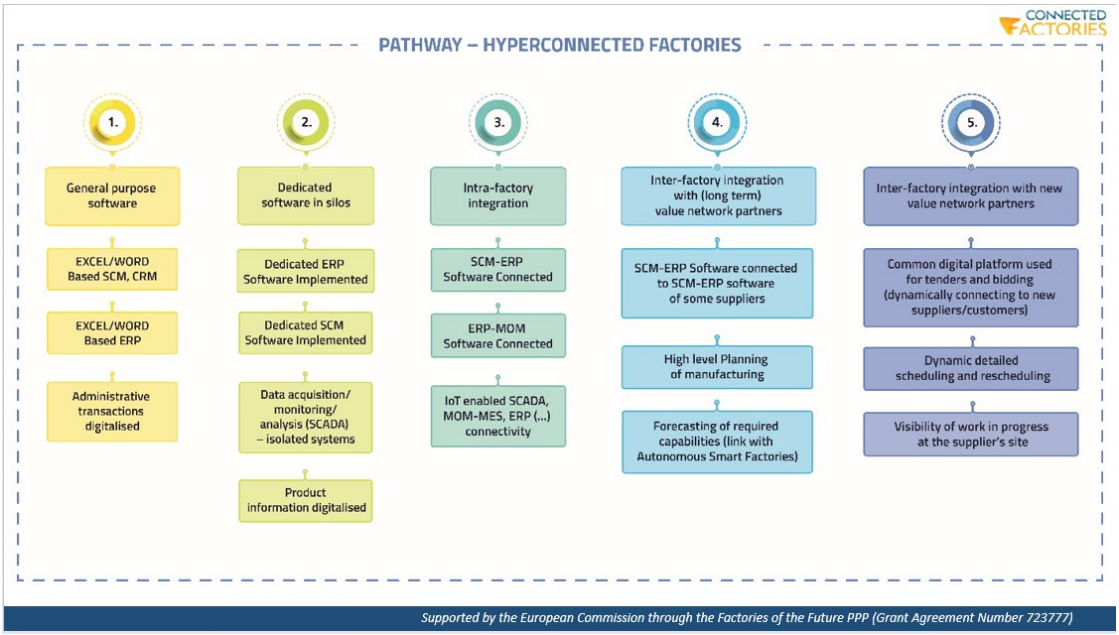


Figure 4 - Hyperconnected Factories Pathway

A Data-oriented interpretation of the three pathways shows unprecedented opportunities and challenges, which will be deeply investigated and analysed in the rest of the present deliverable.

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2 Artificial Intelligence for Manufacturing in EU Policies and Initiatives

In this Chapter 2 of D2.6 we aim to sketch the policy context around the "AI for Manufacturing" theme and CF2 pathway. We start from the EU Digital Decade 2030 and its Digital Compass (skills, infrastructures, business, government) §2.1, then we proceed with the EU AI Strategy and Package §2.2, finally we move to the new ADRA partnership (AI Data and Robotics) and its Smart Manufacturing Industry group §2.3, as well as to the AI4Europe platform and its "AI on Demand" ecosystem §2.4. This analysis aims to find the policy motivations for the **CF2 AI for Manufacturing** pathway development and validation.

2.1 EU Digital Decade and Digital Compass

On **9 March 2021**, the European Commission presented a vision and avenues for Europe's digital transformation by 2030. The Commission proposes a Digital Compass for the EU's digital decade that evolves around four cardinal points:

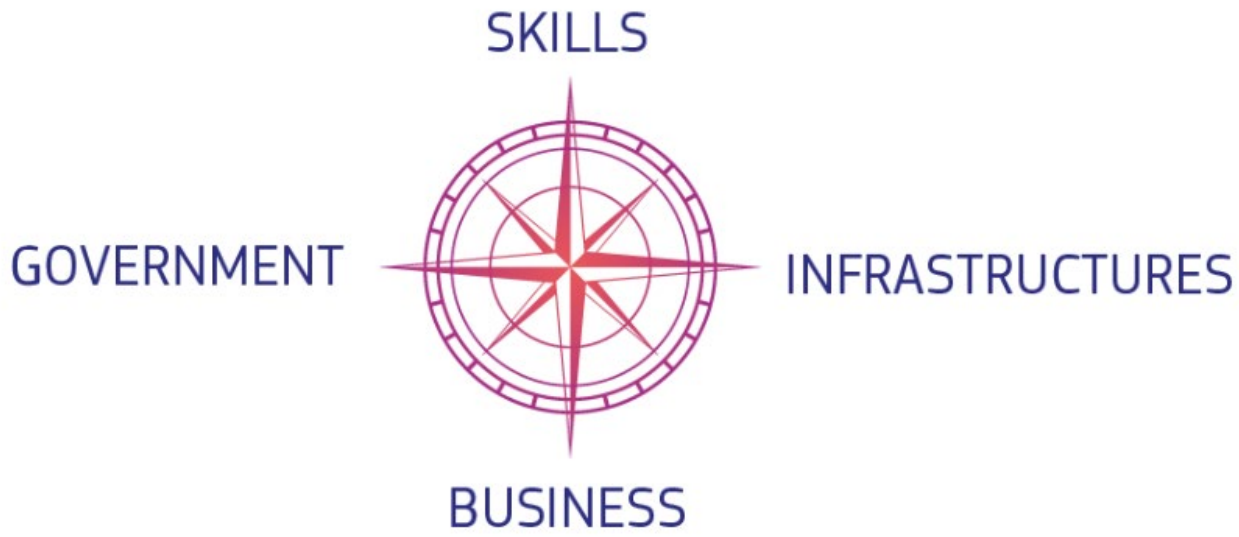


Figure 5 – The 2030 EU Digital Compass and its four dimensions

i. **SKILLS**. Two main objectives here related both to ICT specialists (20 Million with gender convergence) and basic digital skills (80% of population)

ii. **BUSINESS**: Three main objectives here related to Technology Uptake (75% of EU companies using AI Data Cloud); to an Innovators' ecosystem (finance to start-ups, scale-ups and Unicorn); to Late Adopters (90% of SMEs to a basic level of digital intensity)

iii. **INFRASTRUCTURE**: Four main objectives related to Connectivity (Gigabit for everyone, 5G everywhere); Semiconductors (double EU share in global production); Data - Edge & Cloud (10,000 climate-neutral highly secure edge nodes); Computing (first computer with quantum acceleration)

iv. **GOVERNMENT**: Three main objectives concerned with Key Public Services (100% online); e-Health (100% of citizens having access to medical records) and Digital Identity (80% of citizens using digital ID)

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The policy programme Path to the Digital Decade sets up a monitoring and cooperation mechanism to achieve the common objectives and targets for Europe's digital transformation. This governance framework is based on an annual cooperation mechanism involving the Commission and Member States. The Commission will first develop projected EU trajectories for each target together with the Member States, which would in turn propose national strategic roadmaps to attain them.

The cooperation mechanism would consist of

- a structured, transparent and shared monitoring system based on the Digital Economy and Society Index (**DESI**) to measure progress towards each of the 2030 targets
- an annual '**Report on the state of the Digital Decade**' in which the Commission evaluates progress and provides recommendations for actions
- multiannual **Digital decade strategic roadmaps** in which the Member States outline adopted or planned policies and measures in support of the 2030 targets
- a structured framework to discuss and address areas **of insufficient progress** through joint commitments between the Commission and the Member States;
- a mechanism to support the implementation of **multi-country projects**

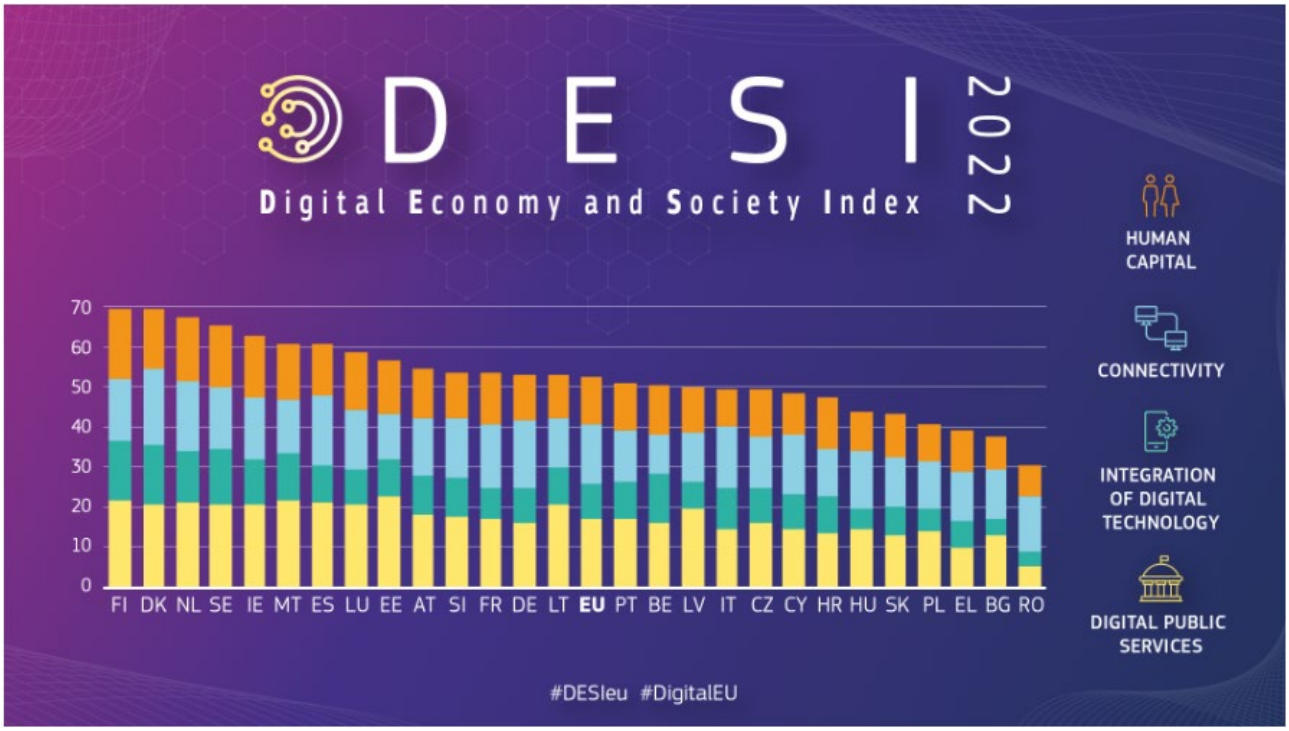


Figure 6 – DESI 2022 Index (Digital Economy and >Society Index) in EU Countries

As identified by the above Country-by-Country diagram, Manufacturing Industry represents some sort of exception in the EU landscape, as the most important EU Manufacturing Countries (Germany Italy France) are lagging behind in DESI index.

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This was also emphasised in the previous D2.2 report regarding the data-driven decision-making critical processes, where the situation of the manufacturing industry, in comparison with other industries, is quite worrying with just the 43% of cases with respect of more than 65% for banking and 55% for insurance and telco.

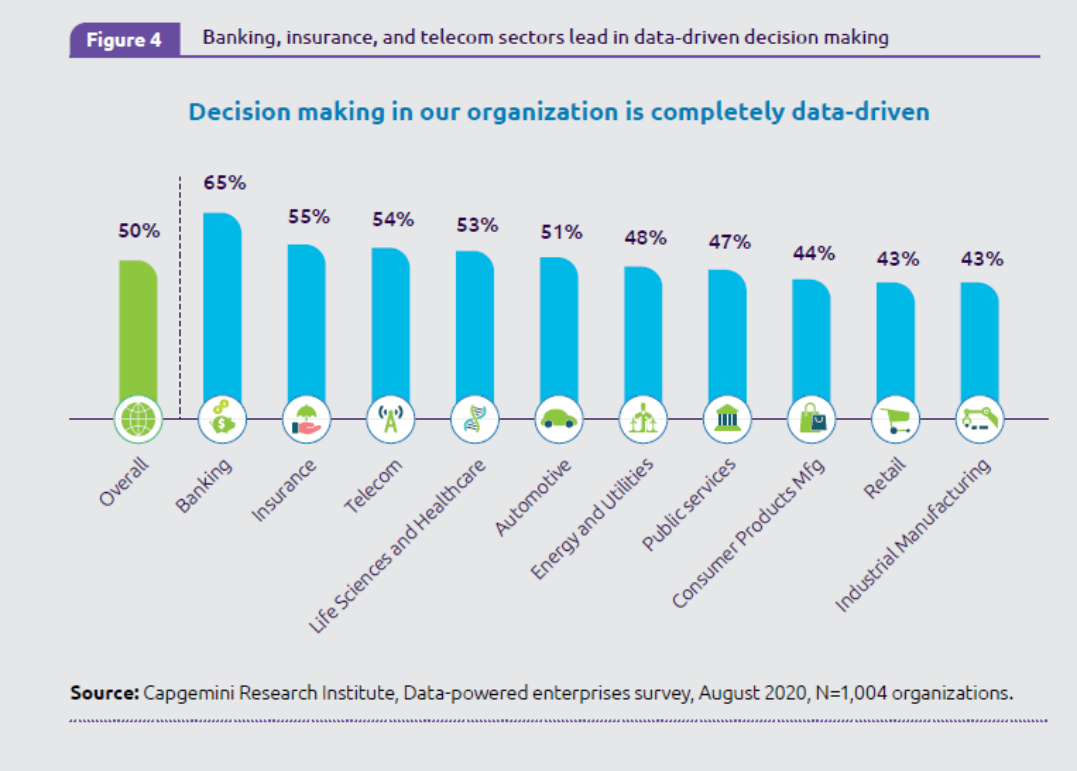


Figure 7 – How many enterprises make Data-driven decision, by sector (The data-powered enterprise)

Manufacturing Industry is the driving sector for European economy and for many of its Countries. However, the full adoption of digital technologies in its critical business processes is still lagging behind, compared to other EU key sectors. The main purpose of **CF Digital Transformation Pathways** is creating awareness, identifying gaps and developing projects to improve the digital maturity of EU manufacturing industry. We started from CF1 pathways (smart autonomous, collaborative product-service and hyperconnected Factories of the Future) setting the scene for three most relevant manufacturing scenarios of production, product c and value chain management. In CF2 we introduced specific digital technology pathways for Data Spaces and AI in Manufacturing. D2.2 described the Data Space pathway and its validation in concrete industrial cases; the present D2.6 is targeting the Artificial Intelligence and Cyber Security pathways and the level of autonomous behaviour of manufacturing systems in production, product lifecycle and in the whole value chain.

2.2 The EU AI Strategy and the AI Package

The EU's approach to Artificial Intelligence centers on excellence and trust, aiming to boost research and industrial capacity while ensuring safety and fundamental rights. The way EC approaches Artificial Intelligence (AI) will define the world we live in the future. To help building a resilient Europe for the Digital

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Decade, **people and businesses** should be able to enjoy the benefits of AI while **feeling safe and protected**. The 2018 European AI Strategy aims at making the EU a world-class hub for AI and ensuring that AI is human-centric and trustworthy.

Such an objective translates into the European approach to excellence and trust through concrete rules and actions.

In April 2021, the Commission presented its **AI package**, including:

- Its Communication on fostering a European approach to artificial intelligence;
- An update of the Coordinated Plan on Artificial Intelligence (with EU Member States);
- Its proposal for a regulation laying down harmonised rules on AI (AI Act) and relevant Impact assessment.

The Commission and Member States agreed to boost excellence in AI by joining forces on policy and investments. The updated Coordinated Plan on AI outlines a vision to accelerate, act, and align priorities with the current European and global AI landscape and bring AI strategy into action. Maximising resources and coordinating investments is a critical component of AI excellence.

Through the **Digital Europe and Horizon Europe programmes**, the Commission plans to invest €1 billion per year in AI. It will mobilise additional investments from the private sector and the Member States in order to reach an annual investment volume of €20 billion over the course of the digital decade. The **Recovery and Resilience Facility** makes €134 billion available for digital.

This will be a game-changer, allowing Europe to amplify its ambitions and become a global leader in developing cutting-edge, trustworthy AI. Access to high quality data is an essential factor in building high performance, robust AI systems. Initiatives such as the EU Cybersecurity Strategy, the Digital Services Act and the Digital Markets Act, and the Data Governance Act provide the right infrastructure for building such systems.

The Coordinated Plan on Artificial Intelligence 2021 Review is the next step in creating EU global leadership in trustworthy AI. The plan is closely aligned with the Commission's digital and green priorities, and with Europe's response to the COVID-19 pandemic. It builds on the strong collaboration between the Commission and Member States established during the 2018 Coordinated Plan. The 2018 Coordinated Plan was a joint commitment to maximise Europe's potential to compete globally and an essential first step in defining actions and funding instruments for the uptake and development of AI across sectors. And, it encouraged Member States to develop national strategies.

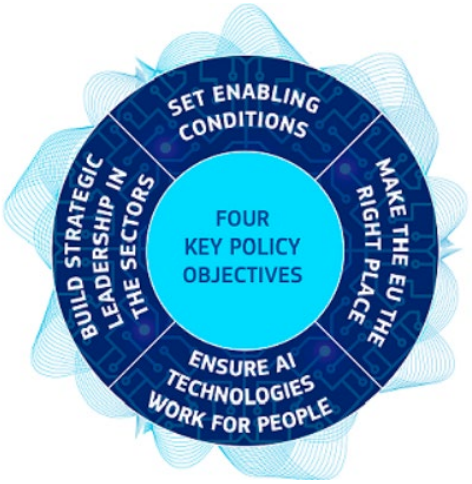
Turning strategy into action, the 2021 Coordinated Plan's key message is that the Commission and Member States should:

- **Accelerate** investments in AI technologies to drive resilient economic and social recovery aided by the uptake of new digital solutions
- **Act** on AI strategies and programmes by fully and timely implementing them to ensure that the EU fully benefits from first-mover adopter advantages
- **Align** AI policy to remove fragmentation and address global challenges

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In order to achieve this, the updated plan sets four key sets of policy objectives, supported by concrete actions and indicating possible funding mechanism and the timeline to:

1. set enabling conditions for AI development and uptake in the EU
2. make the EU the place where excellence thrives from the lab to market
3. ensure that AI works for people and is a force for good in society
4. build strategic leadership in high-impact sectors



Building trustworthy AI will create a safe and innovation-friendly environment for users, developers and deployers. The Commission aims to address the **risks generated** by specific uses of AI through a set of complementary, proportionate and flexible rules. These rules will also provide Europe with a leading role in setting the global gold standard. This framework gives AI developers, deployers and users the clarity they need by intervening only in those cases that existing national and EU legislations do not cover. The legal framework for AI proposes a clear, easy to understand approach, based on four different levels of risk: unacceptable risk, high risk, limited risk, and minimal risk.

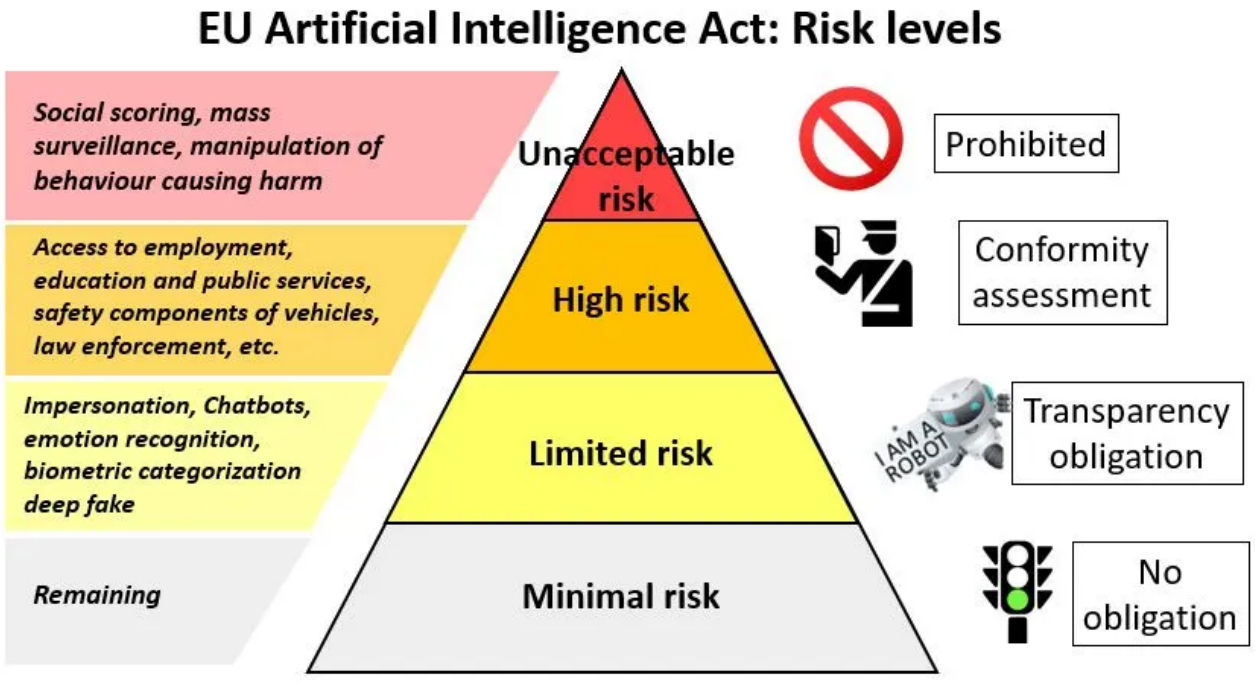


Figure 8 – EU Artificial Intelligence Act: risk levels

i. **Unacceptable risk**. All AI systems considered a clear threat to the safety, livelihoods and rights of people will be banned, from social scoring by governments to toys using voice assistance that encourages dangerous behaviour.

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

ii. **Limited risk**. Limited risk refers to AI systems with specific transparency obligations. When using AI systems such as chatbots, users should be aware that they are interacting with a machine so they can take an informed decision to continue or step back.

iii. **Minimal or no risk**. The proposal allows the free use of minimal-risk AI. This includes applications such as AI-enabled video games or spam filters. The vast majority of AI systems currently used in the EU fall into this category.

iv. **High risk**. This is the major focus of **AI systems in Manufacturing**. AI systems identified as high-risk include AI technology used in:

- critical infrastructures (e.g. transport), that could put the life and health of citizens at risk;
- educational or vocational training, that may determine the access to education and professional course of someone's life (e.g. scoring of exams);
- safety components of products (e.g. **AI application in robot**-assisted surgery);
- employment, **management of workers** and access to self-employment (e.g. CV-sorting software for recruitment procedures);
- essential private and public services (e.g. credit scoring denying citizens opportunity to obtain a loan);
- law enforcement that may interfere with people's fundamental rights (e.g. evaluation of the reliability of evidence);
- migration, asylum and border control management (e.g. verification of authenticity of travel documents);
- administration of justice and democratic processes (e.g. applying the law to a concrete set of facts).

High-risk AI systems will be subject to strict obligations before they can be put on the market:

- adequate risk assessment and mitigation systems;
- high quality of the datasets feeding the system to minimise risks and discriminatory outcomes;
- logging of activity to ensure traceability of results;
- detailed documentation providing all information necessary on the system and its purpose for authorities to assess its compliance;
- clear and adequate information to the user;
- appropriate human oversight measures to minimise risk;
- high level of robustness, security and accuracy.

All remote biometric identification systems are considered high risk and subject to strict requirements. The use of remote biometric identification in publicly accessible spaces for law enforcement purposes is, in principle, prohibited. Narrow exceptions are strictly defined and regulated, such as when necessary to search for a missing child, to prevent a specific and imminent terrorist threat or to detect, locate, identify or prosecute a perpetrator or suspect of a serious criminal offence. Such use is subject to authorisation by a judicial or other independent body and to appropriate limits in time, geographic reach and the data bases searched.

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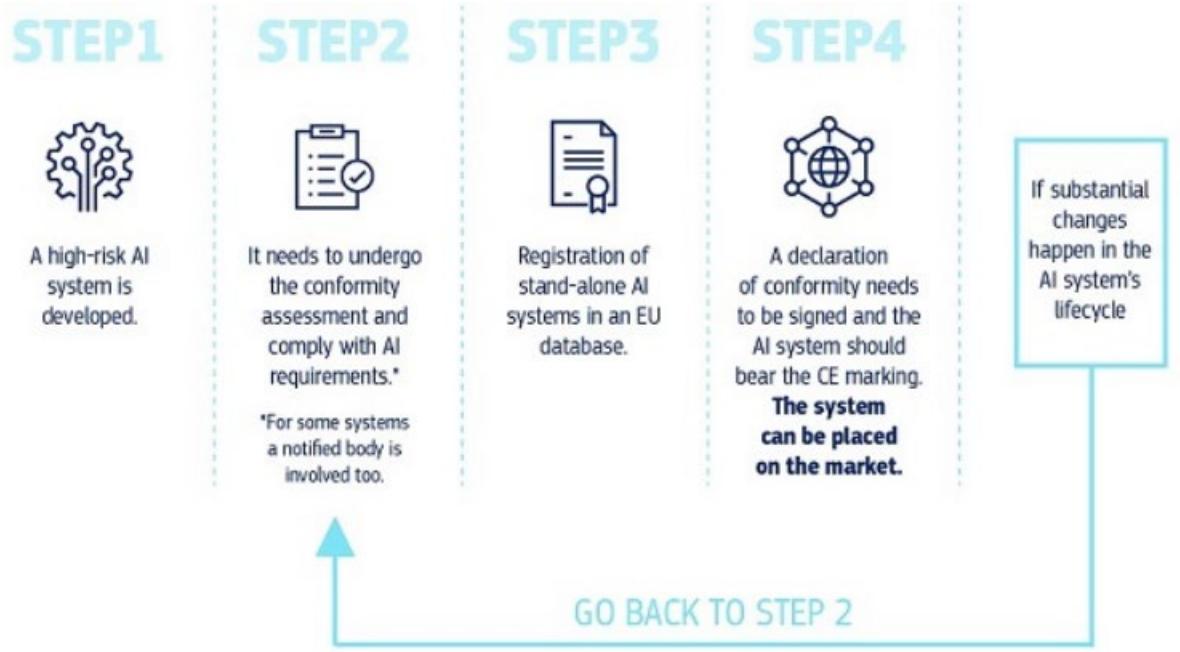


Figure 9 – AI Act: how to manage high risk AI systems

Artificial Intelligence is one of the most relevant technologies for EU Digital Transformation and it is a paradigmatic example on how technological, business, social, regulatory and social aspects need to converge to a common harmonised vision and conceptual framework. Such a complex framework requires the presence of easy-to-use methods and tools for Industry to measure and improve their readiness to AI-driven Digital Transformation. The **CF2 "AI for Manufacturing" pathway** (see Chapter 4) is one of these tools especially devoted to identify the autonomous level of AI industrial cases and the barriers and obstacles met by manufacturing SMEs in adopting AI-based solutions. The autonomous behaviour levels (and in particular the MAL4) also indicate precise instructions on how to address **AI risks**, especially in the case of High Risk as explained in the text before.

2.3 The AI Data and Robotics Partnership and the Smart Manufacturing Industry group

As reported in the previous D2.2 deliverable, the AI, Data and Robotics Partnership[5]'s **Strategic Research, Innovation and Deployment Agenda** (SRIDA) defines the general goals, the main technical and non-technical priorities, and a research and innovation roadmap for the European Public Private Partnership (PPP) on Big Data Value. The activity is driven by the awareness of the advantages brought by a solid European AI system and, indeed, one of the core tasks is to create a European network connecting AI ecosystems.

In the SRIDA it is outlined the context for the operation of the ADRA Partnership, setting out the European integrated landscape for its adoption and development. The picture below (Figure 10) shows in a schematic way the elements that contribute to define the European AI Framework and Enablers.

[5] https://ai-data-robotics-partnership.eu/

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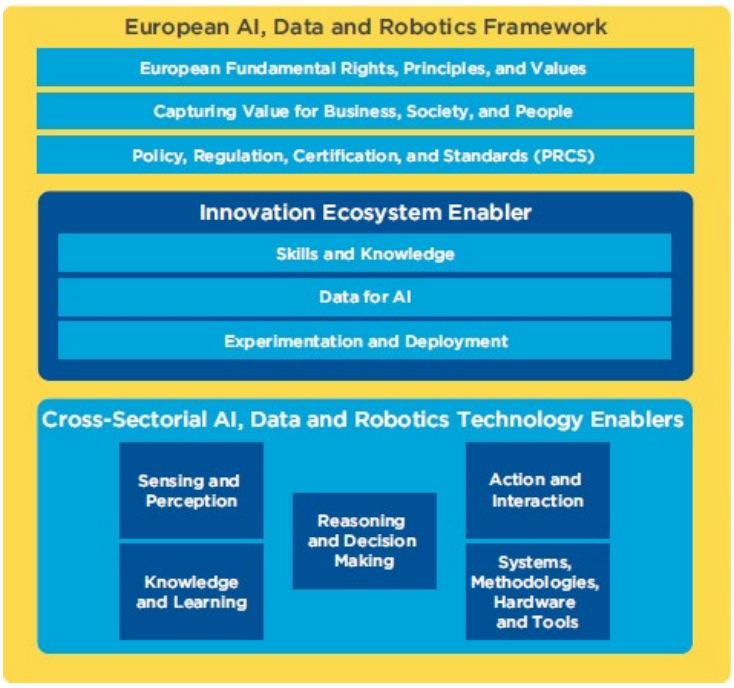


Figure 10 - European AI, Data and Robotics Framework and Enablers released in September 2019

The implementation of the six technology enablers (Data Protection and Privacy, Sensing and Perception, Knowledge and Learning, Reasoning and Decision-Making, Action and Interaction, Systems, Methodology and Hardware) in the Manufacturing Industry is in charge of the **Smart Manufacturing Industry** SMI group in BDVA (ADRA).

In the previous D2.2 document, we reported about the MURAL interactive workshop about the six enablers and the 200+ comments, opinions and reflections gathered.

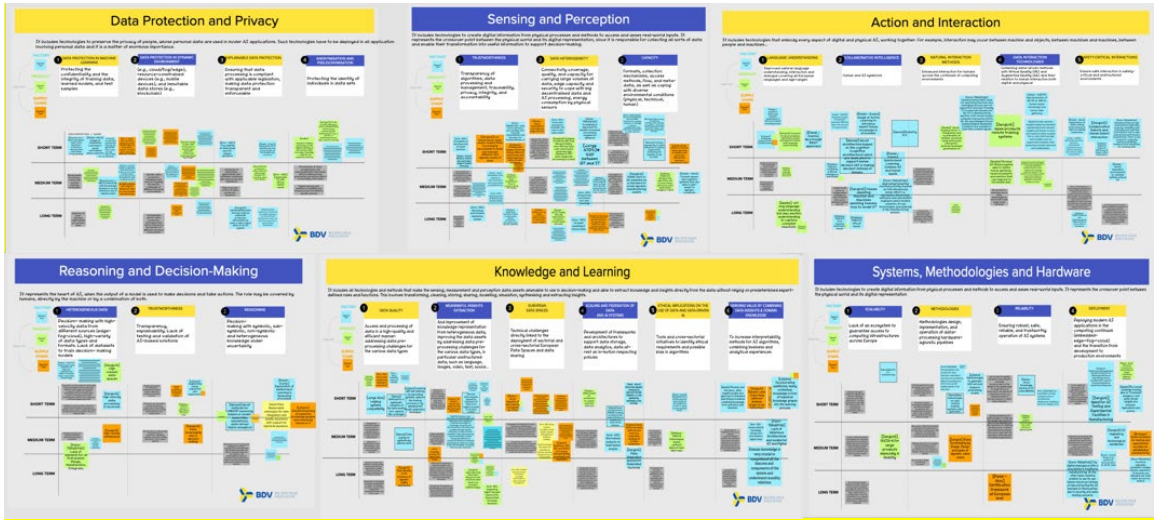


Figure 11 – SRIDA Roadmap validation in the Smart Manufacturing Industry community

In this deliverable, we report about the DATAWEEK2022 online workshop (**A Matter of Quality! Data for Trustworthy AI in Manufacturing**, co-organised by BDVA and CF2 CSA) which was held online on May 30th 2022 and then summarised in presence during the Naples DATAWEEK22 event on June 8th 2022, a fundamental question in "AI for Manufacturing" domain was debated: How relevant is the quality of the

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input Data for AI for Manufacturing applications? Or “Do you think that quality, like beauty, is in the eye of the beholder?”.

Six main speakers presented their viewpoint on the subject and a final sli.do Q&A session was held about data-driven AI for Manufacturing business models in multi-stakeholders value chains. For instance **Carlo Lacagnina** (European Open Science Cloud, FAIR metrics and Data Quality Task Force co-chair) set the scene by identifying what dependencies apply in Data Quality for Manufacturing: dependencies related to i) the application domain (FIT-for-PURPOSE), ii) to the DATASETS and iii) to the different STAKEHOLDERS involved in the process (FIT-for-USE).

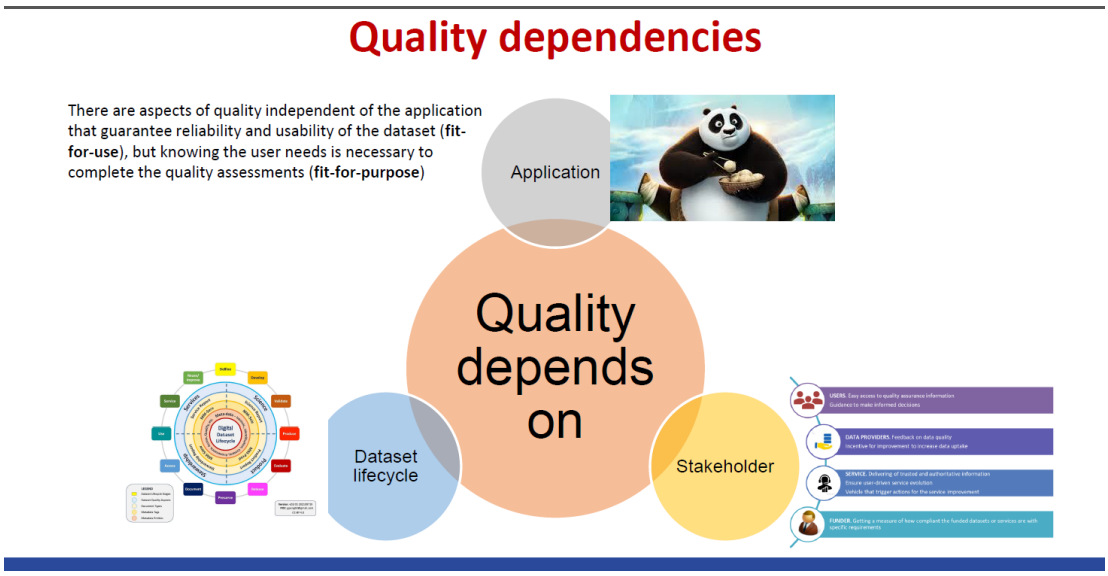


Figure 12 – DataWeek 2022. The Data Quality dependencies scehma (Carlo Lacagnina EOSC)

A second important point was the **AI REGIO DATA4AI platform** presented by Nenad Stojanovic (NISSATECH) where several data quality pipelines have been created for different AI applications but sharing the same subset of Generic pipeline elements in an APACHE Streampipes environment.

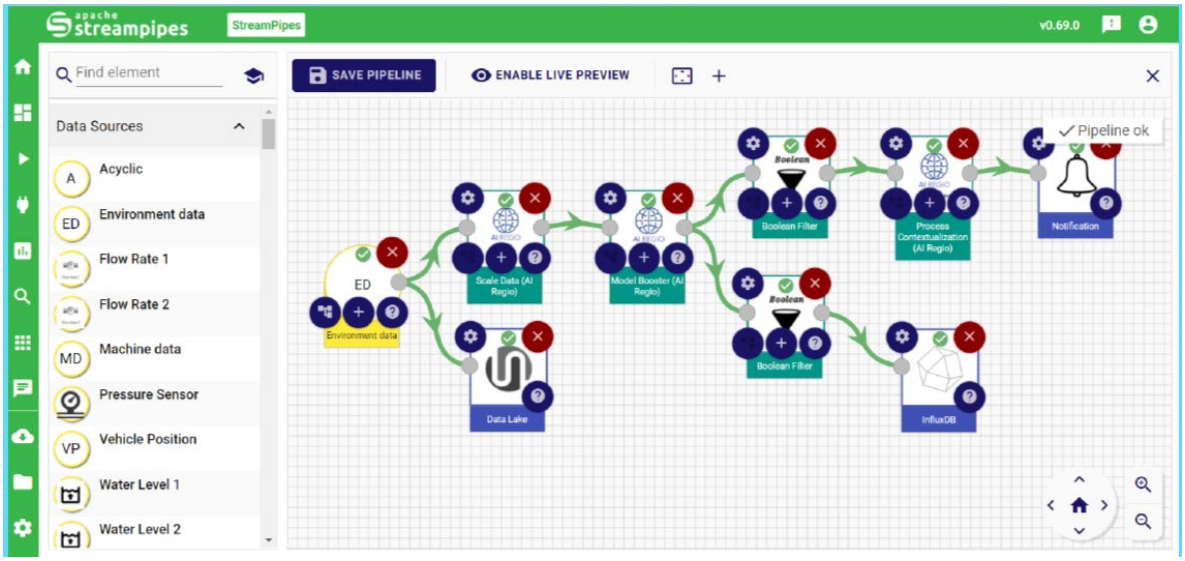


Figure 13 – Data Week 2022, AI REGIO Data Quality pipelines (Nenad Stojanovic NISSATECH)

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John Soldatos (INTRASOFT representing STAR project) underlined the importance of Trust and Security in highly distributed AI for Manufacturing applications, especially concerned with data provenance and origin certification.

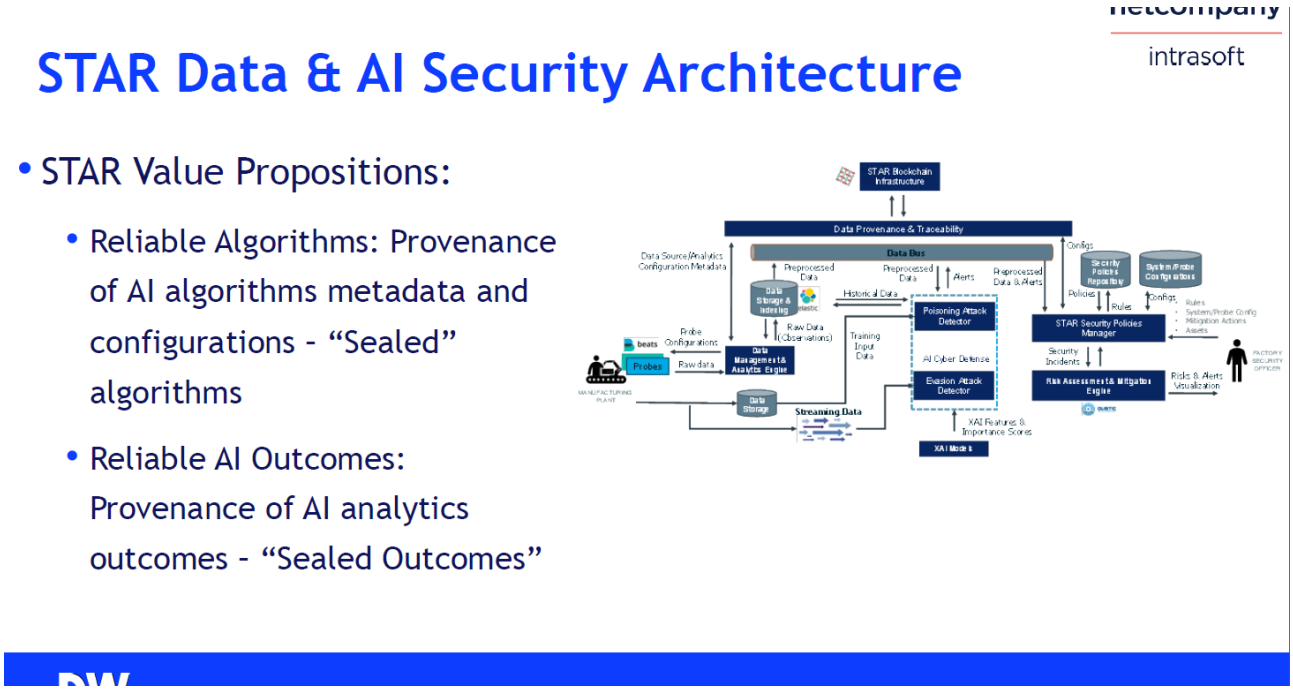


Figure 14 – Data Week 2022, STAR architecture or trustworthy AI (John Soldatos INTRASOFT)

Finally, Fenareti Lampathaki (SUITE5, XMANAI project) presented the main challenges of synthetic data generation in complex AI for Manufacturing applications different scenarios of synthetic data generation.

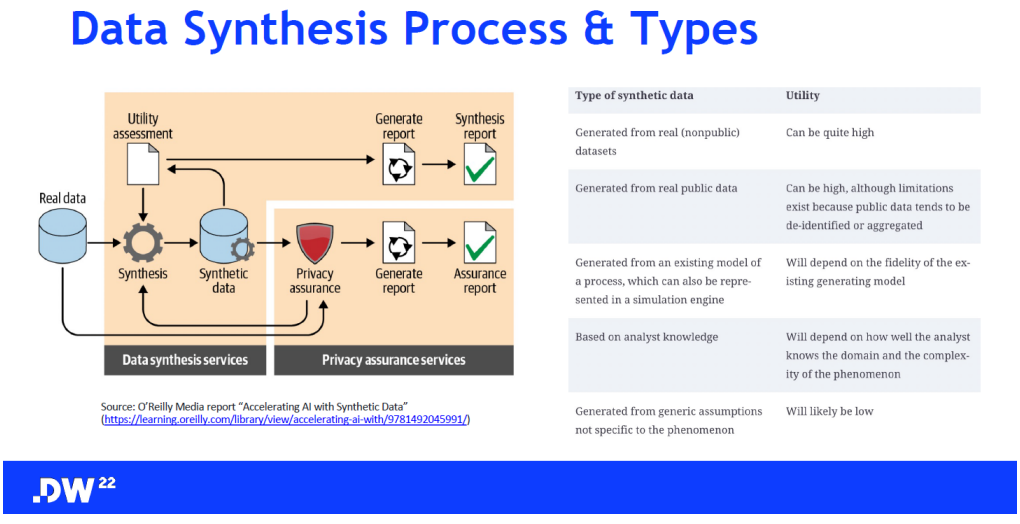


Figure 15 – Data Week 22, XMANAI approach to synthetic data generation (Fenareti Lampathaki SUITE5)

The final discussion showed that the main challenge ahead of us to implement Data Quality in AI for Manufacturing application is in the development of trusted AI Data Spaces enriched with explainability features (75%) followed by the need for an edge-to-cloud continuum Data Space for AI and by the need for

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AI enabled Digital Twins especially when modelling complex manufacturing business processes in multi-stakeholder value chains.

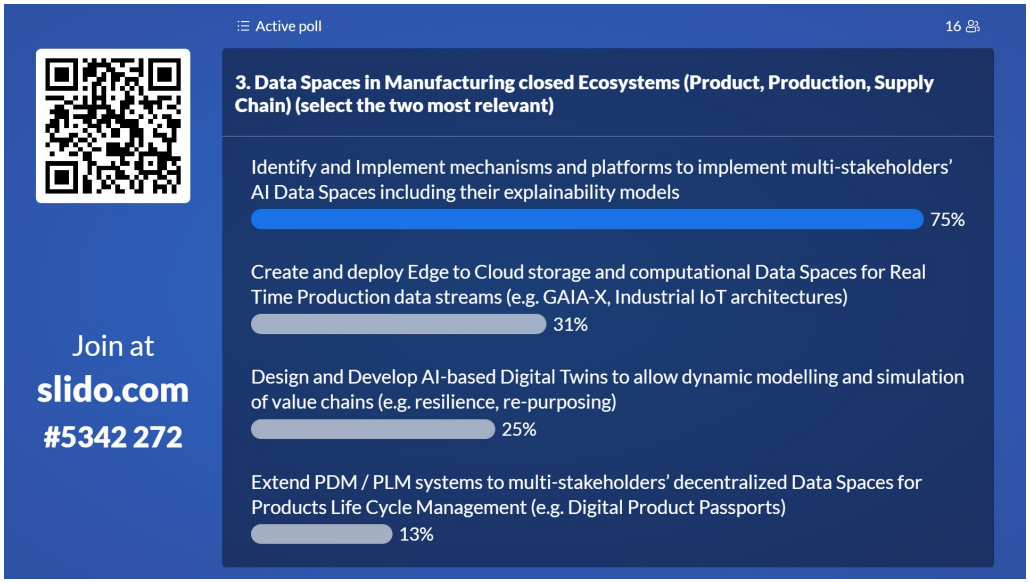
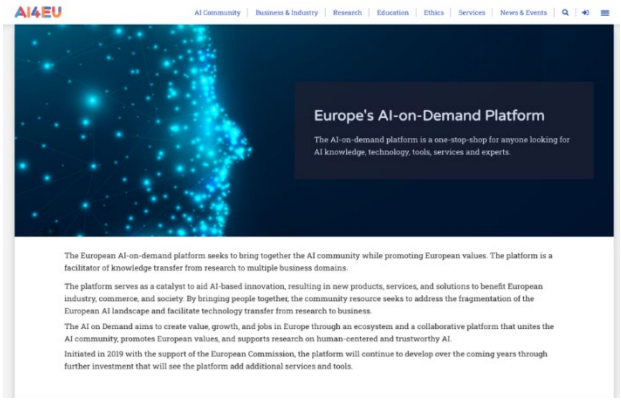


Figure 16 – Data Week 2022 conclusive online poll: Data Spaces in closed Ecosystems

The collaboration between **Manufacturing and Data/AI technological partnerships (Made in Europe vs. AI Data and Robotics partnerships)** and relevant projects / initiatives (CF2 AI pathway and SMI group white papers on AI, Data Spaces and Digital Twins) enables the synergetic harmonisation between technological and business requirements for advanced AI applications in Manufacturing. Manufacturing Industry (SMEs) maturity analysis with respect to both Data Spaces and AI applications (via the **CF2 pathways for Data Spaces and AI for Manufacturing**) is a very useful precondition in order to identify gaps between as-is and expected to-be levels in the adoption of such fundamental Digital Technologies.

2.4 The AI4Europe Initiative and AI on demand Platform

The **AI4EU**[6] project is funded under the ICT-26-2018-2020 call[7] about **Artificial Intelligence,** and it has run from January 2019 to December 2021, intending to **develop a platform** that



- serves as a **central point** to gather and provide access to **AI-related knowledge**, algorithms, and tools;
- **supports potential users of AI** to facilitate the integration of AI into applications;
- facilitate the **interaction with existing data portals** needed for AI algorithms, and resources, such as HPC or cloud computing, and support interoperability.

[6] https://www.ai4europe.eu/

[7] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/ict-26-2018-2020

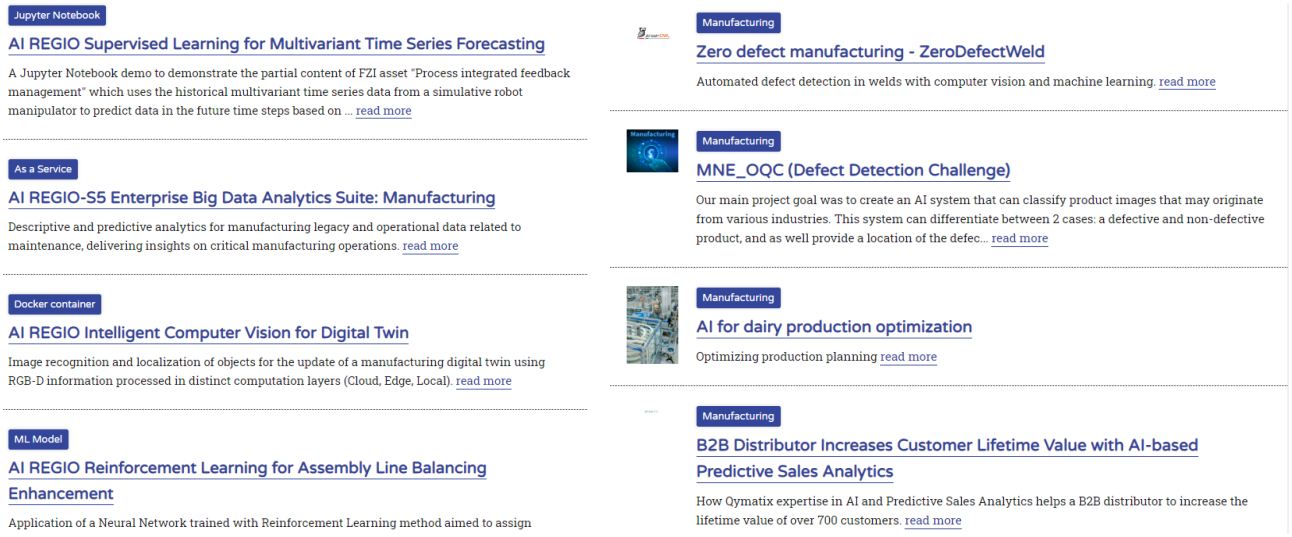
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 873086.

The AI4EU platform, offers a number of services and assets related to Artificial Intelligence, however, it's worth taking into account that the nature of AI varies greatly depending on the application domain. To identify the applications and innovations of AI that are most relevant to a specific business, AI4EU presents a section[8] dedicated to the leading industry sectors, to show how AI is developed across them.

The AI assets, Case Studies, and Organisations mentioned above are grouped by the following sectors:

Agriculture	Cloud, Edge, Infrastructure	Cultural Heritage
Earth Observation	Energy	Healthcare
Manufacturing	Maritime Sector	Public Services
Regional Engagement DIH	Telecommunications	Transportation

Regarding the Manufacturing domain, at today the platform displays 25 organizations, 19 assets (many of them from the AI REGIO H2020 Innovation Action Datasets, Python Libraries, Dockers, Jupiter Notebooks and Executables), provided by different organizations, 3 Training courses (from University of Bologna), 1 event from TAILOR, VISION and CLAIRE (AI for future Manufacturing) and 8 case studies.



Examples of AI Assets and Case Studies in Manufacturing

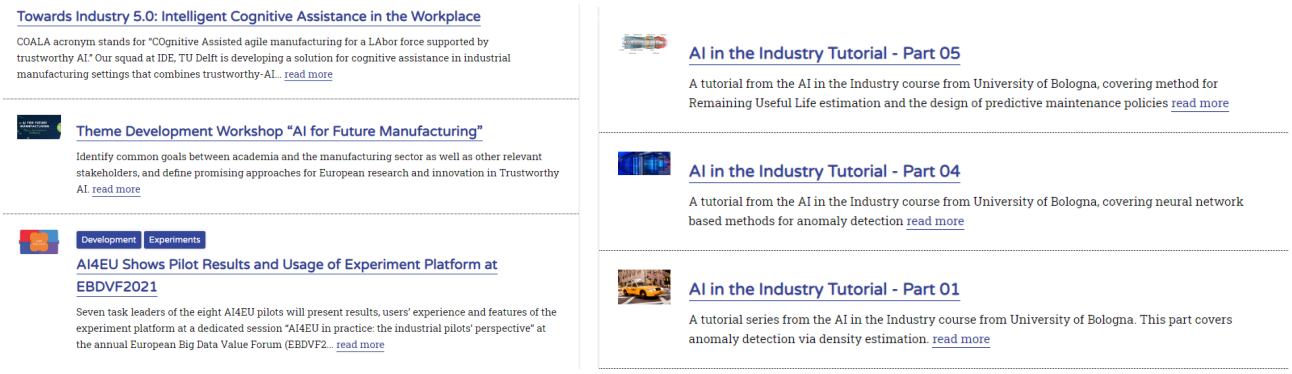


Figure 17 AIforEurope examples of Education and Events in Manufacturing

[8] https://www.ai4europe.eu/business-and-industry

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

The AI4EU experimentation site (https://aiexp.ai4europe.eu/#/home) provides a complete environment where experimenters can design, test, deploy their complex AI solutions.

In the Team Up! Phase a community of developers is created to share open-source assets, ideas, and solutions; in the following Marketplace Phase, the Acumos platform is used to design and implement complex AI pipelines; the first step of using Acumos is to onboard the preferred toolkits so that they are available for all developers of the community to build their own pipelines; the development of advanced AI Pipelines (called experiments) is in charge of the Design Studio.

The following picture summarises the proposed approach

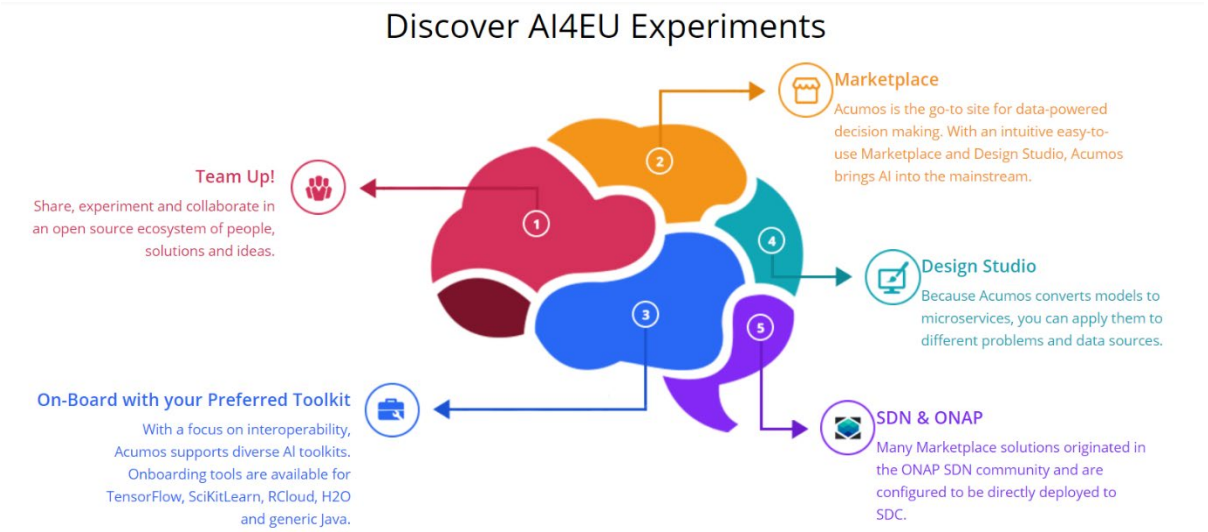
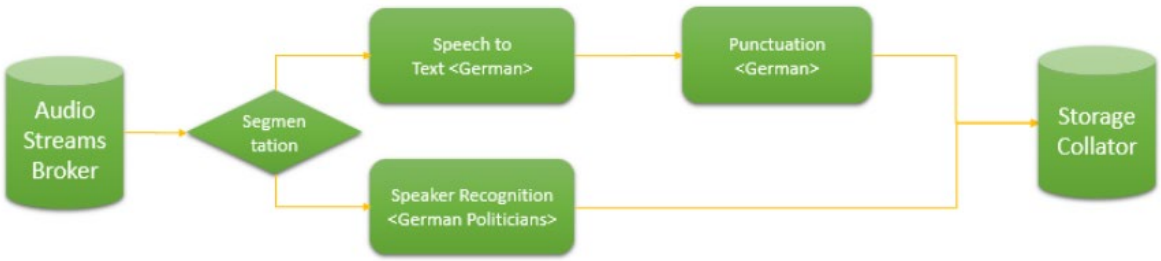


Figure 18 – AI for Europe Experimentation Facility

At the moment, the following 8 experiments have been uploaded, two of them uploaded by the AI REGIO Innovation Action about AI for Manufacturing in DIHs.

i. **EVIDA 4.0 clinical classifier** (Univ Deusto). This model allows **classifying clinical text** related to colon cancer or non-colon cancer texts based on ICD10 categories. The main objective is to get a label (1 or 0) depending if the input text belongs to the C18 ICD category, which corresponds to the Colon Cancer Category. The model is based on distilBERT transformer model and was trained using the CodiEsp dataset. The input is plain text and the output will be a number label;

ii. **Audio Pipeline** (Martin Welss).



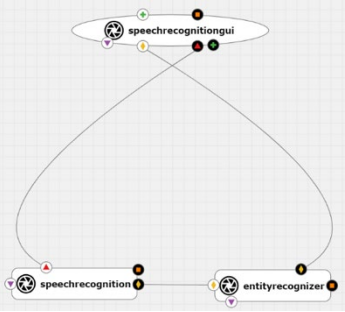
iii. **Advice-img-databroker** (CATEC Centro Avanzado de Tecnologias Aerospatiales Andalusia) collects the user's images placed on the shared folder and releases them into the pipeline

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iv. **I-Energy load forecasting**. This is a forecasting service for predicting the aggregated hourly net electrical load of the Portuguese transmission system operator (REN). The core of the service is a totally recurrent LSTM deep neural network. The model has been trained on the REN load time series for the years 2018 and 2019 (except December 2019). The service is served as a docker container and a client script is also provided to help the user form their inference requests.

v. **AI-based Inventory Management System AI4IMS** integrates simulation, optimization, and search algorithms in an advanced inventory management approach for an adaptive and dynamic response. Firstly, we acquire and cleanse the required data to obtain a reliable dataset including product prices and demand forecasting. As a result of the forecasting, the uncertainty associated with material resources prices and demand is also characterized. Secondly, we capture the production plant and procurement system in a simulation environment. Thirdly, a direct randomized sampling method generates alternative scenarios for handling the uncertainty characterized during the forecasting step. Next, a simulation-based optimization system finds an improved procurement policy within the solution space. Finally, a variability analysis generates alternative solutions, which are provided for decision-maker support.

vi. **AI4MEDIA Demo. (FhG IAIS)**



vii. **Live Speech Recogniser (FhG IAIS).** It is a web UI that can be used with the SpeechRecognition model. It serves as both the data source (audio stream) and the consumer of the results (transcribed text).

viii. **Doc 2 Answer (SPARKD.ai).** The model implements 2 main tasks of the AI4EU call. It is able to parse and extract information from 2 types of previdential documents: "O7" and "SocialCard". The first type locates cells and extracts the content as text (i.e. numbers, dates). The second type locates stamps and classifies them.

At the moment the marketplace includes **247 models**: 49 Classification Models; 113 Data Sources; 25 Data Transformers; 59 Prediction Models and 1 Regression model.

The **Manufacturing Vertical** in the AI4Europe platform is currently a quite naïve and no-structured pool of several different assets and resources without clear design principles and aims. **CF2 Innovation Portal** needs to establish a collaboration contact with the new CSA just funded (AI4europe). Regarding WP2 and the **AI 4 Manufacturing pathway**, such a method and tool could be added to the Catalogue, once stabilised, in order to provide a first methodological support towards a strategic, a tactical and an operational guidance towards AI driven Digital Transformation.

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

3 AI for Manufacturing in EU Research and Innovation Programmes

AI for Manufacturing is one key topic in current and future EC-funded Research and Innovation workprogrammes. This is true for H2020 2019-2020 Workprogramme §3.1 (including the two phases DMP cluster innovation actions in DT-ICT-07 we described in previous D2.2), the HEP 2021-2022 Workprogramme §3.2 (and in particular the three joint topics between Made in Europe and ADRA partnerships) as well as the DEP 2021-2022 Workprogramme about AI for Manufacturing §3.3

3.1 AI for Manufacturing in H2020 Workprogramme

In the H2020 2021-22 workprogramme, AI for Manufacturing was mostly covered by the ICT-38 Research and Innovation Actions (§3.1.1) and by the two I4MS Phase four Innovation Actions (DT-ICT-03-2020: I4MS (phase 4) - uptake of digital game changers) focusing on "Innovative Artificial Intelligence in manufacturing".

3.1.1 The H2020 ICT38 topic and AI for Manufacturing cluster

The **ICT-38-2020 call**[9] **"Artificial intelligence for manufacturing"** of 2020 has the objective of integrating AI technologies in manufacturing systems to exploit their potential in productive processes (discrete and process industry).

The call funded eight Research and Innovation Actions (RIA), aiming to develop innovative concepts and tools that consider the status and availability of all relevant production resources to integrate Artificial Intelligence technologies, touching on key topics such as human-machine collaboration and ethical issues deriving from AI adoption.

The following 8 Research and Innovation Actions have been funded

- **STAR**[10] (January 2020 – December 2023) aims to deploy standard-based **secure, safe, reliable and trusted human centric AI systems**. STAR will research, develop, validate and make available to the community leading edge AI technologies with wide applicability in manufacturing environments, including: Explainable AI (explain to factory workers and quality engineers the AI decisions and increasing transparency and trust in AI systems), Active Learning (query human in collaborative robotics environments and accelerate knowledge acquisition), Simulated Reality (simulate the next actions of reinforcement learning than expecting convergence), Human-centric Digital Twins (simulation and detection of safety issues, development of safety zones), (Cyber)Security for AI systems (against adversarial attacks and poisoning).

- **PROFICIENT**[11] (November 2020 – October 2023)**:** the project aims at designing and developing a **cloud/edge platform to integrate AI systems** in manufacturing. The platform has an edge component (for data ingestion and control) and a number of AI services to the cloud-based platform. It includes the development of digital twins, predictive AI analytics, and holistic generative optimization to meet predefined goals.

- **ASSISTANT**[12] (November 2020 – October 2023)**:** the project aims at **creating intelligent digital twins** by combining machine learning, optimization, simulation, and domain models to provide all required

[9] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/ict-38-2020

[10] https://star-ai.eu/

[11] https://ai-proficient.eu/

[12] https://assistant-project.eu/

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

information to help production managers in designing production lines, plan production and improve machine settings for effective and sustainable decisions that guarantee product quality and safety.

- **COALA**[13] (October 2020 – September 2023)**:** the project aims at developing a solution for cognitive assistance that consists of a composition of trustworthy **AI components with a voice-enabled digital intelligent assistant** as an interface, to support workers that need to use analytics tools. The objective is to reduce the number of quality incidents in manufacturing, the time needed for on-the-job training of workers in manufacturing, and to improve the competencies of blue-collar workers in managing AI opportunities.

- **knowlEdge**[14] (January 2021 – December 2023)**:** the project aims to boost industries towards agile and flexible strategies, respond to the fast-changing customers' needs, and simultaneously optimize their processes and quality control mechanisms. To achieve it, the project proposes six major innovations in the areas of data management, data analytics, and knowledge management: a set of "**edge" AI services**, a **digital twin** able to test the AI models, a **data management framework**, **Human-AI Collaboration** and Domain Knowledge Fusion tools, a set of **standardization mechanisms** for the exchange of trained AI-models, a **knowledge marketplace** platform for AI trained models.

- **MAS4AI**[15] (October 2020 – September 2023)**:** the project aims at developing and testing a distributed and interoperable **AI architecture based on multi-agents technology** in such a way that it contributes to the hyper-agility of European factories through modular and flexible production while at the same time keeps the humans in control of the AI technology. A basic concept is to integrate all Smart Components in a holistic system architecture to enable the easy development and deployment of industrial AI technologies.

- **TEAMING.AI**[16] (January 2021 – December 2023)**:** the project aims at realizing a true human-AI **teaming working scheme** (developing a software platform for human-AI teaming), combining advanced methods for the representation of complex manufacturing processes (as **knowledge graphs** and relational machine learning). The goal is to overcome the lack of flexibility as a limiting factor of current Industry 4.0 while ensuring the role of the human being in the future industrial scenario by means of a human-centred AI collaboration.

- **XMANAI**[17] (November 2020 – April 2024)**:** the project aims at placing the indisputable power of **Explainable AI at the service of manufacturing and human progress**, overcoming the idea of the "black box" in machine learning by developing a platform able to support AI-driven decision making processes. The solution will be tested in four real-life manufacturing use cases, exploiting Explainable AI for demand forecasting, plant optimization and prediction, scheduling maintenance, and quality control.

Also, one CSA has been funded, on the topics of **Cooperation EU-Japan,** to support possible collaboration with Japan in areas relevant for AI-driven innovation in manufacturing and digital industrial platforms.

[13] https://www.coala-h2020.eu/

[14] https://www.knowledge-project.eu/

[15] https://www.mas4ai.eu/

[16] https://www.teamingai-project.eu/

[17] https://ai4manufacturing.eu/

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

- **EU-JAPAN.AI**[18] (January 2021 – October 2022)**:** the project aims at supporting cooperation between the EU and Japan in areas relevant to AI-driven innovation in manufacturing and digital industrial platforms, using an online platform to enhance knowledge and information exchange between all the area-relevant stakeholders.

The nine projects funded under the ICT-38-2020 call are collaborating as "**AI-MAN cluster**"[19], sharing knowledge, experiences and discussing many AI-related topics, exploiting synergies between the projects, and increasing their impact.

The cluster is supported by EFFRA[20] and the Connected Factories[21] project, connecting ICT38 with the DMP (Digital Manufacturing Platform) cluster of DT-ICT-07 Innovation Actions. Common exploitation pathways are envisaged both from the Manufacturing side (e.g., the Digital Factory Alliance) and from the AI Technology side (e.g., the AI-on-demand platform).

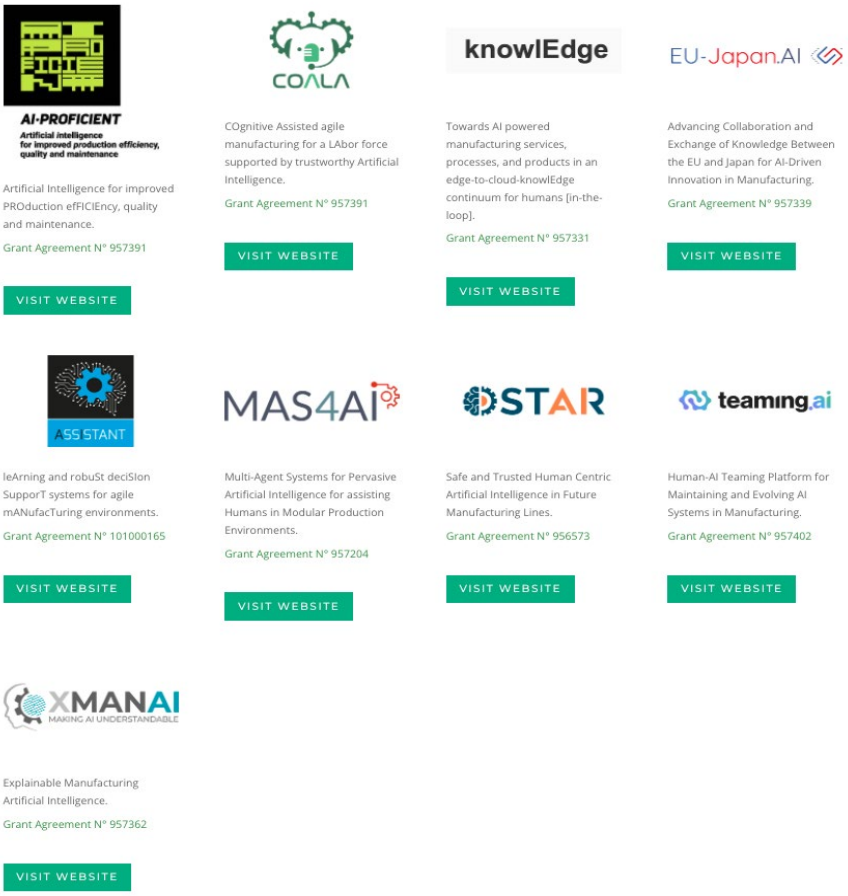


Figure 19 – The H2020 ICT38 cluster of Research and Innovation Actions in AI for Manufacturing

[18] https://project.eu-japan.ai/

[19] https://ai4manufacturing.com/

[20] https://effra.eu/

[21] https://www.connectedfactories.eu/

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

3.1.2 The AI for Manufacturing DIH I4MS IV Projects

The **DT-ICT-03-2020 call**[22] **"I4MS (phase 4) - uptake of digital game changers**" of 2019 has the objective of accelerating the design, development, and uptake of advanced digital technologies by European industry – especially SMEs and mid-caps, where typically the digital and technological transformation is slower. The call aims at identifying and shaping the most suitable tools, methods, and organisations to support SMEs and mid-caps. As part of I4MS Phase 4, in the call, a key role is played by **Digital Innovation Hubs** as supporting organizations toward the digital transformation, specifically in the manufacturing domain. The main topics of the call are Digital Twins, Additive Manufacturing, Artificial Intelligence, Human-Robot interaction, and DIHs for under-represented regions. Additionally, a Coordination and Support Action (CSA) is envisaged to support the network of Digital Innovation Hubs and to help the achievement of broad coverage in technological, application, innovation, and geographic terms, and to link up with regional/national innovation initiatives, and other Digital Innovation Hubs. The Innovation Action (IA) funded projects started in 2020, are:

- **DIGITBRAIN** and **CHANGE2TWIN** under the topic of **Digital Twin**
- **PULSATE** under the topic of **Additive Manufacturing**
- **AI REGIO** and **KITT4SME** under the topic of **Artificial Intelligence**
- **BETTER FACTORY** and **VOJEXT** under the topic of **Cognitive Automation Systems**
- **DIHWORLD** under the topic of **DIHs for under-represented regions**

The CSA, started in 2020 as well, is:

- **I4MS4Ts,** https://i4ms.eu/ the EU initiative to digitize the Manufacturing Industry

Among the five I4MS groups, CF2 WP2 set up privileged collaboration relations with AI REGIO and KITT4SME, which are part of the same AI topic, but it is planning to reinforce the cooperation also with DIHWORLD and other projects, to enhance the collaboration of the DIHs ecosystems.

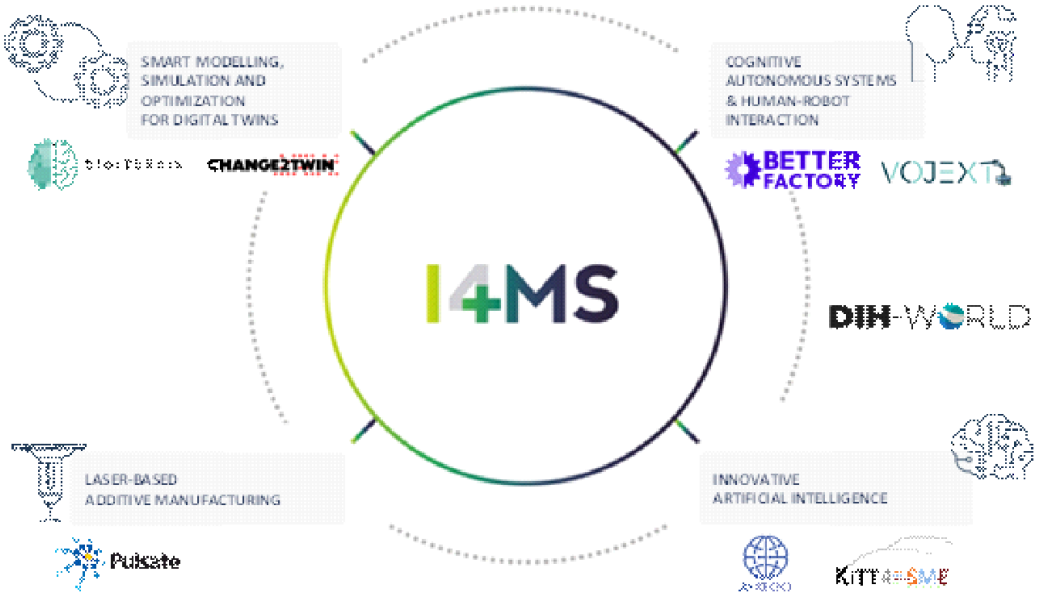


Figure 20 – I4MS (ICT Innovation for Manufacturing SMEs) Phase IV Innovation Actions

[22] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/dt-ict-03-2020

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

AI REGIO[23] **-** Regions and Digital Innovation Hubs alliance for AI-driven digital transformation of European Manufacturing SMEs and **KITT4SME**[24] **-** platform-enabled KITs of arTificial intelligence FOR an easy uptake by SMEs are the Innovation Actions falling under the topic of Artificial Intelligence.

AI REGIO "*aims at building a one-stop-shop platform that enables access to resources for AI-based solutions in efficient and sustainable manufacturing, with particular emphasis on resources that can lower the AI adoption barriers for SMEs*"; while KITT4SME *"is developing scope-tailored and industry-ready hardware, software and organizational kits for European SMEs and mid-caps, aiming at delivering these as a modularly customizable digital platform that can seamlessly introduce artificial intelligence in their production systems."*

Both projects are addressed to SMEs, Technology Providers, and DIHs:

- **SMEs** are the final target of the projects since the digital platform (output of the project) is addressed mainly to them. They can benefit from a hardware/software tool that allows the introduction of Artificial Intelligence in their production system.
- **Technology Providers** can benefit from the business opportunities deriving from the platforms and the possibility to test and assess new AI-based solutions.
- **DIHs** can benefit from the projects' approach by enriching AI-based services and products and fostering collaboration among existing ecosystems interested in the digital platform.

Implementing a collaboration about technical and business topics, **AI REGIO** presented to CF2 some main assets/topics which are complementary to DMP cluster approach.

6Ps METHODOLOGY

Within AI REGIO Task WP2.5 – "Socio-Business continuous assessment, 6Ps Digital Transformation model and Recommendations", AI REGIO has performed the 6Ps assessment to its 17 Experiments of the first iteration, intending to measure the impact of the experiments on the manufacturing pilots.

AI REGIO would like to **apply the methodology also to CF2 pilots**, with a twofold objective:

- To collect an additional number of success stories and lessons learned to enrich the portfolio of cases related to the 6Ps methodology;
- To provide to STAR's pilots a detailed analysis of the impact of the project on their production process.

From both sides (AI REGIO and Cf2), it is considered a good opportunity to exploit synergies and a starting point for further collaboration to improve the AI REGIO platform.

INDUSTRY 5.0

Within AI REGIO Task WP5.1 – "AI DIH Collaborative Intelligence and Industry", AI REGIO has conducted detailed research about Industry5.0 at the theorical level, and the subject has also been included in the Open Calls topics.

At this point, AI REGIO would like **to start a collaboration with CF2 to do further investigations** about technological solutions and the platform required to implement the Industry5.0 paradigm.

[23] https://www.airegio-project.eu/

[24] https://kitt4sme.eu/

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

To enhance collaboration with DIHs' communities, **AI REGIO / KITT4SME** proposes four additional assets/topics: the METHODIH methodology, the DIHIWARE platforms, and the Didactic Factories network, and the TERESA sandbox.

METHODIH

In WP3, AI REGIO developed **METHODIH – a METHOdology for DIHs** (see D3.1 – "Service Portfolio and Customer Journeys" and D3.5 – "AI REGIO DIHs Business and Governance"), that is, a set of tools and methods to ease and better shape the activity of DIHs (Service Portfolio, Customer Journey and Business Model analysis). These tools apply not only to DIHs but also to organizations offering services, such as Didactic Factories and Competence Centres.

The objective is to **extend the network of 13-DIHs in AI REGIO**, including also those from STAR virtual DIH ecosystem, **offering them the METHODIH tools**.

It is expected to be a win-win collaboration since from one side AI REGIO has at its disposal a wider audience to validate its approach. On the other side, the CF2 ecosystem can benefit from a set of tools useful to better shape the activity of DIHs.

DIHIWARE

AI REGIO is involved in the development and implementation of two platforms: the **AI REGIO portal**[25], aiming at fostering collaboration inside the project's community of 13 DIHs, and the **DIH4INDUSTRY platform**[26], with the objective of creating a community of communities involving DIHs from several initiatives.

Both platforms can be exploited by CF2, which can take advantage of the platforms' collaborative services and showcase their portfolios to other DIHs.

As soon as the portal is finalized for the AI REGIO community, a demo of both platforms will be proposed to Cf2 to understand the feasibility of integrating it with the Robotics and Automation MarketPlace (RAMP)[27], which is a common marketplace for manufacturers (mainly SMEs) and technological providers where DIHs offer services on top of assets and that KITT4SME's community currently uses it.

Regarding the DIH4INDUSTRY platform, the section dedicated to I4MS initiatives has already been created, and the DMP cluster Digital Innovation Hubs have been invited **to create their own profile, including their Service Portfolios and their Experiments**.

DIDACTIC FACTORIES and TERESA

Within WP7, AI REGIO is creating its own network of Didactic Factories, with the perspective of extending it, including additional organizations. KITT4SME participated in the Didactic Factory Kick-Off Meeting on 3rd September 2021, presenting a use case to be evaluated for further network extension.

Additionally, in WP7 AI REGIO has developed the concept of TERESA, a "Technical and Regulatory Sandboxes for AI, enabling a direct testing environment for innovative products and services aimed at addressing ethical challenges of the regulatory framework".

Following the "test before invest" paradigm, the TERESAs allow to test/experiment innovative AI applications/tools/services for Collaborative Intelligence-driven human-machine interaction by running

[25] https://airegio-portal.eu/

[26] https://dih4industry.eu/welcome/

[27] https://www.ramp.eu/#/

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

experiments on a limited scale in a secure, gradual and controlled way. The **WISE TERESA** concept is aimed at creating sandboxes able to test and demonstrate **W**ellbeing, **I**nclusiveness, **S**afety and **E**rgonomics of the workers when interacting with AI systems.

Didactic Factories represent the ideal place within the project to implement the TERESAs, since the experiments can be run in facilities and situations close to real factories, and constraints can be relaxed to some extent while at the same time guaranteeing the safety of the participants involved in the experiment itself. Of course, the plan is to propose it to any organization joining the network of DFs.

The **cross-fertilisation** between the CF2 DMP cluster and other H2020 initiatives regarding AI for Manufacturing has produced very positive effects. The ICT38 RIAs are bringing highly innovative lower TRL assets to the community, by exploring new AI components in explainable AI, human-AI interaction, AI security and multi agent systems for AI. The DT-ICT-03 Innovation Actions are instead bringing new methods and tools for SME Digital Transformation via DIHs. Both are very beneficial for the CF2 Innovation Portal and Digital Pathways. In particular, the AI 4 Man pathway has been preliminarily validated by the 17 AI REGIO experiments and will be adopted by the 15+ winners of the Open Calls.

3.2 AI for Manufacturing in HEP / DEP 21-22 Workprogramme

AI for Manufacturing is a fundamental technology for implementing the new HEP / DEP workprogrammes. CF2 AI4Man pathway is ready to be validated in further HEP / DEP projects:

- **HORIZON-CL4-2021-TWIN-TRANSITION-01-01**: **AI enhanced robotics systems for smart manufacturing** (AI, Data and Robotics - Made in Europe Partnerships) (IA). Research activities should be multi-disciplinary and address all of the following areas:
  - Development of robust, easy to use, explainable and compliant **AI tools** for manufacturing environments that require minimal learning and can be configured without highly skilled personnel;
  - Implement and integrate the latest research findings on technologies such as **sensors, actuators, control, edge computing, haptic technologies, mechatronics, robotics and autonomous systems** to enhance collaborative robotics systems in order to develop advanced smart manufacturing human-machine collaborative systems ensuring safe physical and social interactions and efficient collaboration with human workers;
  - Demonstrate complex, **safe and efficient collaboration between multiple agents** simultaneously, e.g. humans, autonomous agents, industrial machinery, AGVs and collaborative robots;
  - SSH should provide a variety of **human-centric approaches** to develop smooth collaboration in the human-machine teams; to improve user experience; and increase awareness comfort, trust, skill and safety (physical and social) of workers in highly automated industrial environments by incorporating a greater understanding of linguistic, historic, and cultural concerns of end-users and workers, while taking into consideration a gender and intersectional perspective;
  - Demonstrate results in at least **three large-scale industrial use-cases**, targeting sectors and tasks typically difficult to automate.

  In this topic, the following projects have been funded and will be soon contacted by CF2:

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

I. AI PRISM (AI Powered human-centred Human Interactions for Smart Manufacturing);
II. CONVERGING (Social industrial collaborative environments integrating AI, Big Data and Robotics for Smart Manufacturing);
III. FLUENTLY (the essence of human-robot collaboration).

- **HORIZON-CL4-2021-TWIN-TRANSITION-01-07**: Artificial Intelligence for sustainable, agile manufacturing (AI, Data and Robotics - Made in Europe Partnerships) (IA). This topic focuses on manufacturing and process industries, addressing the entire lifecycle of products and services from design to remanufacturing and including all the aspects primarily relevant for industrial production. The objective is to exploit the potential of AI as a transformation tool to support circular production in the entire manufacturing and process industry, with due consideration for standardisation activities when relevant. AI will be a strategic instrument to improve sustainability, agility and resilience to external and internal influences, taking account of the European Green Deal objectives. In this topic, the following projects have been funded and will be soon contacted by CF2:
  I. AIDEAS (AI driven industrial Equipment product life cycle boosting Agility, sustainability and Resilience;
  II. Circular TwAIn (AI Platform for integrated Sustainable and Circular Manufacturing);
  III. S-X-AIPI (self-X Artificial Intelligence for European Process Industry digital transformation.

- **HORIZON-CL4-2022-TWIN-TRANSITION-01-06**: ICT Innovation for Manufacturing Sustainability in SMEs (I4MS2) (Made in Europe Partnership) (IA). ICT Innovation for Manufacturing SMEs (**I4MS**) aims to support manufacturing SMEs and mid-caps in adopting the latest innovative digital technologies for their business operations. I4MS2 builds on I4MS and addresses more significantly a **sustainable and resilient production**. The pandemic and economic crises demonstrated the key role of digital technologies in responding quickly to external changes. Digitalisation improves resilience, agility and competitiveness, and enables cost-efficient production in Europe. Priority should be given to technologies that can: i) Improve the sustainability of processes and products; significantly reduce or reuse waste and lower the energy and carbon footprint; ii) Make industrial processes more agile, secure and resilient to future changes; iii) Make manufacturing jobs more attractive for humans, whichever the age, gender or social and cultural background, through better human-machine interfaces and more intuitive interaction with digital tools. The following technology areas should be addressed in proposals:
  - **Artificial Intelligence applied to manufacturing**, with a specific focus of AI applications at the edge;
  - **Cybersecure Industrial Internet of Things** enabling trustworthy sharing of industrial data and value creation, to achieve further flexibility and agility of supply chains;
  - **Advanced interfaces and collaboration** within smart working environments such as collaborative robots.

  This topic is still in its Grant Preparation phase.

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

- **HORIZON-CL4-2022-TWIN-TRANSITION-01-07**: Digital tools to support the engineering of a **Circular Economy** (Made in Europe Partnership) (RIA). The focus is on developing new concepts, methods, and digital tools to support further engineering of the industrial processes for recycling, re-manufacturing, refurbishing, and reuse of manufactured products and components. New solutions will enable remanufacturing and high-quality recycling by digitalisation of product and component information throughout the whole product lifecycle, in line with the 2020 Circular Economy Action Plan. Proposals should cover all of the following aspects:
  - Development of innovative concepts, methods, and tools that track and trace the status of relevant manufactured products and components, such as electronic systems and components as well as machine tools, and increase transparency and accountability for these along their lifecycle;
  - Inclusion and handling of real-time production data in analysis software and tools, notably for decision making and control, as well as knowledge management;
  - Demonstration of the support tools in at least two different realistic production environments with a clear target of improving quality and sustainability with significant economic value. If applicable, legal obstacles to implementation of the proposed solutions should be identified.

  This topic is still in its Grant Preparation phase.

- **DIGITAL EUROPE 2.3.2.1 Testing and Experimentation Facility for Manufacturing**. The manufacturing TEF will provide physical and virtual access to real-life manufacturing resources that can be used for testing and experimenting with AI solutions. Examples of such manufacturing resources are **model factories** that combine different technologies such as additive manufacturing, machine tools, intelligent conveyor systems, automated warehousing, trusted and secured access to data, IoT infrastructure and more, covering multiple industrial processes. The manufacturing TEF will address the manufacturing sector's needs **for Industrial AI**, taking into account domain-specific requirements in terms of time criticality, safety, security and effective interaction and collaboration between robots, AI solutions, and humans who are in control, as well as resource efficiency and environmental performance. The TEF site will offer support and best practices in AI solution implementation, testing and training of algorithms including: full integration, industrial validation and demonstration up to pilot manufacturing in dedicated assembly lines and production cells. The TEF needs to support testing and experimentation of main AI-related services, which cover areas of machine learning, robotics, planning and scheduling, optimisation, self-configuration, computer vision, formal methods, natural language processing, automated reasoning, game theory, multi-agent systems, complex systems, system verification, bioinformatics and others. The TEF site will define and establish European test and training data sets in cooperation with manufacturing data spaces. The project is encouraged to collaborate with other relevant Digital Europe Programme projects, in particular the edge AI and other sectorial Testing and Experimentation Facilities, to ensure appropriate synergies.
  This topic is still in its Grant Preparation phase.

The **cross-fertilisation** between the CF2 DMP cluster and other HEP DEP relevant will be pursued also after the end of the CF2 CSA especially regarding the validation of CF2 Pathways, such as the AI4Man one. In this perspective, preliminary contacts have been already established with the coordinators of the winning projects, so that AI4Man validation can be performed in the as-is situation as soon as possible

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4 The CF2 "AI for Manufacturing" Pathway

The AI for Manufacturing pathway aims at developing a conceptual model and a series of tools, to position industrial cases in an evolutionary 5-levels framework related to the adoption of AI in Manufacturing industry critical business processes.

Owing to the exceptional variety of AI technologies and of application cases in manufacturing, we decided to consider industrial cases using some (combination) of the following main six technological enablers

i. **Machine Vision and Robotics**, very related to the Smart Autonomous Factory CF1 pathway
ii. **Embedded AI in Products** (Smart Products), very related to the Collaborative Product-Service CF1 pathway
iii. **Machine Learning and Knowledge Discovery**, very related to 5V Big Data repositories typical of the Hyperconnected Factories CF1 pathway
iv. **AI Forecasting and Prediction**, applicable to all CF1 pathways and related to the Foresee cluster of projects
v. **AI Diagnosis and Maintenance**, applicable to all CF1 pathways and related to the forZDM cluster of projects
vi. **Recommendation and Decision Support Systems**, applicable again to all CF1 pathways in the presence of Human users and related to the ICT-38 AI4Manufacturing cluster of projects

These enablers are not to be meant as horizontal rows of a matrix, but as inspiration examples on how AI can support manufacturing processes. Regarding the five levels of maturity, we decided to focus on one precise aspect of the adoption of AI in Manufacturing (focus on Smart Autonomous Factories of the Future): the level of autonomy in the Human-AI interaction. The reference model is the Level-0 Level-5 Model of Autonomy of the German Plattform 4.0 initiative, and in particular the so called MAL4 (Level 4), which is considering the most relevant challenges in the interaction between Humans and AI systems

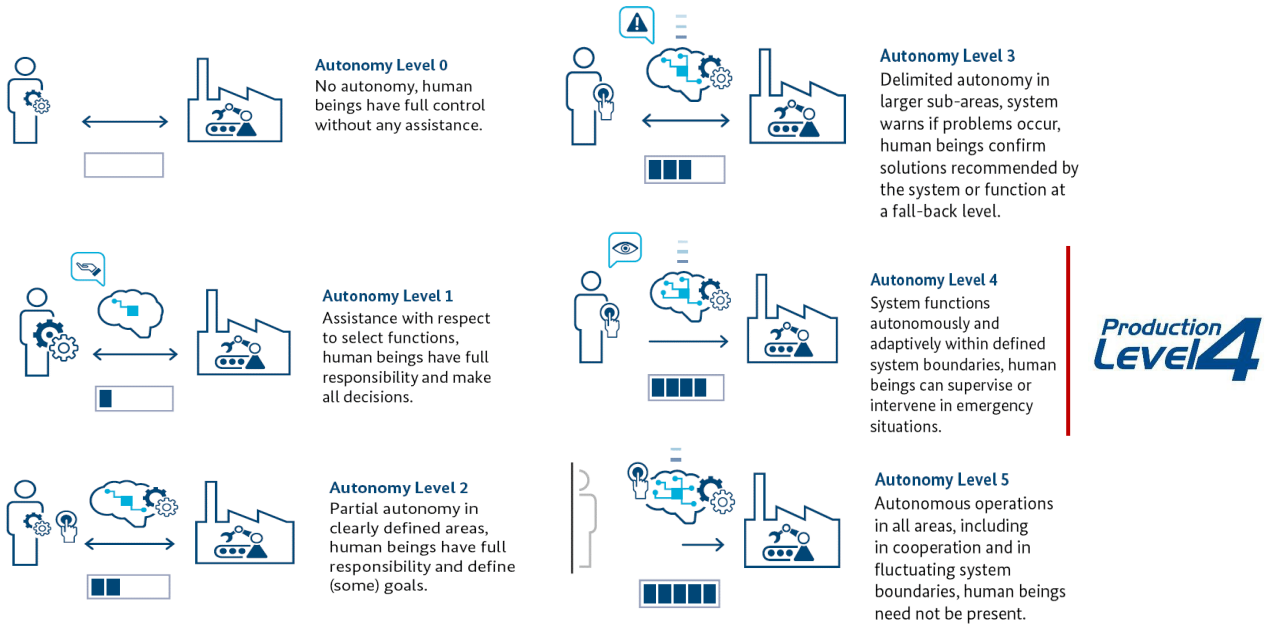


Figure 21 – Plattform 4.0 Manufacturing Autonomy Levels

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The analysis of maturity of an industrial case through the 5 levels of the pathway (§4.2) represent conceptually follows a more strategic analysis, where companies business processes are analysed from a comprehensive AI point of view (§4.1)

4.1 The AI for Manufacturing Maturity Model

POLIMI is developing a new AI maturity assessment model, mainly targeted at SMEs. The model aims to provide SMEs with a tool that, although synthetic, allows them to measure their level of AI maturity on a broad spectrum of business aspects, while offering insights and information to the SME on what AI is currently able to offer to improve processes and performance.
The development of this new model does not start from scratch, but aims to compare with two important reference areas:
- other assessment models (of digital maturity) already in use at POLIMI
- work carried out by other institutes on AI maturity assessment
Regarding the first aspect (models already in use at POLIMI), references are the **Dreamy** model, a digital maturity assessment model to generate awareness and guide manufacturing companies towards Industry 4.0 and the **Industria 4.0 Test**. The former is an in-depth assessment model, which analyses six business functions related to Industry 4.0, and is carried out on-premise; the latter is a faster assessment model, available online; it derives from Dreamy, but covers practically all business functions.
Our new AI maturity assessment tool takes the approach of **Test Industry 4.0** and is intended as an appendix to it; it will therefore have its same structure of questions and answers and will be filled-in online; it can be completed either as the last section of the Test I4.0 or independently from it; this will enable us to address the many SMEs that have already completed the Test I4.0 without their having to repeat it.
The second area of reference are the assessment tools that already exist in the European context; each of them has its own specificity (focus on technologies; quick assessment, etc.); our model wants to propose itself with its own original content and with a distinct approach from the others.
In particular, it is important for us to dwell on the usefulness that the model will have for the SME not only to measure its degree of maturity, but also for the informative function towards the SMEs in offering information and concrete solutions; in fact, SMEs are often caught up in day-to-day operations, and do not have the time to dwell on the study of the technologies offered by the AI market; our model wants to offer insights, in the form of AI solutions that are proposed inside the same questions and answers.
The model has a total of 30 questions (as there are already 128 questions in the Test I4.0, to which it is combined), divided as follows:

- AI Strategy, People and Organisation	6 questions
- AI Implementation	6 questions
- AI Data & Technology	4 questions
- AI Marketing & Sales	4 questions
- AI Products & Services	4 questions
- AI-supported Processes	6 questions

The questions are constructed for three different types of answers to give to the model the maximum effectiveness and flexibility.

- simple-answer questions: the first five sections contain almost all simple-answer questions, which contribute to the AI Maturity score; e.g:
  What role does AI play in your business strategy?

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1. We have no initiatives in AI.
2. We have initiatives to adopt AI in our processes, products and services.
3. Some of our processes, products and services are developed and managed in an AI vision, with quantifiable benefits.
4. The use of AI in process, product and service innovation is part of a strategic development vision and the results are monitored (at least partially) through dedicated KPIs.
5. We are leaders in some AI topics within our ecosystem.

- multiple-choice questions: they serve to provide information on the SME's context of operations:
  With which partners do you collaborate on AI issues? (multiple answers)
  - Technology providers and consulting companies
  - Universities and research institutes.
  - Institutional partners (DIH, Competence Centres, trade associations).
  - Partners in the production and distribution chain (supply chain).
  - Enterprise networks.

- questions with matrix answers: in the last section of the model (AI-supported Processes), answers cross some typical processes of the function examined (e.g. PRODUCTION MANAGEMENT) with AI technologies, suggesting possible solutions to the SME's issues; the scope of these answers is not exhaustive, but to "core drill" the SME's experience with AI, while offering useful suggestions

4.2 The five Maturity Levels of the Pathway

The following picture represents the model of the AI for Manufacturing pathway and its five levels

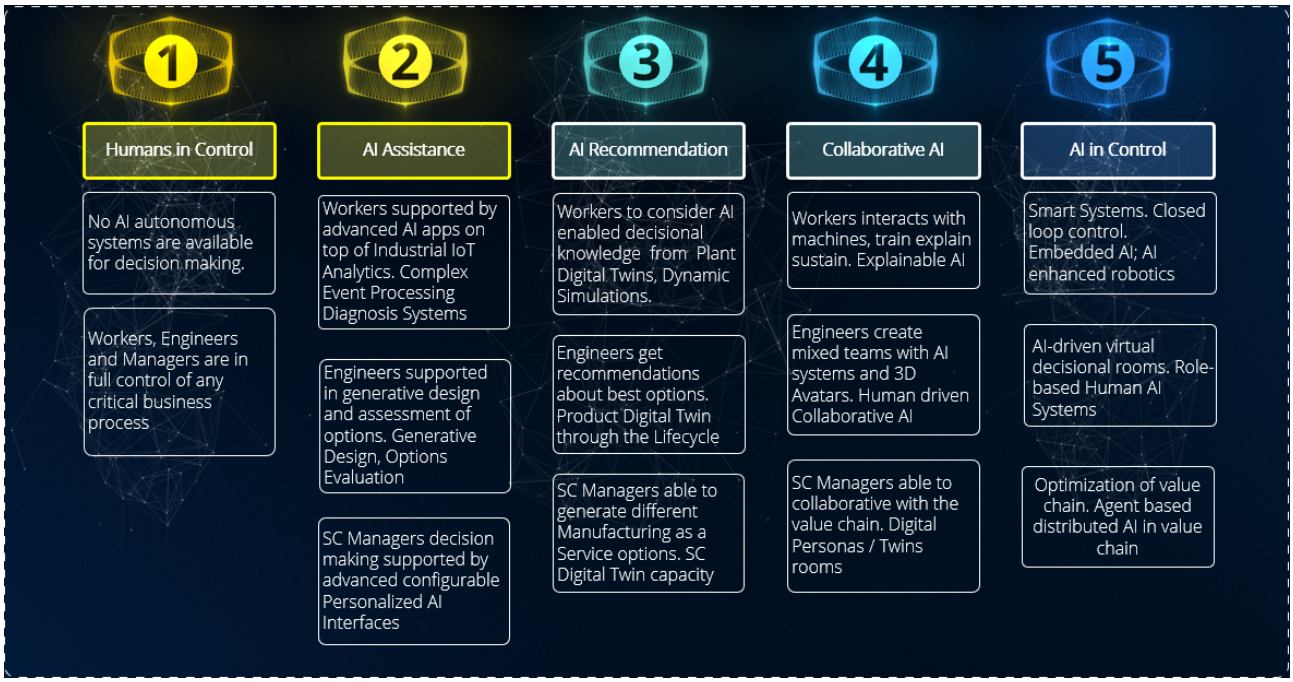


Figure 22 – The CF2 Ai for Manufacturing pathway and its five maturity levels

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Level_1. Humans in Control. AI systems (although sometimes present) do not influence the decisional processes which are firmly in the hands of the Humans.

Level_2. AI Assistance. AI is able to provide additional information to the user (e.g. hidden knowledge discovery, clustering of cases, anomaly detection), who is then taking his/her decisions in autonomy

Level_3. AI Recommendation. AI is able to suggest some decisional options, which are then assessed and evaluated by the Humans

Level_4. Collaborative AI. Virtuous mixed teams of Humans and AI systems are set up and decisions are taken in a collaborative way thanks to train-explain-sustain interactive patterns

Level_5. AI in Control. AI is taking decisions autonomously especially under real time constraints which do not allow a human intervention

4.3 Validation of the "AI for Manufacturing" CF2 Pathway in DMP Cluster

A first validation of the AI4Man pathway occurred inside the AIREGIO project and its 17 experiments grouped in 4 clusters. As you can see in the picture below, many of the experiments remain at the level 2 or 3 of the pathway and there is no specific focus on level 4.

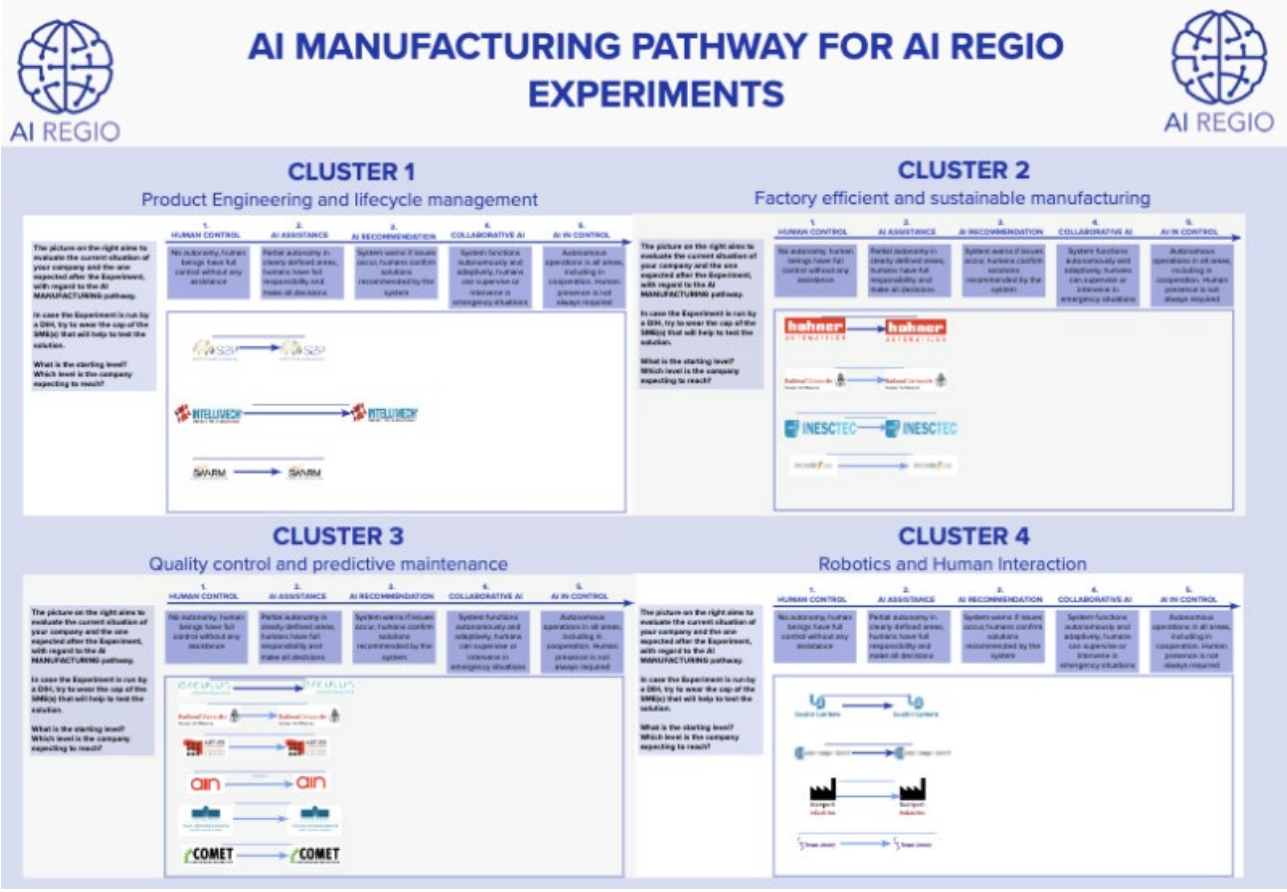


Figure 23 – Validation of CF2 AI for Manufacturing pathway in 17 AI REGIO SME-driven experiments

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On June 13th 2022, a physical validation workshop was held in Brussels before the EFFRA General Assembly, where projects' presentations took place and in the end a sli.do interactive session about the main enabling / preventing factors for the AI4Man transition levels have been discussed and agreed.



Projects' presentations have been held by representatives of the extended CF2 ecosystem (the DMP community. A detailed report of the discussion about future opportunities and challenges will be reported in **D3.5** Foresights and Recommendations of Digital Manufacturing Platforms for a Digital Europe), The following projects have been presented and discussed:

i. AI REGIO: positioning AI REGIO experiments in the AI for Manufacturing pathway - Sergio Gusmeroli, POLIMI e Fabiana Pirola, UNIBG;
ii. KYKLOS 4.0: using AI to leverage Circular Economy: The KYKLOS 4.0 Approach - Jason Mansell, Tecnalia
iii. SHERLOCK: AI seamless enabled Human-robot collaboration - Sotiris Makris, University of Patras –
iv. KITT4SME: making AI affordably usable for SMEs - Andrea Bettoni, SUPSI
v. TEAMING.AI: Dynamic knowledge graph approach for human-centred manufacturing in I5.0 - Mario Pichler, SCCH
vi. MAS4AI: optimization agents coordination in a bearing production line - Luis Usatorre, Tecnalia - MAS4AI: agents for planning activities in the bicycle industry - Kosmas Alexopoulos, University of Patras
vii. ASSISTANT: data-driven production management - Simon Thevenin, IMT-atlantique
viii. knowlEdge: understanding the AI roadmap in the knowledge project - Stefan Walter, VTT

The final sli.do interactive session was centred on the consideration of the obstacles and barriers preventing manufacturing companies (SMEs). Seven barriers (**a. Data Availability** (Quality, Synthetic Data, Data Space); **b. Skills and Competencies** (new roles, up- / re- skilling, DIHs); **c. Trust Building** (solution providers, solution users, DIHs); **d. Business Benefits** - Best practices, success stories and common agreed KPIs -; **e. Data Sharing** motivation and incentives; **f. Security and Confidentiality** (IPR protection, Data Sovereignty); **g. AI Solutions' Complexity** (costs, efforts)) have been proposed as possible answers to exemplify obstacles and barriers for the 4 transitions of the AI4Man pathway:

i. **Transition from level 1 to Level 2: how to persuade SMEs to use AI 4 Manufacturing Technologies**.

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Comments during discussion. Lack of comparison with other companies; Lack of trust; Dashboard can create first level trust; Extracting knowledge is the main challenge; you don't need specific AI skill at this level; Data availability is one of the main barriers from level 1 to superior; cost-benefit ratio; SMEs don't care about technology, about AI, just want a solution; we have to create trust first.

Sli.do votes. Two main barriers have been voted as most relevant in the transition from Level1 to Level2: the need to have evidence of best practices and success stories bringing agreed benefits from both the economic (efficiency, quality, optimisation) and the social viewpoint (wellbeing, green sustainability, circularity); the need to lower the entry barriers to AI in manufacturing, by providing affordable and easy-to-use solutions also by non-digital experts

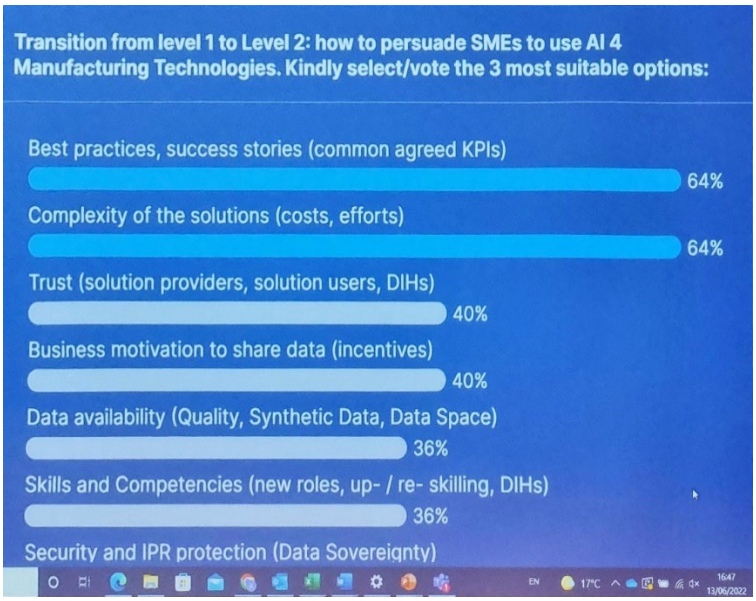


Figure 24 – CF2 workshop 13 June 2022: the barriers from level 1 to level 2 of the AI for Man pathway

ii. Transition from level 2 to level 3: how to persuade SMEs to take decisions taking into account recommendations from AI systems.

Comments during discussion. Level 3: recommendation given by the AI system but decision taken by the worker; Best practice in the sense showing what happens when the operator follows the recommendation provided by AI; Human fears to lose the power; Training to know how to clean data, how to interpret result (understand the recommendation); some AI are success stories others are not, because in some case you know where to start (e.g.: image recognition); Validation of the model

Sli.do votes. From level 2 to level 3, the “Skills and Competencies” barrier acquires more and more importance together with Best Practices and Complexity of the Solutions. The role of the human workers to at least understand what AI is doing comes into action here.

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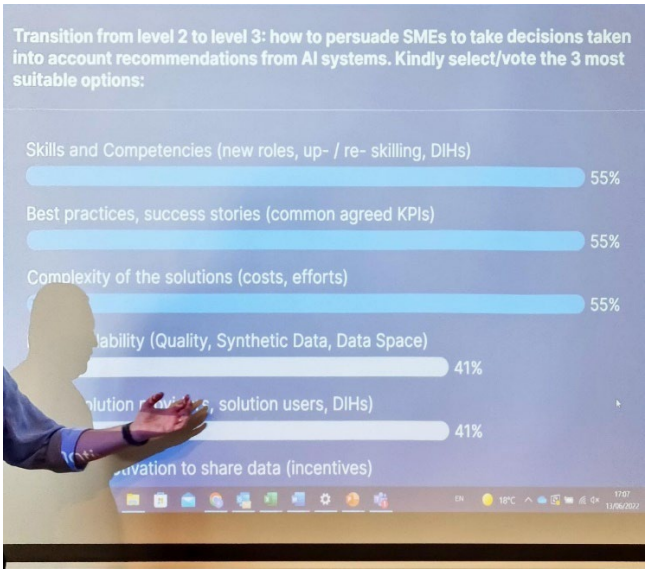


Figure 25 – CF2 workshop 13 June 2022: the barriers from level 2 to level 3 of the AI for Man pathway

iii. Transition from level 3 to level 4: how to persuade SMEs to establish collaboration interaction between humans and AI systems.

Comments during discussion. An SME is not going to hire an AI specialist, but reskill an employee; Changing the way solution providers operate and offer their solution, supplier should solve not only one problem, but address more problems; SMEs or Large Companies? SMEs are more agile - Large companies have data scientists, AI engineers; Centralized Solutions (better but hard to setup) vs Distributed Solutions (easier to setup but with limits of data volume and significancy); organizational transition. Solution are complex and costly, but the problem is demonstrate the impact. If the impact is demonstrated, the cost doesn't matter --> TRUST. In most of companies, data scientist just performs statistical analysis --> no AI.

Sli.do votes. When human workers need to constantly interact with AI, the Complexity of the solutions seems to be the most relevant barrier as well as the AI literacy of the workers.

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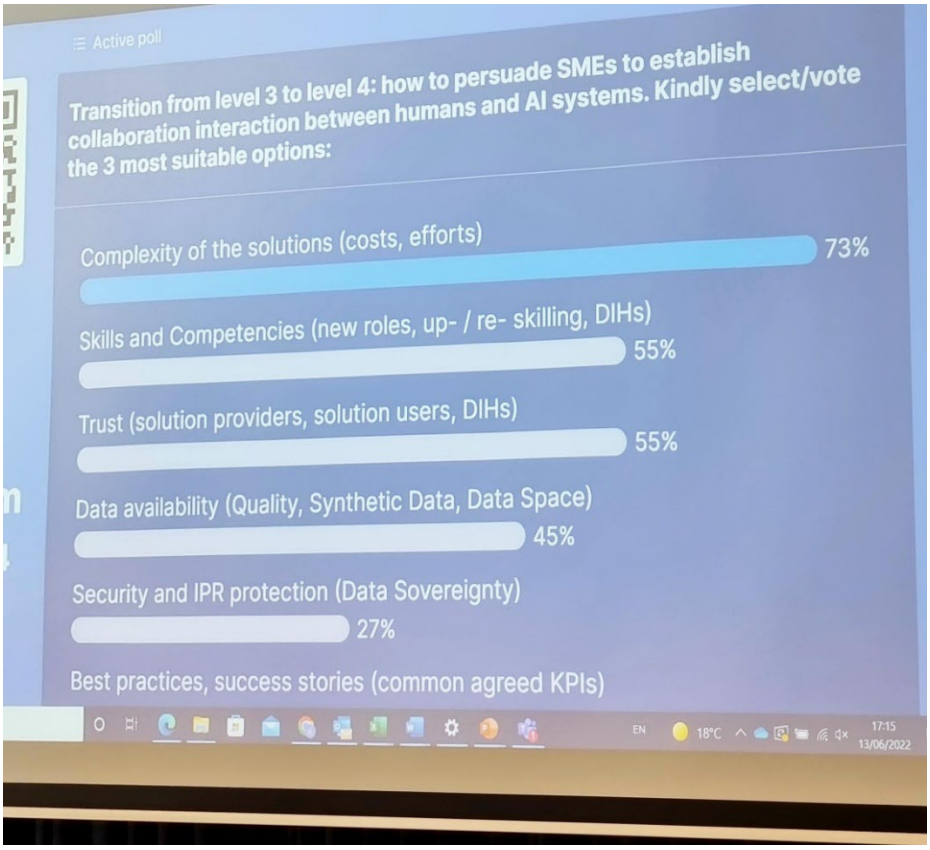


Figure 26 – CF2 workshop 13 June 2022: the barriers from level 3 to level 4 of the AI for Man pathway

iv. Transition from level 4 to level 5: how to persuade SMEs to fully trust AI decisions.

Comments during discussion. Trust depends on application area and manufacturing sector. AI autonomy if it is demonstrated that is better (e.g. sorting system fully automated is ok if it is proven that it is better than manual work); Responsibility-Liability, who is going to be responsible in case of problem? Solution must comply with regulation and safety; We have to separate AI from data spaces.

Sli.do votes. At this transition, TRUST (and SECURITY) barriers appear as the most voted and considered. This refers not just to technological solutions (cybersecurity, blockchain) bit mostly to organisational ones, i.e. the need to setup industrial agreements in the value chain on how to automate processes and conveniently trust the decisions taken by AI systems

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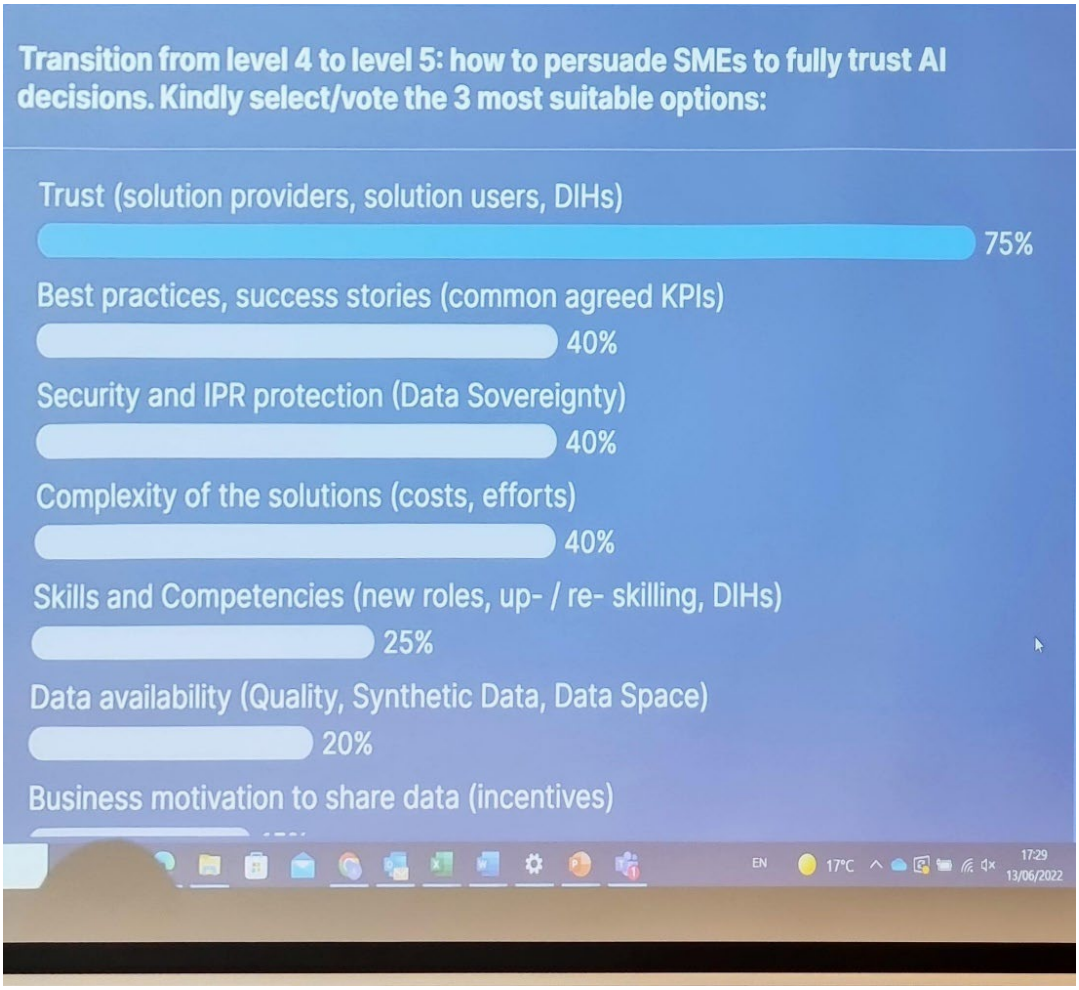


Figure 27 – CF2 workshop 13 June 2022: the barriers from level 4 to level 5 of the AI for Man pathway

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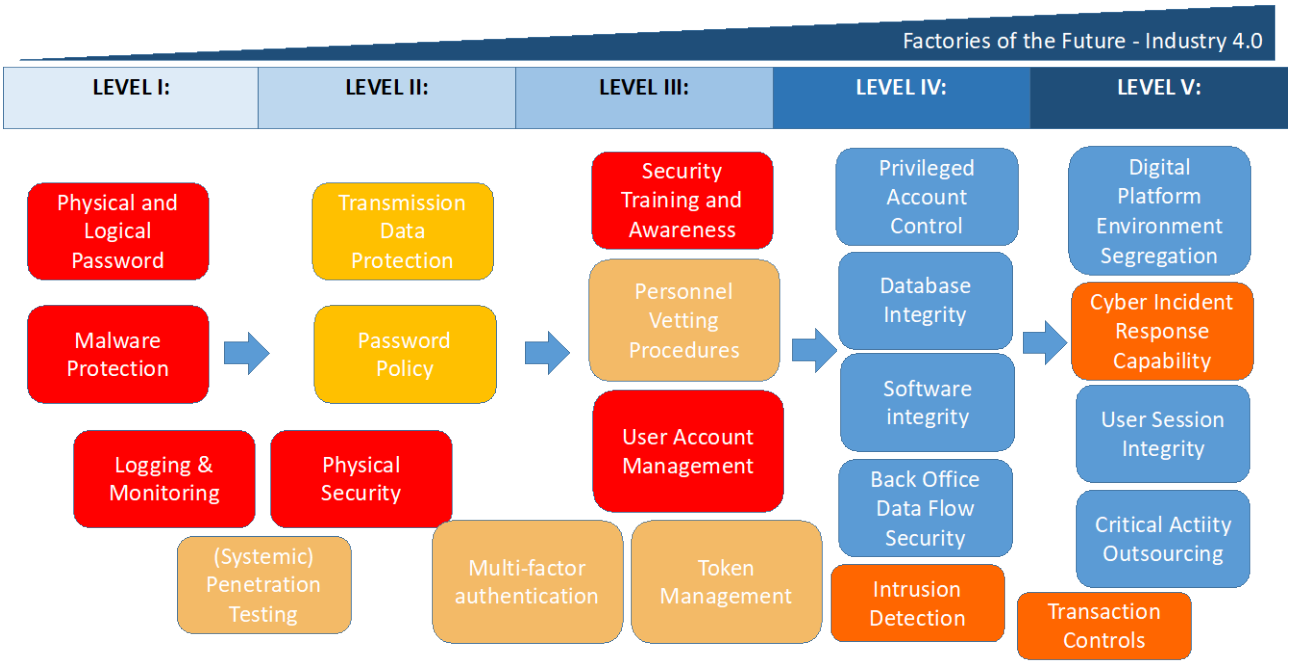
5 The CF2 "Cyber Security" Pathway

The Cyber Security Pathway was introduced during the Connected Factories project in 2018 and subsequently finalized in a first version in 2020, following the observation that similar to digitalization technologies, manufacturing companies and Digital Manufacturing Platforms were struggling to get a grip on the variety and complexity of challenges related to CyberSecurity they are being faced with. CyberSecurity was, and still is today, one of the main drivers for companies struggling to transform digitally. In addition, challenges related to the existing manufacturing environment of non-automated and automated equipment, also defined as manufacturing "legacy systems" and the fact that many of these Operational Technologies (OT) were not designed even considering CyberSecurity or even Security for that matter; raised the necessity to facilitate more attention and focus on the topic. The Digital Manufacturing Glossary

5.1 CyberSecurity Pathway in Connected Factories

The first CyberSecurity Pathway was developed with a perspective of manufacturing companies and developers of digital manufacturing platforms with different sets of skills, competences, technical capabilities – overall an appreciation of the level of maturity.

Without the intention to categorise or to classify any specific platform, system or company, the intention was to support entities to ensure they can try to meet a number of basic cybersecurity capabilities. Instead of trying to achieve a maximum from the start, which without a reasonable risk and cyber-risk assessment, would not be highly effective, the components indicate some fundamental cyber hygiene. The pathway doesn't even consider whether systems are fully connected, or what level of complexity they are executing.



The pathway was derived out of different interviews and workshop with multiple manufacturing companies and platform developers, both from industry and research (the FOF-11-projects) and resulted in a structured guidance of a series of components that classify the necessity of CyberSecurity mechanisms to put in place. As it is a Pathway - a guided lightning path - it refrains from being patronizing and instructive, rather than encouraging and stimulating. Even with the different colors, indicating the absolute necessities to be put in

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place (on the far left) such as physical and logical password / access and the logging and monitoring as basic fundamentals that will return with either environment where it is finally being put into operation.

While it is built upon existing standards such as ISO27k, IEC62443 and different other de-facto and industry cybersecurity standards and regulatory requirements for CyberSecurity in manufacturing and industrial environments, it is not intended to be a complicated approach but rather a simplified technological perspective of requirements. Finally, the CyberSecurity Pathway provides guidance on further improvements and next steps; on which the Connected Factories 2 Pathway was built.

For a better understanding of all of the components related to the CyberSecurity Pathway[28] elements, we refer to the Structured Wiki on the EFFRA portal[29] that describes all of the individual elements of the Pathway and adds references and suggestions of technology components (example: CSIRT.- incident response capability[30]) that can serve as tooling to establish the Pathways.

The Connected Factories 2 CyberSecurity Pathway builds on top of these, and still expects manufacturing companies large and small, Digital Manufacturing Platform developers from research up to integration to keep levels I to V of the CyberSecurity Pathway as the key instrumentation for the continuation of levels VI up to level XX (see further).

This approach allows to continue to adopt the CyberSecurity Pathway following additional evolutions driven by the market (need for highly integrated manufacturing), by technology (the use of virtualization on the shopfloor, or the use of the cloud as manufacturing execution system) or by CyberSecurity challenges (disruptions caused by ransomware/malware; industrial espionage by leveraging privileged accounts, …).

In the following paragraphs the continuation of the CyberSecurity Pathway is being described.

[28] https://portal.effra.eu/wiki/taxonomy-list-taxon/2132
[29] https://portal.effra.eu/home
[30] https://portal.effra.eu/wiki/taxonomy-list-taxon/1113

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5.2 CyberSecurity Pathway II: additional collections of guiding lights

The CyberSecurity Pathway II is providing a holistic approach, solutions oriented and non-exhaustive collection of different approaches as CyberSecurity to the further maturing manufacturing environment or Digital Manufacturing Platform.

Similar to the first Pathway approach, the guiding lights have been indicated with different colors indicating

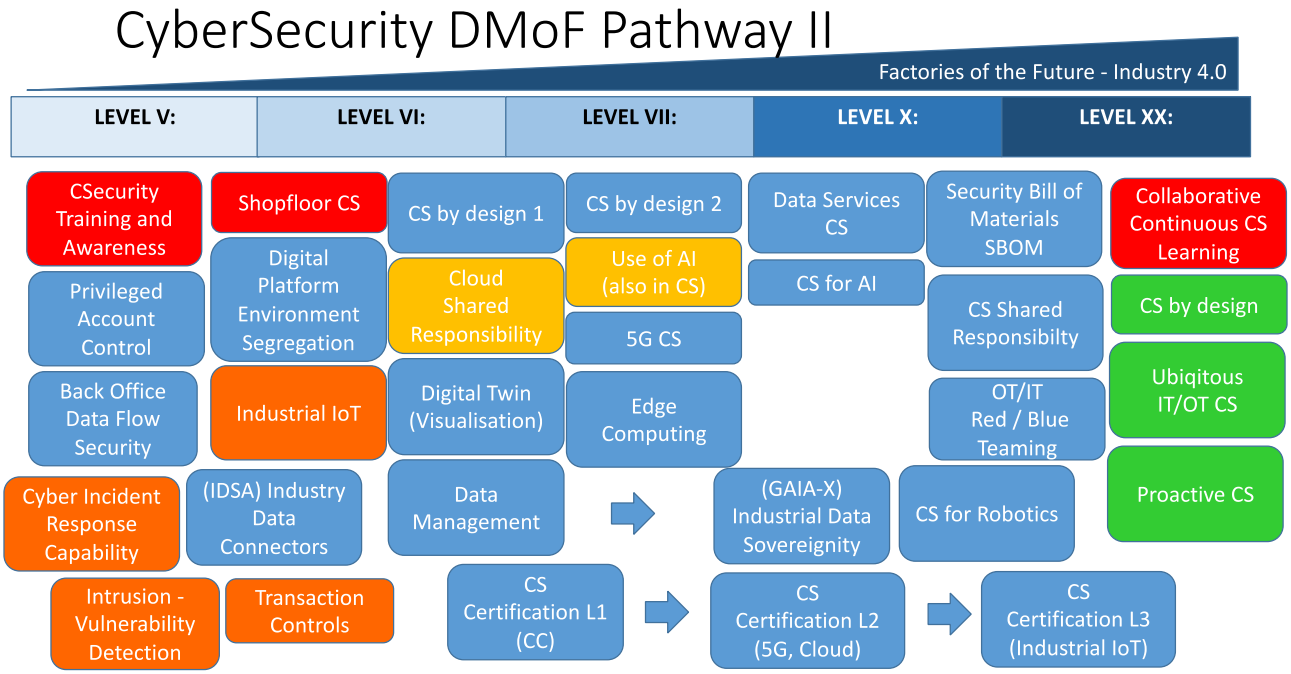


Figure 28 : CyberSecurity Pathway in CF2, evolving on the basis of external societal and technological factors and increasing CyberSecurity challenges

the necessity of manufacturing companies of Digital Manufacturing Platforms to consider adding CyberSecurity capabilities as listed in red colors.

CyberSecurity (CSecurity) Training and Awareness is continuously identified within all different projects as a requirement for CyberSecurity throughout any stage and lifetime of a manufacturing company or platform, without therefore always specifying what type of training or awareness that would entail. In a level V maturity, training and awareness creation would need to be provided alongside all additional technological improvements within the platform where an operator or a user of a platform should consider his actions or actions resulting from the platform that could have an adverse effect on the operation. Employees and contractors should be made aware regularly about CyberSecurity allowing them to detect and pre-empt a CyberSecurity incident from happening. They should be capable of raising incidents and take precautionary actions or coordinated actions together with the CyberSecurity incident management teams.

Shopfloor CS indicates the requirement of operators working with Digital Manufacturing platforms to be able to manage and maintain CyberSecurity on the production floor, ensuring all consoles and workstations have been properly Cybersecured and equipped with up-to-date end point protection and access control measures.

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Collaborative Continuous CS learning indicates the need for all employees and contractors to receive regular and periodical additional insights, that can cause a behavioural cybersecurity responsibility that can quickly respond to suspicious activities and take the necessary actions if needed.

Level V type of maturity level considers for instance a digital Supply Chain integration such as amplified in the HyperConnected factories[31] approaches. It identifies challenges related to backoffice integration and suggests the use of data flow security (or the concept of using enhanced security measures such as provided by the International Data Spaces Association – and considered by a number of projects). It also considers the use of privileged access management, not so much ensuring the access by privileged users – rather than focusing on managing the access and enhancing the focus on visibility of activities by monitoring of data transmissions and activities on systems as a basic instrument for further detection and analysis.

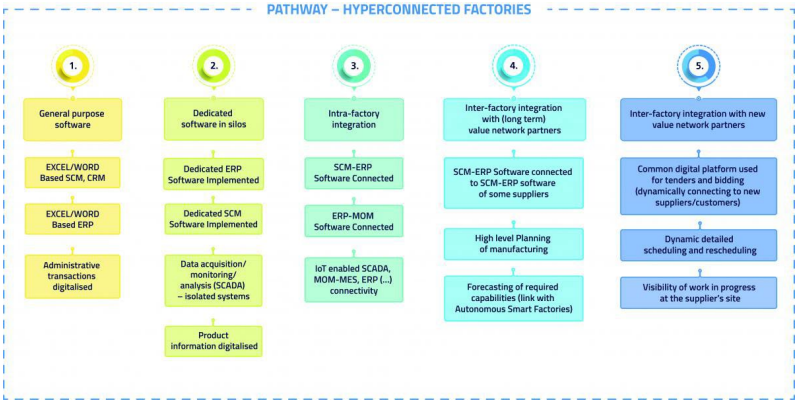


Figure 29 : CF1 Pathway Hyperconnected Factories. The CyberSecurity Pathway 2 considers its requirements from Level V and up.

The orange colors indicate identified higher needs for manufacturing companies and related, or digital manufacturing platforms that should either facilitate this in their own environment or provide connectors and capabilities to ensure for instance Intrusion Vulnerability detection. By knowing potential risks identified within the Digital Manufacturing Platforms themselves (by indicating used Open Source components and their related identified Vulnerabilities – CVEs or others) transparency allows for a better understanding of potential risks, and allows for management of them. Cyber Incident Response Capability requires to be able to deal with identified vulnerabilities or incidents that can happen. Developing for instance CSIRT-capabilities through training, hiring but equally working with external managed security services providers that can provide capabilities to respond to them. In some instances – for instance under regulatory frameworks such as the NIS2 – directive, these capabilities will be legally required over time.

Indicators in yellow are CyberSecurity risks that require continuous attention. By means of policies and working closely with development and architecture teams, a continued perspective on clear and present risks of utilizing technologies such as AI and cloud should be maintained. Not all Digital Manufacturing Platforms will be needing cloud-based instances, but if they do specific CyberSecurity measures should be setup. For cloud, a shared responsibility model indicating CyberSecurity measures depending on the use of infrastructure as a service (IaaS) up to Software as a Services (SaaS) should be investigated, monitored and managed properly. Some Digital Manufacturing Platforms are considering the use of the cloud for data storage and in depth data analytics and should provide transparency in the transactional data. Some research projects are considering the use of Secure Multiparty computation (SMPC) or digital ledgers to control transactional data, such as the COLLABS-project[32].

[31] See Connected Factories Pathways Hyperconnected & Autonomous Factories on the EFFRA-portal.
[32] https://www.collabs-project.eu/

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Additional maturity levels (level VI through X) are an indication of incremental complexities of systems and use of digital technologies within the manufacturing environment. By adding technologies for Digital Manufacturing (also in the platform) such as 5G, Digital Twins, Edge Computing, … add additional layers of CyberSecurity challenges – and opportunities. 5G CyberSecurity for instance offers in principle a higher level of CyberSecurity measures than its 4G or wireless predecessors (wifi, NBIoT, Lora, …), but needs to be investigated and documented properly. Many of the CyberSecurity functionalities of 5G will not be offered automatically and standard by all 5G technology and services providers (such as slicing & dicing of data traffic on the public 5G network, allowing for segmentation of specific industrial data).

Indicators in blue are therefore components that can drive attention to these new technologies and the fact that for many of them specific CyberSecurity considerations and best practices or even standards and de-facto standards are being developed, on which CyberSecurity teams of manufacturing companies and research and development teams of Digital Manufacturing Platforms can rely and build upon. CyberSecurity by Design for instance is a practice that both System Integrators and manufacturers could also consider when implementing their next Digital Manufacturing Platforms. The by design approach enforces the use of security measures in an agile development process, in such a way that it has to be specifically chosen why NOT to consider CyberSecurity measures upfront rather than forgetting about them from the beginning, resulting fundamental flaws later on in the process.

Therefore, the green indicators are a way of determining readiness for the future; by applying a continuous by design or Proactive CyberSecurity approach; this will better prevent up and coming external and internal threats and challenges.



Figure 30 : ubiquitous, proactive and continuous CyberSecurity approach

The CyberSecurity Pathway 2 does not specifically mention the widely acclaimed and hyped Zero Trust-model[33] which has been conceived as a way of thinking many years ago and has received more interest lately more than a fundamental principle, by having a number of technologies trying to provide mechanisms and tooling to support the principle. In our consideration, there will always be a level of trust between supplier and users, and especially manufacturing companies that have a history of fundamentally relying on their technology providers, or even handing out the management of their manufacturing platforms for decades through services contract to their suppliers will require more to shift the trust paradigm.

5.3 External Developments impacting CyberSecurity Pathway

In ConnectedFactories2 new market developments such as the ones described as pathways in this document (Artificial Intelligence and Data Services), but also new approaches such as the increased virtualization in operations (augmented reality, virtual reality, digital twins), the use of data for production impacting data integrity and the increased regulatory framework for manufacturers (sovereignty and cyber resilience). There is a continuous impact of changes happening in society on CyberSecurity and have to be considered more than any other technological evolution, because of their external origins.

[33] https://www.ncsc.gov.uk/collection/zero-trust-architecture

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Some of these developments and CyberSecurity approaches have been documented in the Connected Factories portal and will continue to be added as illustration of a number of both societal, technological and CyberSecurity-related developments taking place.

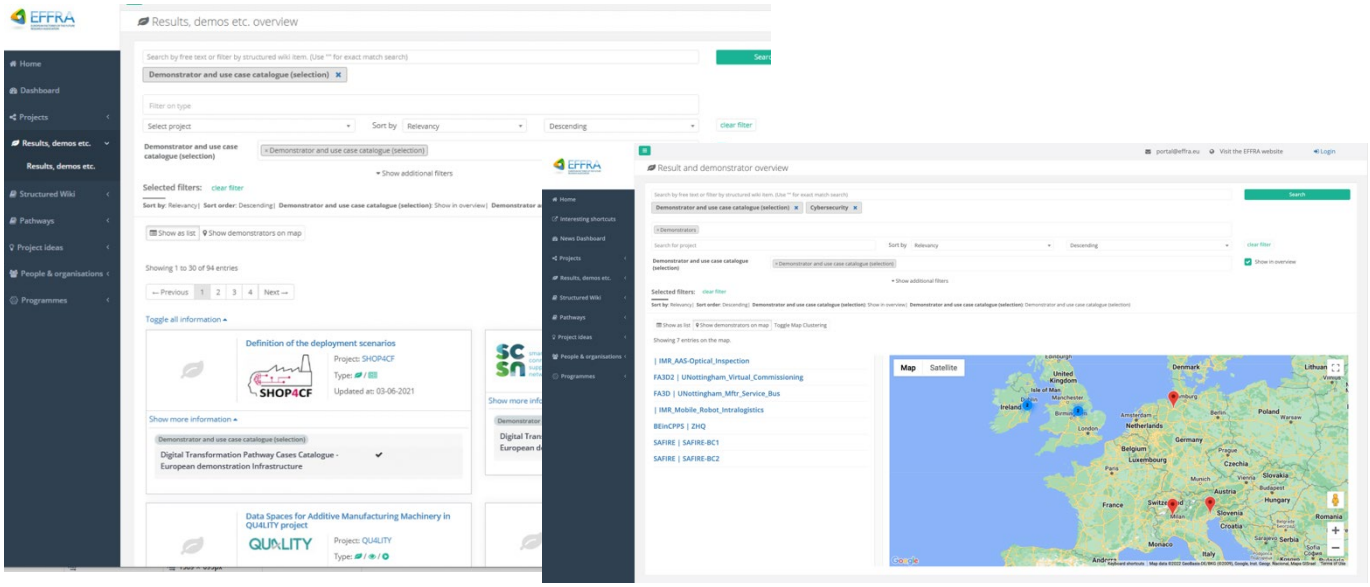


Figure 31 : examples of the CyberSecurity pathway in evolution in DMPs on the CF2 portal

5.3.1 Societal challenges and developments impacting the CyberSecurity pathway

Over the last decade the continuous developments of **digitalization** are transforming a**ll different vertical sectors, not only manufacturing**. Manufacturing companies and digital manufacturing platforms have to consider working with digitalized systems for procurement, transport and logistics, payments and support services. All digitalization services require intensive exchange of data and providing electronic privileges to both systems and persons. Based on the digitalization efforts are the continuous evolution of industrial automation (Industry 4.0), technological capabilities coming from sensors and data processing, increases in efficiency, energy savings, capabilities allowing lot size one and customized production, …



While these are obviously also fundamental drivers for Digital Manufacturing Platforms, other societal challenges in relation to **climate change, the global pandemic, and international crises** such as the Ukraine war have an impact on the global supply chain. They are factors stimulating international policies and considerations such as European sovereignty and the challenge related to import and export restrictions, or requirements for CyberSecurity baselines for trustworthy products and services.

Manufacturing companies relying on Digital Manufacturing and Digital Manufacturing Platforms more than other manufacturing companies will be increasingly dependent from the **reliability and reliance of their systems and resilience**. Companies which are exposed to the outside world, with an industry (such as healthcare) or part of the world or country becoming the target or object of dispute can receive more disruptions because of targeted attacks. Some of these attacks will be aimed at disrupting society, the

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economic system or important supply chains, which in the end will have an impact on manufacturing companies. In recent years we have seen car manufacturers and electronics manufacturers that needed to slow down or even stop production due to major CyberSecurity incidents in the supply chain. These types of incidents are expected to increase further in volume and versatility.

CyberSecurity measures will have to be adopted, providing for instance further resilience capabilities, independencies from supply chains, focus on supply chain attacks, business continuity, capability of remote operations, …

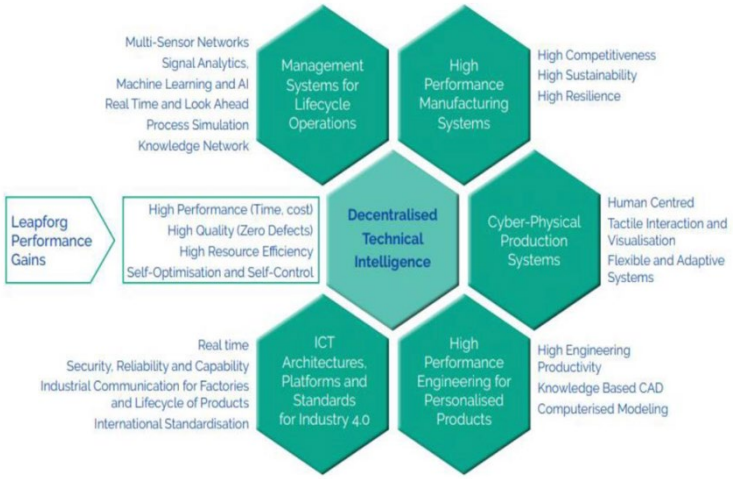


Figure 32 : source : Eclipse/ArrowHead, NISTIR, 2022; how digital manufacturing is evolving due to multiple integrated systems, and becoming dependent on external systems

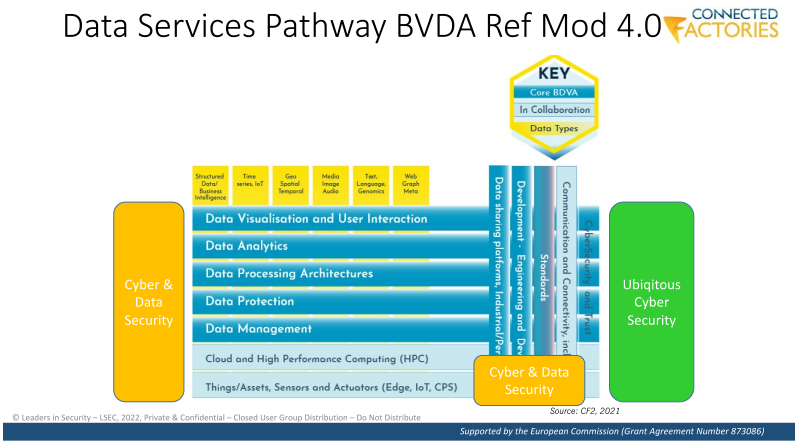
5.3.2 Technological developments

Societal developments obviously result in technological developments, but technology is also developing by itself driven through innovation, incremental and revolutionary advancements. Some of these domains such as AI, cloud, virtualization impact requirements for CyberSecurity.

5.3.2.1 Increased CyberSecurity requirements coming from the use of data

The increased use of digital sensors and data capturing capabilities in Digital Manufacturing Platform allows for new and interesting opportunities for manufacturing companies, but equally provides many additional challenges in relation to CyberSecurity.

Challenges are related to getting access to data, with basic or enhanced privileges, without the necessary authorizations. With data, **data services** are being setup quite easily providing automated access through webservices or API's into data sources. Many of those remain unprotected. And even while they are read-only; they could result in data loss, industrial espionage or manipulation of data before they will be (automatically) interpreted by another entity. Some data could be considered to be personal data, which will require additional levels of data protection efforts. Industrial data could be shared and even served as a new means of valuable service or good, resulting in the needs for higher reliability. Data needs to be protected from potential adversary attacks causing an impact on data integrity – which could have an adverse effect on the produced goods and services.



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During the CyberSecurity for Manufacturing conferences and in preparation of the new Digital Manufacturing Pathways, the Big Data Value Reference Model[34] was considered as a model where CyberSecurity was identified with a need for ubiquitous CyberSecurity, basically identifying the need for CyberSecurity on all respective levels of data handling (from visualisation to data management).

5.3.2.2 Increased CyberSecurity requirements coming from the use of AI

The use of **analytics** in Digital Manufacturing Platforms is just a next step, from the use of data and production of data. But in the case of **Machine Learning**, or advanced analytics, also the data- and analytics-models or AI mechanisms need to get some additional attention. During the early stages of CyberSecurity investigations into the impact of AI for CF2 challenges related to adversarial attacks, integrity and reliability were identified, which need additional attention from CyberSecurity. While still in their infancy, it has already become clear that adversarial attacks are focusing on for instance flooding data into the platform, causing the Machine Learning capabilities to interpret data wrongfully. Other identified attacks could harm the overall operation such as with Denial of Service.

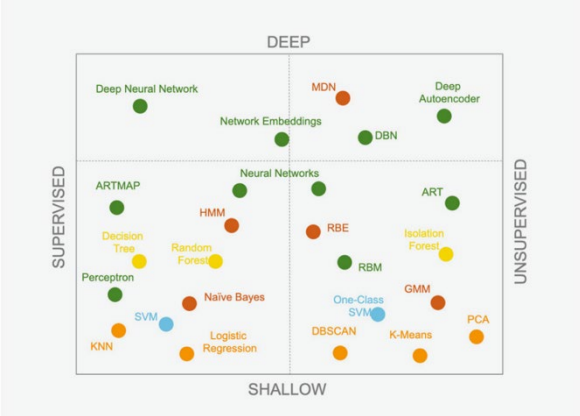


Figure 33 : different AI techniques and their relative reliabilities, focus areas for adversarial attacks (source : VectraAI, 2022)

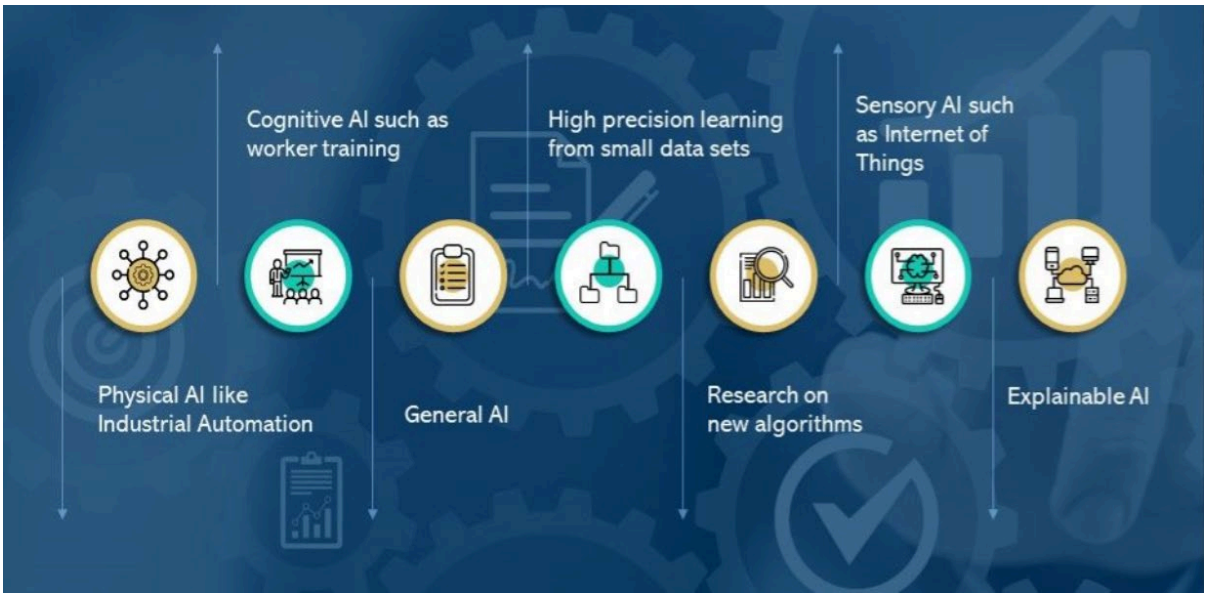


Figure 34 : AI is becoming ubiqiutous in Digital Manufacturing, thus increased attention needs to be paid to its CyberSecurity (source : IBM, 2022)

Many examples have been presented whereby the interpretation of the analytics model delivered unreliable results (for instance during visual inspections), causing failure of recognizing defects and raising quality issues. While **AI** is being integrated in many different aspects of Digital Manufacturing, the potential impact

[34] https://elements-of-big-data-value.eu/big-data-value-reference-model/

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of these systems on the production system and the manufacturing companies is equally increasing, and thus the risk it causes to the enterprise is widening.

5.3.2.3 Increased CyberSecurity requirements coming from the use of Sensors - IoT

IoT, IIoT (Industrial Internet of Things) and ICS (Industrial Control Systems) have proven to be a major disruptor even for the internet at large. Devices are being equipped with connectivity and internet capabilities, without carefully considering CyberSecurity measures. Industrial Control Systems, or operational devices became publicly accessible for anyone with malicious or even non-malicious intentions. Accidents happened whereby the control of hundreds of thousands of devices had been claimed, causing massive botnets[35] that started flooding the internet. Less impactful, but equally damaging the manufacturing operations, were incidents that were intended to eavesdrop into production and data collection. Most commonly, compromised devices are being used to serve as a host into other systems, but production and information systems to get access to valuable data sources that can be used for exploitation and exfiltration.

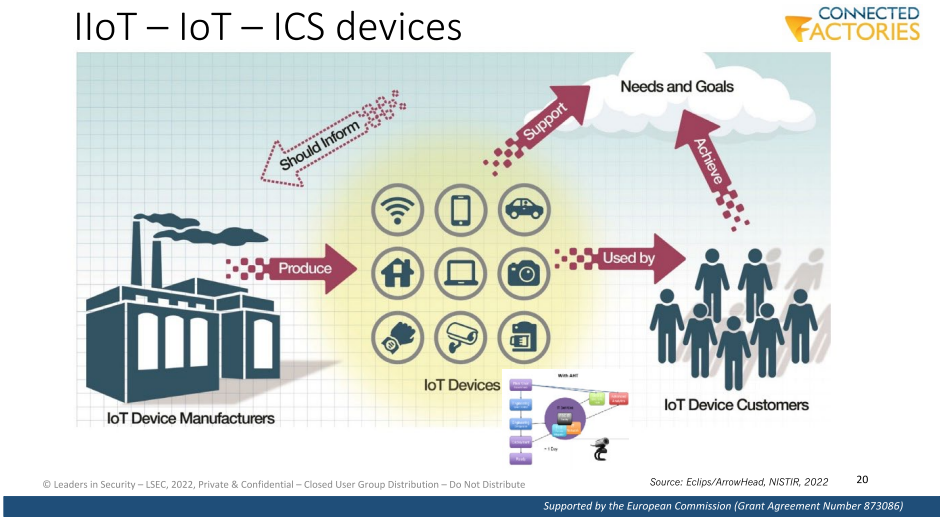


Figure 35: IoT in manufacturing and by manufacturers; consumers and producers of electronic equipment where CyberSecurity measures should be imminent.

For digital manufacturing it should be considered that manufacturing companies can be both consumers as well as producers of these devices. I(I)oT device manufacturers should be building in CyberSecurity measures into their products and solutions. For manufacturing companies to use electronic devices, they need to consider during procurement and throughout the lifetime of the devices maintaining regular CyberSecurity updates and CyberSecurity hardening. IoT devices are being used - not only in the manufacturing process, but equally to supervise, control and analyse the production - as they are being used for logistical purposes and to optimize the production process itself.

5.4 CyberSecurity Pathway II: built for future needs

The current CyberSecurity Pathway II has been developed with a **continuous maturity improvement** in mind, allowing to further progress in time and based upon technical advancements, without judgement over one or the other maturity level; but built to last and ensure previous steps were not forgotten. The model is there to support CyberSecurity improvement, even for manufacturing companies starting with their first Digital Manufacturing platforms. This allows it to last with additional challenges and opportunities being added to the model, and related CyberSecurity measures to be added.

[35] https://www.avast.com/c-mirai

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The model is **not** intended to be **exhaustive**, nor to provide a full perspective on all CyberSecurity approaches and devices large and small - but rather to allow to match them to identified needs today and in the future. The model is built with **both evolving regulatory and standardization requirements in mind** and should allow for further research and identifying gaps and identifying approaches to complete the gaps.

A **systematic approach of CyberSecurity** from the **design phase** (shift left), will allow identifying gaps and matching solutions early on, where the CyberSecurity Pathway II facilitates the process.

The CyberSecurity Pathway II considers a **Shared Responsibility Model**, where **AI** and **cloud** or derivatives are omnipresent. It recognizes the **value of Data**, being everywhere. These measures require ubiquitous, but also maximally automated CyberSecurity mechanism that continue using and allow for evolving CS standards

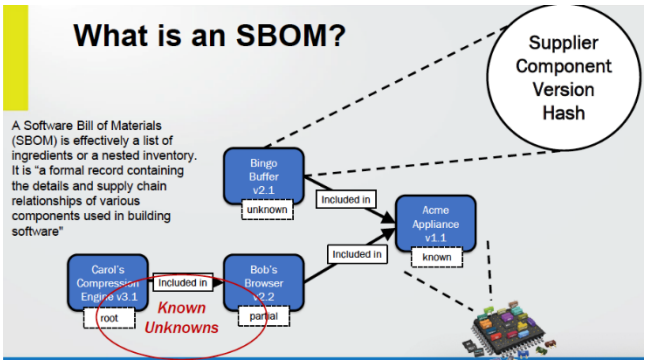
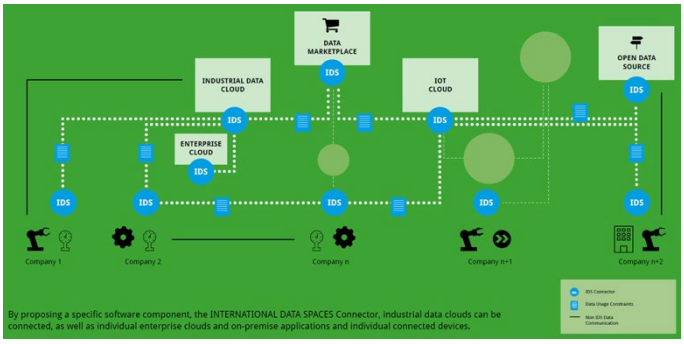


Figure 36 : SBOM - Software Bill of Materials - collecting and documenting the components of software and security elements

Additional requirements on the usage of any external system brings along the need for properly documenting and recording development decisions, component descriptions and mainly paths to vulnerabilities. In **SBOMs** (software bill of materials) governments require basic bill of material requirements. Manufacturers of ICT-technologies and Digital Manufacturing Platforms can consider documenting in transparency all different software components they rely upon and documenting this for their customers. This intelligence can be used by the CyberSecurity product managers in case of the vendors or system integrator. By the security operations and incident teams it will be used to better map potential vulnerabilities from the outside to the internal systems and avoid potential flaws such as the Log4J to the maximum. For privacy and security purposes manufacturing companies should consider the use of cryptographic mechanisms for data sharing and information system measures. Technologies such as Digital Ledgers or Secure Multiparty Computation allow for intense, but better secured data exchanges, while respecting personal data protection requirements- or individual data sets. For production companies and Digital Manufacturing Platform provider this data could become expoitable, supporting the idea to find means to exchange data and provide secured data sharing capabilities. Data marketplaces or reversely providing Open Data Sources require adopted levels of CyberSecurity.



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6 Conclusions and Future Outlook

D2.6 is focussing on AI and Cybersecurity digital technologies adoption by manufacturing industries. Two new CF2 pathways have therefore been developed and validated with the projects belonging to the DMP cluster and beyond.

Regarding AI, the five levels of the pathway have been put in relations with seven obstacles / barriers which currently prevent the adoption of AI solutions in Manufacturing (SMEs). **LACK of EVIDENCE** of BUSINESS BENEFITS is the main obstacle for the first levels of the pathway, when companies have to be convinced about the economic impact of AI solutions. **SKILLS and COMPETENCIES** come immediately after when companies need to develop their own AI literacy (independent or externalised to e.g. DIHs). **TRUST and SECURITY** have been proved to be the main barrier along the most mature levels of the pathway, when important and critical data and document need to be exchanged in the value chain. Reducing the **COMPLEXITY** of the AI solutions and improving the train-explain-sustain interaction cycle between humans and AI is the most fundamental barrier to be removed and it is valid for all the levels of the pathway.

Regarding Cybersecurity the maturity levels of the first CyberSecurity Pathway have been adopted to new societal and technological challenges impacting CyberSecurity needs for Digital Manufacturing Platforms. The components of the Pathway are not exhaustive and provide a holistic guidance to companies transforming towards Digital Manufacturing. It includes guidance for challenges related to AI and Data Value models, and provides additional hardening measures that allow to overcome the challenge related to the TRUST and SECURITY barriers. The model has been validated in a series of workshops, and with existing and developing regulatory and standardization frameworks.

The outcomes of the CF2 Digital Pathways have been particularly useful for the implementation of Horizon Europe Destination 1 topics and in particular for the 2021 **TWIN-TR-01-07: Artificial Intelligence for sustainable, agile manufacturing** and the **TWIN-TR-01-08: Data-driven Distributed Industrial Environments**, where maturity levels could be used for a personalised adoption strategy of both Data, Cybersecurity and AI digital technologies. Projects awarded under these topics (**AIDEAS** AI Driven industrial Equipment product life cycle boosting Agility, Sustainability and resilience; **Circular TwAIn** AI Platform for Integrated Sustainable and Circular Manufacturing; **s-X-AIPI** self-X Artificial Intelligence for European Process Industry digital transformation in **01 07**) (**5G-TIMBER** Secure 5G-Enabled Twin Transition for Europe's TIMBER Industry Sector; **RE4DY** European Data as a PRoduct Value Ecosystems for Resilient Factory 4.0 Product and ProDuction ContinuitY and Sustainability; **Zero-SWARM** Zero-enabling smart networked control framework for agile Cyber Physical Production Systems of Systems in **01 08**) are going to start in Summer-Fall 2022 and have already been contacted as further validation points of the Digital Technologies pathways of AI and Cybersecurity.

Next Digital Technologies to be included in possible pathways are in our opinion **Digital Twins and HPC/cloud** (edge-to-cloud continuum), which have been subject of many topics in the HEP 2022 work programme (**TWIN-TRANSITION-01-06: ICT Innovation for Manufacturing Sustainability in SMEs (I4MS2)** and **HORIZON-CL4-2022-TWIN-TRANSITION-01-07: Digital tools to support the engineering of a Circular Economy**) and which will see the awarded projects (currently in Grant Preparation) starting beginning of 2023.

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