

Strategic Action Line LI7: Digital Platforms, Modelling, AI, Cybersecurity



Pierpaolo Pontrandolfo, Guido Colombo, Rosanna Fornasiero,
Maria Cristina Vistoli, Angelo Messina, and Francesco Zanichelli

Abstract The objective of this chapter is to describe the strategic action line related to digital technologies for production processes and systems (LI7). In particular, this chapter proposes research and innovation priorities aimed at innovative digital architectures for the monitoring, control and management of manufacturing activities and related assets, modelling new products/services and production processes, use of AI, Big data and adequate Cybersecurity systems. More specifically, the research and innovation priorities are based on the assumption that criteria need to be defined for the management and transformation of raw production data into strategic information for decision makers, identifying the information to be collected from each digital access point by means of suitable enabling technologies and then delivered as appropriate. Digital platforms and cybersecurity also play a significant role in the definition of dynamic supply chain models.

Keywords Digital platforms · Industrial IoT · Business analytics · Cybersecurity · Supply chain

P. Pontrandolfo (✉)
Politecnico Di Bari, Bari, Italy
e-mail: pierpaolo.pontrandolfo@poliba.it

G. Colombo
Orchestra Srl, Torino, Italy

R. Fornasiero
CNR-IEIIT, Padova, Italy

M. C. Vistoli
INFN-CNAF, Bologna, Italy

A. Messina
ENGINSOFT SpA, Trento, Italy

F. Zanichelli
Università Di Parma, Parma, Italy

1 Introduction

The different organizational and technological maturity levels of companies, especially of SMEs, call for a reference framework that is sustainable and feasible over time and that can adapt to each company's specific capabilities and the peculiarities of the Italian context. The following aspects should be considered:

1. The high number of SMEs that are part of the Italian subcontracting supply chains. A considerable portion of them has yet to adopt effective digital solutions to be integrated and compete also on the international scene.
2. The wide spectrum of digital solutions available in Italy where there are no dominant players with the capacity to set standards for the adoption and use of digital solutions.
3. The ability of the Italian producers of machines, lines and plants to integrate them with digital and automated solutions.

The digitalization of Italian manufacturing focuses on the development of flexible, reconfigurable, easily integrated digital architectures at sustainable costs, enhancing the professional profiles connected to the digitalization of companies.

In particular, cloud-based approaches should be integrated with edge computing solutions, to make the most of the benefits associated with technologies such as AI, digital twin, Industrial IoT. The various enabling technologies are chosen and adopted by the products available on the market, and combined with each other on the basis of actual needs and of the advantages they can guarantee in the short, medium and long term.

Investment in research and innovation activities that go beyond business solutions is necessary. The use of platforms can profoundly change operation methods in the manufacturing sector, opening up scenarios that can be promising for companies, allowing companies to federate and increase their critical mass. There is however an element of risk, as platform managers may gain a dominant position and limit the freedom of movement of the companies that use the platform.

This set of challenges prompts the vision of Industry 5.0, which expands the typical technological aspects of Industry 4.0 to include in the new technological developments the role of humans and add emphasis on sustainability.

Strategic action line LI7 aims to define research and innovation priorities for the development of innovative digital architectures for the monitoring, control and management of the progress of production and its assets, the modelling of new products/services and production processes, the use of AI solutions, Big data and adequate cybersecurity systems (Fig. 1).

In particular, the research and innovation priorities of the LI7 line must take into account that it is becoming increasingly necessary to define criteria for the management of raw data in production and to transform them into strategic information for decision makers, identifying the information to be collected from each digital access point through suitable enabling technologies that need to be appropriately conveyed.

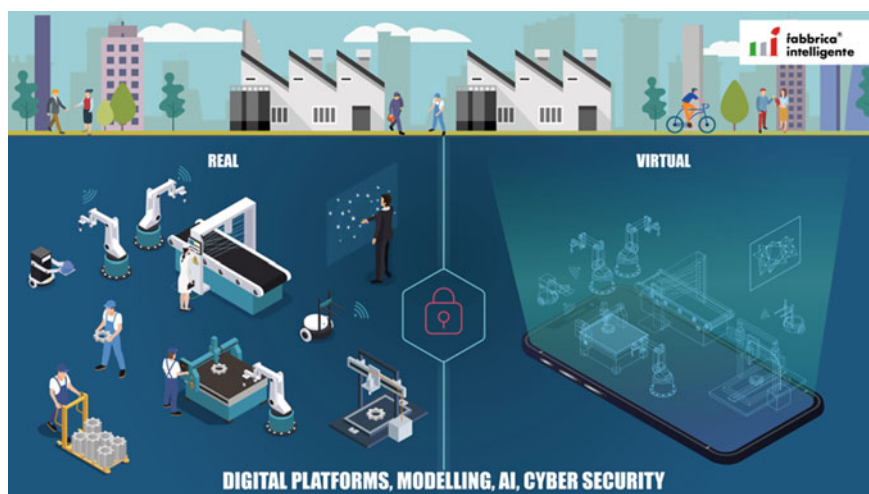


Fig. 1 Strategic Action Line 7—Digital platforms, modelling, AI and cyber security

The new systems to be developed must ensure that each digital access point provides adequate information at the appropriate organizational level, growing in complexity and granularity depending on the size of the company.

Particular attention must be paid to the advantages offered by solutions that are:

- Open, to allow interoperability between systems through open-source software products used in compliance with the Copyleft granted by the author.
- Flexible and reconfigurable, even remotely, to support the resilience of companies in the face of unexpected and unplanned events.
- Based on models that can interpret the meaning of the collected data.

LI7 aims to formulate its goals taking into account that:

- (1) Manufacturing companies must integrate their processes and flows into their upstream and downstream supply chains, especially if they are SMEs working through subcontracting arrangements. Dynamic Supply Chain models based on collaboration platforms make it possible to manage networks to increase their efficiency, productivity and resilience.
- (2) The new consumption dynamics are gradually shifting from purchase of durable equipment to their use in terms of services (servitization), therefore the entire design and production process must be based on new models and tools, to improve the offer of product-service solutions.
- (3) The integration between design, production and business management forces companies to remove the existing barriers between digital systems for product and process design (CAD, CAE, CAPE, CAM, CAPP), process and system supervision and control (MES, CMMS, QA) and management systems (ERP, Logistics, CRM, BI). Such integration can be implemented by adopting new

systems/products, and promoting their functional interoperability. At factory level, it is necessary to integrate production, logistics, quality and maintenance to increase efficiency and effectiveness of production systems.

- (4) Given the heterogeneity of machinery, there is a need for infrastructures and production processes, field architecture for the interconnection of machines, data collection, processing and integration with IT systems, to ensure evolution and scalability over time, as well as the possibility to use and integrate the various technologies available, and provide advanced digital services to users at various levels of the organization.
- (5) Advanced business and industrial analytics methodologies will have to support the time-consuming operations typical of off-line simulation and Deep-Learning in order to feed on-board edge systems with predictive models.
- (6) Digital twins based on constantly updated and reliable “single sources of truth” should support decisions in all phases of the process and product life cycle, and produce a single and synchronized information flow.
- (7) The integration between the physical and the digital world (combined with the growing proliferation of vulnerabilities at all levels, persistent cyber threats due to synergy of different attack vectors, from the physical, to the digital and social worlds) exposes industrial realities to new types of risk and to potentially negative impacts in terms of interruption of manufacturing services, quality and integrity of products, damage to tangible production plants, up to physical damage to the people involved in the production cycle.

Because of the value-added services it has introduced—such as predictive maintenance and, more generally, connectivity to IoT platforms inside and outside company networks—digital transformation increases exposure to cybersecurity risks. Developing a series of architectures, platforms and services that guarantee resilience in a manufacturing plant’s activity is therefore an essential business and regulatory compliance requirement.

Expected impact: pervasive use of digital platforms, technological infrastructures, advanced services for production chain management and distribution of product/service systems targeted to the end customer, to increase efficiency and productivity and achieve an adequate connection between supply and demand; improvement of trust creation processes in business networks; greater interconnection between the players in the supply chain; faster delivery of advanced digital services; full integration and normalization of data; interoperability and scalability of the deployed systems; greater effectiveness and efficiency of technologies thanks to cybersecurity; increased safety of production systems.

The research and innovation priorities of the strategic action line on Digital Platforms, Modelling, AI and Cybersecurity are:

- PRI7.1. Models and tools for the management of collaborative companies and dynamic supply chains
- PRI7.2. Design of integrated product-service solutions
- PRI7.3. Models and tools for production monitoring and asset management
- PRI7.4. IIoT models and tools for factory data collection

PRI7.5. Business and industrial analytics methodologies

PRI7.6. Tools for modelling and management of information based on digital twins

PRI7.7. Models and tools to support Information and Cybersecurity.

2 PRI7.1. Models and Tools for the Management of Collaborative Businesses and Dynamic Supply Chains

The strategic scenario that Italian manufacturing is facing is characterized by high international competition, both in terms of cost and technological innovation, turbulence and uncertainty in the upstream and downstream markets (recently emphasized by the tensions on trade regulations). Moreover, there is a need to manage complex and dynamic business networks where reconfigurations can be associated with political events, such as custom duties or Brexit, and environmental, or health care events, such as the Covid 19 pandemic.

The scenario shows comparatively higher stresses in Italy, due to typical aspects like the well-known small scale of companies and the heavy dependence on foreign countries in both upstream raw material procurement markets and downstream final product markets.

With regard to raw material procurement, approaches based on circular economy have considerable importance. They show advantages not only in terms of environmental sustainability, but also in terms of reduction of procurement risk (both in relation to resource availability and cost).

As described above, it is essential for companies to operate effectively and efficiently within their global Supply Chains (SC). They should also aim to enter new SCs dynamically, and with similar efficiency, based on specific business opportunities.

Integration should be increased, in the first place, by improving machine connectivity within the various supply chain plants, and the capability for monitoring and controlling work-in-progress in real time, keeping track of both products and operating conditions, at different production sites. Integration, however, relies on data and information that are often available in different formats, and are a key prerequisite for collaborative integration in global SCs.

The full exploitation of this data is based on collaborative management within the SC and ensures integration of processes and flows that go beyond the corporate scope of each SC member. For these opportunities to become operational, it is necessary to develop methods and approaches that encourage trust among the participant, extract value from information and share the benefits among them.

The aim of this research and innovation priority is to study and develop new technological and organisational solutions and foster the creation and adoption of digital platforms according to an open model, based on interoperability of the various systems adopted by the different SC actors, and characterized by specific vertical process applications mapped onto mobile (e.g. 5G) or fixed (fibre) network architectures. These infrastructures are a key prerequisite for implementing approaches based

on big data analytics and AI algorithms in support of decision-making processes. In this sense, the distributed ledger paradigm offers features consistent with the distributed nature of the organizational processes and supply-chain flows.

The solutions developed should be geared to overcome trust problems between the various SC actors and increase transparency in the exchange of information all along the supply chain, possibly in a selective and suitably manageable way, and overcome the fragmentation of information thanks to an ontology-based vision of data.

Digital platforms become a key asset for the collaborative management of dynamic supply chains and are based on the following specific research goals:

- **Models and systems for the configuration of the SC:** these models should support the design and configuration decisions of the supply chain (e.g., selection of a new supplier, location of a production or logistics centre) through the following developments:
 - Systems for expanding the physical traceability of each product and component: ensuring tracking systems so that the causes of a problem can be easily identified throughout the supply chain. Such systems would have a useful application also in terms of managing counterfeiting issues;
 - Information-certification systems related, for example, to the processes carried out by suppliers, subcontractors, and distributors to extract reliable data through suitable mechanisms, making such data selectively accessible through distributed ledger and blockchain mechanisms.
 - Big Data analytics and Artificial Intelligence systems to support supplier analysis and selection based on specific performance not only in terms of operations (costs, time, and quality) but also of sustainability.
 - Definition of trust improvement mechanisms in collaborative contexts. In order to improve coordination within the SC, especially when decision-making is distributed, approaches to design and develop mechanisms for the definition of smart contracts also by means of blockchain as enabling technology;
 - Methods and tools to evaluate and optimize supply-chain robustness and to design supply chains to ensure the expected performances in different reference scenarios.
- **Models and systems to support the SC's operational management:** these models should be based on a system transparency level that ensures the necessary sharing of information for the management of manufacturing progress and general operations, extending to all the players in the SC. In addition, these models should help decision-making even during disruptive events, to ensure target performance thanks to techniques such as machine learning, simulation and artificial intelligence, and to guarantee data security and privacy. Particular attention should be paid to the study of innovative models for the management of dynamic and collaborative SC that enable the management of a products' end of life and support circular economy in general.

- **Digital twin for the SC:** study and development of a digital twin for the SC, based on methods to connect different digital models of the products, machines, lines of the SC's actors, ensuring the overall consistency and the modelling of complex interactions that generate emerging, hard-to-predict behaviours.

Interaction with Other Strategic Action Lines

Possible interactions with other Strategic Action Lines are as follows:

- **LI1—Personalised production:** the support in the definition of mechanisms that ensure the transparency of processes, the streamlining of the decision-making process and the facilitated collaboration along the SC can be synergic with the theme of modular factories.
- **LI2—Industrial sustainability:** SCs consisting of dynamic and collaborative companies make sustainable production processes easier and, particularly, consistent with circular economy. They also facilitate the management of flows between different SC players who exchange by-products as secondary raw materials. The objectives mentioned above can be linked to some general issues such as circular economy. For instance, transparency along the supply chain (in terms, for example, of time, quantity, quality) is essential to enable the use of by-products as secondary raw materials in a supply chain (indeed, the availability of this information is critical because by-products flows have lower continuity and predictability than conventional raw materials); smart contracts can foster such exchanges making them profitable and safe for the parties involved.
- **LI5—Innovative production processes & LI6—Evolving and resilient production systems:** both these LIs pursue actions related to “internal requirements” as defined above (one for all, process digital twin for LI5 and machine digital twin for LI6). These “internal requirements” are enablers of the PR at issue.

Time Horizon

Short-medium term goals (2–3 years).

- Models and systems for the configuration of the SC, to speed decisions at project level (e.g. selection of a new supplier) by using suitable indicators for company profiling.

Medium-term goals (4–6 years):

- Development of models and systems for the operational management of the SC, and development of distributed digital twins that allow the evaluation of emerging behaviours, thus supporting decisions concerning the configuration of the SC itself and operations management.

3 PRI7.2. Models and Tools for Designing Integrated Product/service Solutions

Durable equipment is increasingly being managed through a service-based model while until recently durable assets were mainly purchased in ownership. The commercial transaction is thus valorised not so much on an ownership basis but through the use of the asset itself. This trend is already established in both the B2B and B2C segments, for example in the aeronautical sector, where engines are supplied to aircraft manufacturers as a cost-per-flight-hour service, or in the automotive sector where vehicles or construction equipment are rented long term and paid per mile or working hour.

Also in the sector of capital goods for manufacturing, servitization makes it possible to integrate the sale of assets with services that ensure a machine's operating availability through on-condition and predictive monitoring and maintenance services.

This model also includes manufacturing processes supplied as a service (manufacturing as a service) by specialised companies that provide a machine's pay-per-use service to other manufacturing companies for particular processes that cannot be carried out on site.

The goals of this research and innovation priority are:

- **Platforms and solutions for advanced digital services** that enable traceability of a product's use to improve its configurability and support remote assistance through, for example:
 - o Innovative APP and HMI for end users in SaaS (Software as a Service) mode and development of new interfaces between products and service to facilitate exchange of information between one component and another of an integrated solution and to enable appropriate support services.
 - o Digital platforms for the management of multi-tenant cloud digital services.
- **Digital solutions for revamping** the existing product range, extending product life and improving product use, providing new interconnective functions to corporate systems or digital service platforms. In particular, it is necessary to focus on the study and development of:
 - o Solutions involving the sensorization of machines to connect them to factory systems, in a safe and minimally invasive way;
 - o Generation of interfaces that automatically and/or semi-automatically integrate existing solutions and ensure communication with a machine;
 - o Automatic and/or semi-automatic systems interconnecting to company's MIS software or low-cost digital cloud service platforms that can be easily integrated to control work-in-progress and the improvement of predictive maintenance and factory automation;

- o Vision systems designed to interpret and reconstruct the system's appearance in order to rebuild and interpret the appearance of the shop floor even when only partial information is received from the sensors.
- **New multidisciplinary models and new PLMs** for the joint design of a product/service. They must integrate different knowledge and technologies necessary at the various design levels (Mechanics, Electronics, Automation, System software, Application software, remote and proximity connectivity, etc.). These tools can help design new products, redesign existing products and design services as an integral part of the life cycle of the new product/service, through design software that can assess the impact of design choices on the use of a product, to estimate for example the Total Cost of Ownership, and related services. Cybersecurity-by-design systems are necessary to design a new product/service from a PLM perspective.

Interaction with Other Strategic Action Lines

- LI1: Personalised production systems: personalisation of the solution through the supply of integrated digital services to support the product
- LI2: Industrial sustainability: development of services to support the monitoring and control of the sustainability of products and plants.
- LI3: People in the factory: development of digital services to support workers online.

Time Horizon

Short-term goals (2–3 years):

- Digital solutions to revamp existing products by providing new interconnection capacities to company systems or digital service platforms.

Medium-term goals (4–6 years):

- Advanced digital services that enable traceability of the use of a product by integrating it with company systems or new digital services managed in the cloud to improve configurability and remote assistance.

Long-term goals (7–10 years):

- PLM design tools for products and services with a view to cybersecurity-by-design and to planning solutions that consider their impact throughout a product's life cycle.

4 PRI7.3. Models and Tools for Production Monitoring and Production Asset Management

It is increasingly urgent that production processes be managed in synchrony with other business processes so that useful information is exchanged in real time and in a reliable way at different levels in the organization. By way of example, real-time management of information could be applied to the monitoring of product availability when the order has been placed, to plan the handling of semi-finished products within the factory, or to optimize transport times and costs, internal and external logistics, and the maintenance and data exchange with management systems.

A production process should generate objective and certified data, to facilitate analysis of the areas in which production should be improved, consolidate budgeting capacity and ensure availability of production resources for an efficient planning.

Industrial implementation of these solutions is at present almost entirely the prerogative of large companies, and that poses an additional limitation to their implementation. Furthermore, the focus is on individual and specific assets that tend to be complex and expensive. It is therefore necessary to make this production process accessible to full production systems at different complexity levels (even distributed and remote), and small and medium-sized companies, which cannot manage to exploit effectively the data they generate despite investing in I4.0-compliant machinery.

More and more frequently, operations technology (machines, automations, controls, SCADA, etc.) produce data that must be transformed into ready-to-use information for MIS (ERP, BI, logistics, etc.), including other production-related systems with which they can interface, such as MES, CMMS, PLM etc.

The objectives of this research and innovation priority concern:

- **Modular solutions for dynamic asset management** that can solve resource management and monitoring problems by appropriately combining specific modules. These solutions should be designed in such a way as to: a) be sufficiently generic (avoiding ad hoc solutions), but at the same time take into account the specific production structure where they are intended to be implemented (set up times, type of production, etc.); b) ensure that monitoring and scheduling can be adapted according to the configuration of constantly evolving assets, also in consideration of any changes related to resilience or circular economy. These infrastructures should be designed based on a weakly coupled architecture, providing SMEs with the ability to build their own scalable and modifiable solution at any time according to criteria of:
 - o Interoperability in the horizontal and vertical integration of their systems
 - o Flexibility in the reconfiguration of their processes and information flows
 - o Data control and certification for the consolidation of decision-making systems
 - o Integration with digital supply chain platforms.

- **Solutions for factory communication based on 5G:** infrastructures for the dynamic management of assets must be able to convey diverse data in real time and in a massive manner by exploiting the URLLC (Ultra Reliable Low Latency Communication) operating modes of the 5G network. In addition, the development of a process' specific vertical applications (Verticals) will have to ensure reliability and security of communication and, at the same time, minimize latency. In particular, certain features of industrial 5G are inextricably linked to the typical requirements of operation technologies, and should be based on the creation of “connectivity bubbles” that connect the elements found within the corporate campus by integrating 5G and WLAN as required by the standards and ensure an adequate performance of reliability, availability, data-rate and latency. It will also be necessary to study the issues related to Beyond5G which involve the joint use of sensing and communication techniques.

Interaction with Other Strategic Action Lines

- LI5: Innovative Production Processes
- LI6: Evolving and Resilient Production Systems

Time Horizon

Short-term goals (2–3 years):

- Development of Connectivity solutions based on 5G Private Industrial and 4G Public connectivity over WAN. Creation of PoCs and extension of coverage to the entire supply chain. Introduction and integration of standardized wired/ wireless connectivity platforms to ensure the necessary connectivity for Industry 5.0 processes and solutions.

Medium-term goals (4–6 years):

- Study and development of modular solutions that can solve resource management and monitoring problems. These solutions must be designed in such a way as to be sufficiently generic (avoiding ad hoc solutions), but at the same time they must take into account the specific production structure where they are supposed to be implemented (set up times, type of production, etc.).
- Study and development of factory communication solutions based on 5G.

Medium-term goals (7–10 years).

- Study of Beyond5G communication systems that involve the joint use of sensing and communication techniques.

5 PRI7.4. IIoT Models and Tools for Factory Data Management

A fundamental infrastructural element in the field of digital solutions concerns architectures and technologies for the generation (such as microsensors and connected MEMS), collection, processing, integration and sharing of raw data from the field which, transformed into appropriate information, can lead to an improvement in productivity and a reduction in environmental impact through the smart management of plant assets.

The paradigm of Industrial IoT, borrowed from the Internet of Things (more oriented to the interaction between user and smart object in the home or smart city) and based on the adoption of mission-critical technologies (for timing and QoS, reliability, security and privacy purposes) for M2M interaction, opens the way to a deeper understanding of the manufacturing process, thus enabling efficient and sustainable production, and process innovation (Xu et al., 2018; Sisinni et al., 2018).

The main objectives of this research and innovation priority include:

- **Vertical systems and applications** that enable on the basis of **edge computing architectures** the management of signals from the field in near-real or real time and transform them into easily usable information,. In particular, the approaches required should allow also the local use of artificial intelligence, such as the use of neural networks to interpret information at an appropriate level before it is transmitted to the highest decision-making level. In addition to appropriate sensors that cover different types of signals such as vision sensors (infrared, x-ray, hyperspectral, etc.), sound sensors, electromagnetic sensors with very sophisticated local processing capacity, it will be necessary to develop new types of local processors that take into account the different sources from which data is collected (both from objects and from workers through wearable sensors).
- **Systems to support the transformation of data** (in most cases massive, unstructured and heterogeneous) into **information** and to facilitate its transfer to decision-making systems also through 5G-enabled wireless communication systems. In the case of plant data, these systems must ensure that the transmitted information has high reliability, high security and low latency.
- **Communication systems (wired or wireless)** that ensure real-time and low-latency dialogue between sensors located in different data collection points, so that they can convey a stereoscopic view and ensure the interaction of edge computing even at a local level. It is thus possible to have a local distributed intelligence, which dialogues and appropriately transmits data and/or artificial intelligence or machine learning models, to limit the amount of information transmitted without introducing too many penalties on the accuracy of the inference results.
- **Mission critical technologies and platforms** of smart M2M interaction at different stack levels, from communication and middleware to distributed processing between local systems, Edge and Cloud with different latency and capacity features that can work together to best meet application requirements.

Such systems must also be designed to ensure the reconfiguration of the network itself.

- **Wearable hardware devices that ensure**, for example, interaction with gesture language, or non-wearable devices to visualise 3D objects locally and manage, for example, the maintenance of machinery and the training of operators. Such technologies can improve workflow and productivity through the convergence of physical and digital elements. Furthermore, the availability of computational resources that can be accessed with very low latency enables the creation of innovative convergent services, including proximity AR, to support on-board maintenance and 3D HMI for remote diagnostics of the machines, avoiding otherwise complex navigation between traditional HMI data (lists, diagrams, alarms).
- There is also a close relationship between pervasive connectivity in production lines and cybersecurity, which must protect it without limiting operations. Therefore, new methods, architectures and algorithms must be sought, on the basis of unified and standardized approaches that also take into account the great diversity of equipment and technologies, both in terms of technological generation (in particular legacy systems) and for suppliers, typically present in production factories.

The identified goals can be summed up as the full achievement of data integration and normalization, including in real-time, and the improvement of security, interoperability and scalability of the systems in the field, at project and implementation level, also considering the large installed base of legacy systems.

Interaction with Other Strategic Action Lines

There is no doubt that the research and innovation priority has strong interactions with strategic action lines:

- LI5—Innovative production processes and LI6—Evolving and resilient production, for which it is one of the main enabling technologies.
- PR7.5 Business Industrial Analytics and PR7 Information and Cybersecurity, as synergistic and complementary to the achievement of the goals of efficiency, resilience and innovation of production processes.

Time Horizon

Short-term goals (2–3 years):

- Interaction and communication systems between sensors, even of different types
- Wearable hardware devices

Medium-term goals (4–6 years):

- Design of interaction methods and data fusion systems to obtain information from the set of data collected by sensors useful for an industrial context.

6 PRI7.5. Advanced Business and Industrial Analytics Methodologies

Digital transition opens significant opportunities in the management of systems, components and industrial plants. These opportunities improve efficiency and reduce environmental impact, but they also present significant new challenges.

The possibility to improve machinery and tools with sensors, the increase of communication speed, and the spread of computing capacity both locally (Edge) and remotely (Cloud) make available large volumes of data (including images) that through Artificial Intelligence algorithms can be used, for instance, for predictive maintenance and problem diagnostics, to optimize plant configuration and production strategies, to collaborate in real time during the production phases with customers (B2B). Furthermore, the new methodologies enable a direct feedback to the plant from sales and products usage data, to generate new solutions with an integrated B2B2C approach. In order to get value from industrial data, it is necessary to resolve the constraints posed by the collection of data in a plant environment, and precisely:

- The large amount of raw data, often showing lack of uniformity (sampling frequencies, semantics, structure, format) and lack of historical data and data in systems regimes different from normal operation, in particular for complex plants
- The differences in the treatment of micro-stops (more frequent and resolvable with on-site intervention) or critical stops (rare and typically related to components to be replaced);
- The difficulty of exploiting non-empirical information, such as knowledge of the plant structure (or component) (because of the lack of plant and component models)

In light of the above, the objectives of this research and innovation priority concern:

- Data Analytics, Machine Learning and Image Recognition method and tools for the system automatic monitoring with the following features:
 - Ability to manage data applying ontological and reasoning approaches and to evaluate cause-effect relationships from information derived from heterogeneous sources such as tools, machinery and systems.
 - Ability to combine input information from operators and machines and obtain information that would otherwise escape observation.
 - Ability to re-train the non-deterministic models within times compatible with production plants.
- Self-awareness solutions for production systems, with reference models that use digital twin representation taking into account interaction between the different lines and cells that make up the system.

- Virtual sensors: solutions that link system model to existing sensors. This approach is based on the development of models that allow the combination of information gathered from reality and overcome the difficulties of exploiting non-empirical information, such as plant knowledge.
- Systems to integrate data analytics methods on hybrid infrastructures (Edge and Cloud type): new solutions should integrate Cloud systems overseeing time-consuming operations typical of off-line simulation and re-training of the models and Edge systems on board of the plant to run real time predictive models.

Interaction with Other Strategic Action Lines

Interactions with almost all the research priorities of this action line, namely:

- PRI7.3 Models and tools for monitoring production and managing production assets,
- PRI7.4 Stack IIoT for factory data management and
- PRI7.7 Information and Cybersecurity, as synergistic and complementary to achieve the objectives of efficiency, resilience and innovation of production processes.

This research and innovation priority has strong relations also with LI5 and LI6 as regards the development of technologies at the various factory levels and with LI1-4 as regards the support it can give in defining solutions that can reinforce data management in relation to personalised products, sustainability, staff development and high efficiency.

Time Horizon

Short-term goals (2–3 years):

- Virtual sensors

Medium-term objectives (4–6 years):

- Ensure data fusion to give meaning to the various data collected from the field
- Methods and tools for automatic monitoring of the system status

Long-term goals (7–10 years):

- Self-awareness solutions to support the management of production systems
- Systems to integrate data analytics methods on hybrid infrastructures

7 PRI7.6 Tools for Modelling and Management of Information Based on Digital Twin

The progressive implementation of digital technologies (IoT, Advanced Sensors, Connectivity, Cloud and Edge Computing, Big and Small Data, AI) in companies makes it desirable and necessary to study and develop software tools and methodologies that exploit the advantages that can (and must) be obtained from these technologies.

At the moment, especially for PMEs, advantages mainly consist of an improvement of production efficiency. Clearly, that cannot be all. Further advantages will be the exploration and identification of new production paradigms aimed both at a better use of resources (e.g. circular economy, zero-defect manufacturing, reuse, remanufacturing and recycling), and at increasing business potential through greater efficiency in responding to market needs (e.g. mass customization, lot-size one production, reconfigurability of production systems) or new positioning in the value chain (e.g. servitization).

The development and use of dynamic digital models of all the physical entities composing the factory, i.e. digital twins, is desirable and necessary. In fact, a digital twin can be made for a product, machinery, plant, factory, system and should interact with its real twin (in a cyber-physical production system) in operation through a single, continuous, bidirectional and synchronized flow of data. Data coming both from the simulation models used mainly in the design phase, and directly from the field (embedded sensors, artificial vision, etc.) are sent, through IoT systems, both to proximity computers (edge computing), and to remote ones (cloud computing).

The objective of the research and innovation priority is the development of methodologies and calculation tools to improve the use of the data flow generated by the digital twins, with a view to exploit their enormous potential for increasing performance (economic and business, environmental and social sustainability) over the entire life cycle of the product. To do so, the virtualization of production systems (local or distributed) should be accompanied by:

- **Hybrid simulation systems of complex production systems** containing models based both on simulation (CAE, Analytics, DES, Agent Commissioning), and on data from the field, more and more finely honed to reality through the input of continuously synchronized data, coming from digital twins.
- **Decision-support systems and tools (DSS)**, based on simulation models of complex production systems, optimization and forecasting, focused on different scenarios (e.g. optimization of maintenance, production, supply chain, etc.). These systems must be scalable (by complexity and costs) and have customizable HMIs (Human–Machine Interface) of contents and hierarchies for the individual tasks and for the different players interacting in the process of designing and managing product and production systems (product design and production systems, process planning, process commissioning, maintenance, quality control, procurement management, plant and/or production site management, HR, commercial area and top management).

- **Algorithms and methodologies for simulating human behaviour in flexible automation production systems.**
- These multi-agent distributed control algorithms based on cognitive sciences are expected to model and implement digital twins including for the human components that act in a production system. That is particularly relevant in flexible automation production systems, where operators are required to “collaborate” with robots.

Interaction with Other Strategic Action Lines

This priority is complementary to all research and innovation priorities of this research line.

Strong interaction with all the other Strategic Action Lines and, in particular, with the lines focusing on the various “Production Systems”: LI1, LI4, LI5, LI6.

In fact, the development of this research and innovation priority would impact all types of production systems, which could even represent test cases for the development of this research and innovation priority.

Time Horizon

Medium-term goals (4–6 years):

- Hybrid solutions for simulation of complex production systems and decision-support systems and tools (DSS), as developments are essentially methodological and need to be translated into IT tools, which should be based on technologies already present on the market. This is an essential requirement for their use in businesses, especially in SMEs.

Medium-long term goals (4–10 years):

- Algorithms and methodologies simulating human behaviour in production systems with flexible automation currently involve pioneering research activities.

8 PRI7.7 Models and Tools to Support Information and Cybersecurity

The risks associated with cyber-attacks, rated in the last years in the top ten risks of any business and government, must be assessed and managed at all levels (from governments to industries, to individuals).

Recent scientific literature confirms a growing attention to cyber risk and to research and innovation priority due to:

1. **An essential connection between industry 4.0 and cybersecurity, where heterogeneous models can become an obstacle to the prompt and secure adaptation of business to the new requirements**, particularly where there are interconnected technologies with different cyber resilience and people (internal technicians and/or suppliers) who work with different approaches to security;

2. **The binding link between the digital and physical world**, which has created cyber-physical environments where data breaks can **create direct critical impacts in the real/physical elements**, both in terms of security (e.g. breaking of components) and safety (e.g. fraudulent handling of cranes/robots), whether in **environmental** terms (e.g. manipulation of water reclamation processes) or **indirect social impact** (e.g. on the internal workforce or on allied industries in the event of production interruptions);
3. **The continuous evolution of threat scenarios and 4.0 industrial processes** which requires a continuous process of identification and monitoring of the effectiveness of the protection measures;
4. **The partial effectiveness of available technological solutions taken individually**;
5. The potential high costs of available cyber technologies, in the purchase, implementation and management phases.

The security processes that companies must implement to effectively counter growing risks cannot be separated from ongoing research, development and adoption of suitable process solutions and cyber security technologies. Research must necessarily be an iterative process, following both the continuous evolution of threats and the technologies/systems that must be protected.

Research and development in cybersecurity technical solutions should take into account:

- The enabling technologies such as artificial intelligence, from machine learning to predictive models, Big Data Analytics, Blockchain.
- The data from heterogeneous sources, so that hostile behaviour can be identified effectively (i.e. with a low number of false positives).
- Usability throughout the life cycle of the product, both during production and safety management.
- The right compromise in terms of costs/benefits.

In light of all this, the following goals are identified for this research and innovation priority:

- **Innovative systems for the governance of cybersecurity** for: a) the management of risk throughout the production chain for the protection, reliability and integrity of data (from suppliers to customers), allowing the comparison of risks related to different production contexts and supply chains; b) a safe and sustainable progressive integration of new technologies into the industrial network, to support the design, analysis and enforcement of Industry 4.0, ensuring the resilience of industrial systems and production processes against a variety of possible threats; c) the definition of contents for an effective training on cybersecurity, also *using enabling technologies of Augmented reality and Simulation (e.g. digital twin of production chains)* to obtain realistic simulated cyber-physical attack/impact scenarios.
- **Solutions to support the resilience of systems** to a) **increase the protection capacity of industrial systems (OT and IoT)**, to reduce the possibility that external threats could compromise the normal functioning of the system or the

recovery of information, if necessary. The main objectives of research on industrial control systems (ICS) are the analysis of vulnerabilities and frameworks for the detection of the safety and security properties of ICS/SCADA systems; b) **enabling micro-segmentation** in isolated cells of industrial systems, and allowing granular isolation in order to prevent lateral propagation of threats on other manufacturing systems; c) **increasing the security of the maintenance processes** of industrial systems, to prevent the propagation of threats from the systems used by the maintenance service to the industrial systems.

- **Protection of communication flows** to: a) ensure the secure definition of the unilateral nature of network flows (by devising “data diode” solutions), and collect operational data from critical industrial networks (for example in *data lakes*), effectively mitigating the possibility of introducing threats into critical industrial networks; b) avoid the transmission of unauthorized industrial commands (industrial firewalls with deep packet inspection); c) decouple industrial system data flows and protocols from business processes, to prevent areas with different security levels from having a direct need to communicate with each other; d) using standardized encryption protocols for wireless connectivity as well as SIM-based authentication systems for network access.
- **Security monitoring of the Cyber-Physical world** for: a) a non-intrusive monitoring of networks and systems for the detection of anomalies; b) the identification and analysis of threats in the Cyber-Physical world in real time, thanks to an executive abstraction layer that allows to understand the possible risks, threats and problems related to manufacturing operational processes, facilitating the interpretation and synergy of groups with heterogeneous skills; c) development of a Cyber Risk Governance approach integrated with Enterprise Risk Management. This approach must be conceived with a holistic vision of risk management not only in terms of cybersecurity but also of safety, physical security and environmental risks. Furthermore, it is necessary to bring to the attention of the highest corporate level the topic of cybersecurity, to avoid the risk that the topic might be confined to a purely technical area (IT /OT).

The evolution of cybersecurity technologies is based on the creation of ad hoc public libraries to be adopted from time to time as part of the technologies, in order to ensure effectiveness and efficiency. In particular, in terms of effectiveness, the continuous development of increasingly refined algorithms by exploiting the enabling technologies will make it possible to identify/counteract promptly the ever-evolving threats. In terms of efficiency, the development of agile representation and maintenance models throughout the life cycle will allow the management of cybersecurity technologies, avoiding dissipation of value and effort.

Interaction with Other Strategic Action Lines

Strong integration with the other action lines, in particular:

- LI4-LI5: continuous technological evolution as a result of the other strategic action lines requires new processes, new interconnections and the attribution of

ever greater value to data, and a continuous reassessment of risks and necessary mitigating actions;

- LI4-LI6: sustainability (in terms of efficiency and effectiveness) in the development and adoption of protection systems is strictly correlated with the other research priorities in the OT/IoT area;
- LI4- PRI7.6: the results obtained from other lines of intervention and from other priorities (e.g. digital twin) can be adapted and used to further refine and evolve the objectives of this priority.

Time Horizon

The short-term goals (2–3 years):

- The development of systems for the governance of cybersecurity to support risk management throughout the production chain, ensuring the gradual integration of new technologies into the industrial network
- Systems for the protection of communication flows that can guarantee the secure definition of network flows and control the transmission of unauthorized industrial data

The medium-term objectives (4–6 years):

- System resilience to be improved by implementing actions on the protection capacity of industrial systems (OT and IT) and the study of solutions for industrial systems' micro-segmentation that can help overcome segregation in homogenous groups.
- Security monitoring systems in the cyber-physical world and in real-time threat analysis require medium-term actions since it is necessary to study and develop advanced, non-intrusive monitoring systems for networks, which should be supported by advanced AI and machine learning technologies.

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