

Chapter 1

The Italian Flagship Project: Factories of the Future



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Abstract This chapter deals with the central role of manufacturing in developed and developing countries, assessing how relevant it is from economic and social perspectives. The current international and Italian manufacturing contexts are analysed by highlighting the main criticalities and the impact of relevant global megatrends. Then, the main ongoing industrial research initiatives are presented both at international and Italian level. Based on the elaboration of current context and research initiatives, the Italian Flagship Project *Factories of the Future* defined five research priorities for the future of the manufacturing industry. Based on these priorities, the flagship project funded a total of 18 small-sized research projects after a competition based on calls for proposals. The results of the funded research projects are analysed in terms of scientific and industrial results, while providing references for more detailed descriptions in the specific chapters.

1.1 The Importance of Manufacturing Industry

Manufacturing industry plays a central role in the economy of developed countries for the generation of wealth, jobs and a growing quality of life. Beyond being a sector capable of directly producing wealth and employment, manufacturing industry is a fundamental pillar of the whole economy. In 2016 the value added of manufacturing represented 15.6% and 14.3% of the Gross Domestic Product (GDP) at world and European Union level, respectively. A relevant number of persons are directly

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employed in industries, in particular 22.5% and 24% at world and European Union level, respectively.¹ During the last ten years the share of manufacturing value added with respect to the GDP has been declining in developed areas like USA, European Union, Japan, whereas the share of service value added has been increasing. However, it must be stressed that services and manufacturing are strictly interwoven. Indeed, manufacturing industry produces the goods needed to support the delivery of several services and, more important, it generates the need of acquiring new services, thus increasing the demand in the market. The interactions between manufacturing and services can be found along whole industrial value chain [1]:

- Upstream services in the value chain, e.g. product design, innovation activities, research and development. The acceleration of production and information technologies innovation requires more and more specific and advanced scientific and technical support.
- Core services in the value chain, e.g. services strictly related to production activities like supply management, process engineering, production engineering, maintenance services.
- Downstream services in the value chain, e.g. marketing, distribution, pre- and after-sales services to generate further value added. The concept of servitization [2] is included in these services; about 4% of manufacturing gross output was due to secondary services, i.e. services sold together with the product [1].
- Transversal services, e.g. Information and Communication Technologies (ICT) related services, management and strategy consulting to support an global enhancement of company competitiveness.

In Europe the average content of services in manufactured goods accounts for about 40% of their total value. The most relevant services are related to distribution (15%), transport and communication (8%), and business [1]. Moreover, it is important to highlight the role of manufacturing as a job multiplier, i.e. each direct job in manufacturing leads to additional jobs in service activities. In USA it has been estimated that the manufacturing multiplier is equal to 1.58 on average [3], but it can be higher depending on the region and how technology intensive is the manufacturing sector. In the European Union one out of four jobs in the private sector is in manufacturing industry, and at least another one out of four is in services that depend on industry as a client or supplier [4].

The world economy is constantly evolving through scenarios of global change and development that have an impact on the lives of people, companies and communities, thus generally influencing the society and the economy [5]. The analysis of socio-economic megatrends is important to understand and anticipate what a sustainable manufacturing industry will have to cope with in the future [6]. Among the others, it is possible to identify five megatrends that will deeply affect the structure of industry: demographic change, new emerging markets, scarcity of resources, climate change and acceleration of technology process [7].

¹Source: World Bank Open Data, <https://data.worldbank.org/>.

The global population is expected to grow from 7.55 billion in 2017 to 8.55 billion in 2030 and 9.77 billion in 2050, with a growth rate much higher in developing countries.² Together with the expected increase of the overall population, also the population ageing is a relevant process at global level. By 2030, over 22% of the population in high-income countries will consist of people with age 65 and above, thus determining a significant rise of the old-age dependency rate. These demographic changes will pave the way for the need of always more customized products (niche products), as well as services, to cope with new specific needs in terms of comfort, health and well-being of individuals or communities. In addition, it will be necessary to find a right balance between the need to let over-65 people prolong their working life and the need to offer job opportunities for the young generations while improving, at the same time, the worker well-being in terms of satisfaction, safety and inclusivity. Moreover, it is foreseen that almost 60% of the global population will be living in cities by 2030 pushing the development of the so-called megacities.³ Hence, new production models implementing *urban manufacturing* strategies (factories as a good neighbour of cities) need to be settled to permit the workers to combine the work with their personal lives [8].

The extraordinary population growth in the developing countries will push also the growth of their economies, even though at lower rates. This will lead to a significant increase in the middle class population. If the middle class population was about three billion people in 2015 (half of them living in Asia), then it is expected to be over five billion by 2030 [9], thus creating new emerging markets. In this scenario, the manufacturing industry will have to cope with continuously mutating market conditions being able to manage complex global networks of enterprises. Indeed, the globalisation process has already created new markets but also new competitors, therefore the need of innovation becomes stronger and stronger. Hence, factors such as a strong industrial tradition, manufacturing culture, consolidated design skills, the presence of research institutions and technology transfer centres will play a key role to enhance competitive advantages.

An overall increase in natural resource consumption is foreseen because of the socio-economic growth in developing countries. In particular, the world energy consumption is expected to increase by 28% between 2015 and 2040. The increase will be higher in non-OECD countries (+41%) than in OECD countries (+9%) [10]. Also the consumption of water, food and several raw materials are going to increase in the next few years. Therefore, manufacturing industry needs to adopt the circular economy paradigm [11] to considerably reduce waste through re-use, remanufacturing and recycling. At the same time, production systems should become always more efficient in the use of raw materials.

A more efficient use of the resources is also driven by the need to cope with climate change that has started to affect the overall planet. Hence, economies need to become more resilient to change, efficient in the use of resources and rely on high levels of eco-innovation to remain competitive.

²Source: United Nations, DESA/Population Division, <https://esa.un.org/unpd/wpp/DataQuery/>.

³Source: World Bank Open Data, Population estimates and projections, <https://data.worldbank.org/>.

Finally, the continuous acceleration of the technological progress, the integration of advanced technologies and cross-fertilisation of different technologies will be increasingly important to enhance innovation and create new markets. In addition, greater flexibility and reconfigurability will be essential requirements for the future manufacturing industry to cope with the turbulence of markets and the unpredictable changes in demand.

1.2 Italian Manufacturing Industry

In 2016 Italy was the seventh manufacturing country in the world in terms of value added (2.2% of the total), even though the position is declining since it was at the fifth place in 2007 (4.9% of the total). Indeed, the manufacturing sector of countries like China, India, and Rep. of Korea is growing at a higher rate. China has already overtaken the USA manufacturing sector as the first in the world, representing 26.2% of the global manufacturing value added.

In Europe, Italy is the second manufacturing country behind Germany, in spite of representing just the fourth Gross Domestic Product (GDP)⁴ behind Germany, France and United Kingdom.

Manufacturing plays a key role in the Italian economy since its total output was equal to 897 billion euro (28.6% of the total) and the value added equal to 245 billion euro (16.3% of the total) in 2016.⁵ The detailed contribution of the various manufacturing sectors is shown in Fig. 1.1. The production of machinery and equipment is the top sector. Moreover, Italy is among the largest producers in all the sectors and in the textile sector holds the first position, as shown in Table 1.1.

In 2016 almost 3.9 million Italian people were directly employed in the manufacturing industry (15.5% of the total), earning 20.6% of the total compensation of employees. However, the overall unemployment rate at 11.7% in 2016 was still higher than the pre-crisis level and youth unemployment was particularly significant; moreover, a significant regional heterogeneity can be noticed [12].

In spite of the still relevant position of its manufacturing sector, the Italian economy has been slowly declining and is characterized by historical problems related to productivity [13] that is not converging in the euro area [14]. Indeed, the real GDP per hour has been flat in Italy, whereas it has been growing in other countries of the euro area [12]. After the recessions in 2008–2009 and again in 2011–2013, the Italian manufacturing sector has been slowly recovering competitiveness, even if at a lower rate than the other main European countries. The second recession of the years 2011–2013 was mainly caused by a decreasing or stagnant internal demand [15] and a positive role was played by the export of Italian manufacturing companies, that keeps on growing (+1.1% in 2016) and represents 3% of the world export, even though the world trade is slowing down [15]. However, a growth based on export is

⁴Source: World Bank Open Data, <https://data.worldbank.org/>.

⁵Source: eurostat, <http://ec.europa.eu/eurostat/data/database>.

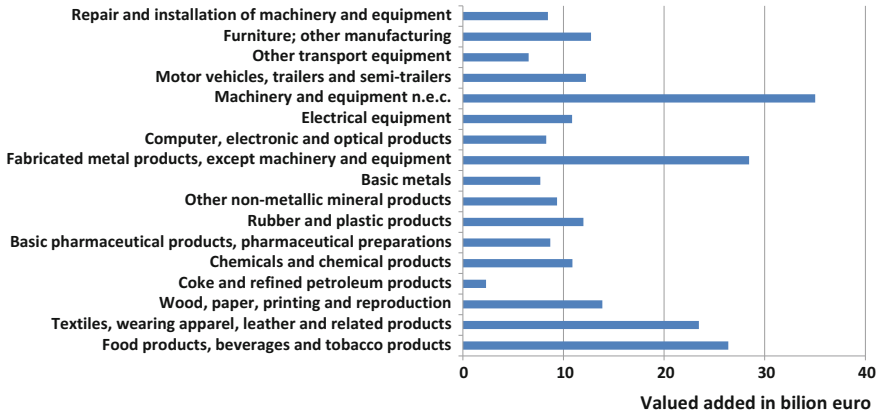


Fig. 1.1 Value added of the Italian manufacturing sectors (*Source* Eurostat 2015, NACE Rev.2 A*64 classification)

hardly sustainable in the long run and exposes the economy to external shocks (like it happened in 2008). Moreover, it must be noted that the Italian post-crisis recovery of competitiveness has been achieved also thanks to a general policy of wage moderation, in particular real public wages have decreased since the start of the recession mainly because of missed inflation adjustments [12]. Even if wage moderation and the enhancement of labour market flexibility may lead to short-term increase of competitiveness, these policies have counterproductive consequences in the mid-long run, because on average labour and total factor productivity are depressed [14].

Given the current scenario and boundary conditions, investments in industrial research and innovation represent one of the few viable options to improve the competitiveness of Italian manufacturing companies and economy in general. In particular, a higher share of ICT investments may lead to a long-run increase in labour productivity [14]. Therefore, the following sections will present the main international (Sect. 1.3) and Italian (Sect. 1.4) research initiatives on manufacturing.

1.3 International Research Initiatives on Manufacturing

The Technology Platform *Manufuture*⁶ [16] was launched in the first decade of the new millennium to develop and implement the European research and innovation strategy. The Strategic Research Agenda published in 2006 [17] proposed a change of paradigm by fostering the industrial transformation to high-added-value products, processes and services, while keeping a relevant share in the future world manufacturing output and protecting the employment in a knowledge-driven economy [18]. The following key pillars of the future manufacturing were identified:

⁶<http://www.manufuture.org/>.

Table 1.1 Position of Italian manufacturing sectors in Europe

Manufacturing sector	Largest value added in Europe	Position of Italy in Europe
Food products, beverages and tobacco products	France	5
Textiles, wearing apparel, leather and related products	Italy	1
Wood, paper, printing and reproduction	Germany	3
Coke and refined petroleum products	Germany	5
Chemicals and chemical products	Germany	5
Basic pharmaceutical products, pharmaceutical preparations	Switzerland	5
Rubber and plastic products	Germany	3
Other non-metallic mineral products	Germany	2
Basic metals	Germany	2
Fabricated metal products, except machinery and equipment	Germany	2
Computer, electronic and optical products	Germany	5
Electrical equipment	Germany	2
Machinery and equipment n.e.c.	Germany	2
Motor vehicles, trailers and semi-trailers	Germany	3
Other transport equipment	France	5
Furniture; other manufacturing	Germany	2
Repair and installation of machinery and equipment	France	4

Source Eurostat 2016, NACE Rev.2 A*64 classification

- New added-value products and product/services
- Advanced industrial engineering
- New business models
- Infrastructure and education
- Emerging manufacturing sciences and technologies

The financial crisis of 2007–2008 showed even more the importance of manufacturing in the European economy. A *recovery plan* for the European economy was published in 2008 [19], leading to the formation of Public Private Partnerships (PPP)

between the European Commission and private companies to support the investments in strategic areas and activities:

- Factories of the Future (FoF)⁷
- Energy-efficient Buildings (EeB)
- Sustainable Process Industry (SPIRE)
- European Green Vehicles Initiative (EGVI)

After the initial PPPs proved the viability of the approach, other PPPs were launched in the following years:

- Robotics
- Photonics
- Advanced 5G networks for the Future Internet (5G)
- High Performance Computing (HPC)

Each PPP is linked to an association representing the private side that interfaces with the public sector (i.e. the European Union). EFFRA⁸ (European Association for the Factories of the Future) is the private association of FoF PPP and is composed of companies, trade associations, universities and research institutes. During the years EFFRA produced strategic roadmaps continuously updating the research priorities based on the socio-economic context and the technological progress. The first strategic multi-annual roadmap [20] identified four industrial needs and R&D challenges:

- Sustainable manufacturing
- High performance manufacturing
- ICT-enabled intelligent manufacturing
- Exploiting new materials through manufacturing

In 2013 EFFRA prepared a new multi-annual roadmap [21] providing input for the definition of open calls in the Horizon 2020 Program.⁹ The following research and innovation priorities were proposed:

- *Advanced manufacturing processes.* The products of the future are expected to be more complex (3D, nano-micro-meso-macro-scale, smart), therefore innovative manufacturing processes need to be developed to provide complex and enhanced functionalities in a cost effective way.
- *Adaptive and smart manufacturing systems.* The manufacturing industry of the future should also respond and adapt in an agile manner to the mutating market and factory demands, developing innovative manufacturing equipment at component and system level, including mechatronics, control and monitoring systems while exploiting intelligent robots and machines that can work with human operators in a safe, autonomous and reliable manner.

⁷<https://www.ffa.eu/factories-future>.

⁸<https://www.ffa.eu/>.

⁹<https://ec.europa.eu/programmes/horizon2020/>.

- *Digital, virtual and resource-efficient factories.* Industrial plants (assets, inventories, production and assembly lines) need to be designed, monitored and maintained through new paradigms based on integrated and scalable digital factory models with multi-level semantic access to all the factory resources (i.e. assets, machines, workers and objects).
- *Collaborative and mobile enterprises.* A strong collaborative network and a highly dynamic supply chain are becoming more and more key factors for manufacturing companies. Innovation efforts to make collaborative enterprises mobile enable to quickly take decisions along the value chain. Innovative and user friendly mobile manufacturing applications help to take the decisions independently from the location of the enterprise or the decision-maker.
- *Human-centred manufacturing.* Future factories can increase flexibility, agility, and competitiveness by enhancing the role played by workers that continuously develop their skills and competencies. New technologies help to transfer skills to new generations of workers, while assisting ageing, disabled and multi-cultural workers with better information.
- *Customer-focused manufacturing.* Customers have been demonstrating to be able to influence product development, therefore factories of the future will need to follow a user-centred paradigm to make an impact on the market. Customers will be involved in the manufacturing value chain, from product and process design to innovative services by collecting explicit or tacit customer requirements.

Taking in consideration the wave of Industry 4.0, EFFRA produced recommendations for the work programme 18-19-20 of the FoF PPP under Horizon 2020 [22] by identifying five key priorities:

- Agile Value Networks: lot-size one and distributed manufacturing.
- The Human Factor: human competences in synergy with technological assets.
- Excellence in Manufacturing: advanced manufacturing processes and services for zero-defect processes and products.
- Interoperable digital manufacturing platforms: connecting manufacturing services.
- Sustainable Value Networks: manufacturing in a circular economy.

Several platforms, networks and clusters have been created in the European countries aiming at fostering economic and industrial innovation. For instance, the *Platform Industrie 4.0* in Germany,¹⁰ *Usine du Future*¹¹ and *Alliance Industrie du Futur*¹² in France, *Catapult* network¹³ and its *High Value Manufacturing (HVM)* division¹⁴ in UK, *Piano Impresa 4.0*¹⁵ and the Technology Cluster *Intelligent Factories*¹⁶ in

¹⁰<https://www.plattform-i40.de>.

¹¹<http://industriedufutur.fim.net/>.

¹²<http://www.industrie-dufutur.org/>.

¹³<https://catapult.org.uk/>.

¹⁴<https://hvm.catapult.org.uk/>.

¹⁵<http://www.sviluppoeconomico.gov.it/index.php/it/industria40>.

¹⁶<http://www.fabbricaintelligente.it/english/>.

Italy (see Sect. 1.4.2). Furthermore, the German, Italian, and French governments launched a *Trilateral Cooperation for Smart Manufacturing* in 2017 to promote digitising manufacturing. This cooperation deals with three topics: (1) Standardisation and reference architectures; (2) small and medium-sized enterprises (SMEs) engagement and testbeds; (3) Policy support.

As it happened in Europe, also the USA acknowledged the central role of manufacturing after the 2008–2009 crisis. The American Recovery and Reinvestment Act of 2009 [23] included two billion dollars dedicated to grants for the manufacturing of advanced batteries and components, a temporary expansion of availability of industrial development bonds to facilities manufacturing intangible property (i.e. patents, know-how, copyrights, formula and similar categories), and credit for investment in advanced energy facilities. The report on *Ensuring American Leadership in Advanced Manufacturing* [24] pointed out that the United States was losing the global leadership in manufacturing while other countries were advancing their industries and R&D. Advanced manufacturing is essential to national security and has the potential to create and retain high-quality jobs in the United States. In particular, the report advised the Federal Government to launch an Advanced Manufacturing Initiative (AMI) providing coordinated federal support to academia and industry, public-private partnerships, development and dissemination of design methodologies, shared facilities and infrastructure to help SMEs. This recommendation led to the creation of *Manufacturing USA*¹⁷ (also known as the National Network for Manufacturing Innovation program) after the *Revitalize American Manufacturing and Innovation Act of 2014* was approved [25]. *Manufacturing USA* takes care of coordinating federal resources and programs and has already established 14 manufacturing innovation institutes based on public-private partnerships.

1.4 Italian Research Initiatives on Manufacturing

Similarly to what happened at international level (Sect. 1.3), a set of complementary actions have been established also at Italian level to involve and enhance manufacturing excellences in the international competitive scenario, paying particular attention to advanced and high value added manufacturing. Among these actions, the National Research Program (PNR, Programma Nazionale della Ricerca) 2011–2013 [26] identified two key initiatives: Flagship Projects (Sect. 1.4.1) and Technological Clusters (Sect. 1.4.2). More recently in 2017, the Ministry of Economic Development in Italy (MISE) designed the *National Plan Enterprise 4.0* (Sect. 1.4.3).

¹⁷<https://www.manufacturingusa.com/>.

1.4.1 *Flagship Projects*

Flagship projects are research programmes approved by the Interministerial Committee for Economic Planning (CIPE) and funded by the Italian Ministry of Education, Universities and Research (MIUR) to address strategic themes that represent a national priority. These themes were selected after an assessment based on the contributions provided by public research bodies. PNR 2011–13 identified 14 flagship projects and, among them, seven were coordinated by the National Research Council of Italy (CNR), including the project *Factories of the Future (La Fabbrica del Futuro – Piattaforma manifatturiera nazionale)* that will be presented in Sect. 1.5. Indeed, according to PNR, CNR has a multi-disciplinary mission supporting MIUR, fostering the Italian presence in international projects, and facilitating the integration of various actors (e.g. research institutes, universities, local institutions, governmental institutions, companies and industrial consortia) involved in research activities by favouring the technology transfer. The total budget allocated to flagship projects was equal to 1.77 billion euro.

1.4.2 *Technological Clusters*

Technological Clusters¹⁸ are networks of public and private partners working at national level to foster industrial research, education and training, and technology transfer. The main goal is to gather and better exploit resources to answer the specific needs of the regions and markets.

Each cluster is dedicated to a focused technological and application area playing a relevant role for the national population. Clusters are supposed to coordinate proposals and strategies to increase innovation and industrial competitiveness by means of the following actions:

- Positioning the national research and industrial system in the international scenario.
- Collecting and sharing best practices and competences while fostering networking and collaborations between industry and research.
- Supporting the cooperation between national, regional and local policy makers in the research and innovation field.
- Optimising the exploitation of research and innovation programs that are coherent with the national and European initiatives.
- Working to create the best environment to attract investments and competencies.
- Promoting *Made in Italy* excellence.

In 2012 the MIUR Ministry, after assessing various proposals, approved the institution of eight technological clusters: Aerospace (Aerospazio), Agrifood, Green Chemistry (Chimica verde), Intelligent Factories (Fabbrica Intelligente), Transport and mobility systems of land and ocean surface (Mezzi e sistemi per la mobilità

¹⁸<http://www.miur.gov.it/cluster>.

di superficie terrestre e marina), Advanced Life Science (Scienze della Vita), Smart Living Technologies (Tecnologie per gli ambienti di vita), Smart Communities Technologies (Tecnologie per le Smart Communities). Four technological clusters were added in 2016 to fully cover the 12 research priority areas defined in the PNR for years 2015–2020: Cultural Heritage Technologies (Tecnologie per il Patrimonio Culturale), Design, creativity and Made in Italy (Design, creatività e Made in Italy), Maritime economy (Economia del Mare), Energy (Energia).

Among the technological clusters, the Cluster Intelligent Factories¹⁹ (CFI) is focused on the manufacturing domain and developed a Roadmap for research and innovation including the following strategic action lines [7]:

- Strategies for personalised production.
- Strategies, methods and tools for industrial Sustainability.
- Factories for Humans.
- High-efficiency production systems.
- Innovative production processes.
- Evolutive and adaptive production systems.
- Strategies and management for next generation production systems.

1.4.3 *National Plan Enterprise 4.0*

The *National Plan Enterprise 4.0* (Piano Nazionale Impresa 4.0)²⁰ was developed by MISE to provide the manufacturing companies with incentives for investments in innovation and competitiveness, mainly focused on digitising industry (so-called *Industry 4.0*). The plan includes the following main initiatives:

- Super- and hyper-depreciation as a way to support the implementation of advanced technologies in Italian manufacturing companies.
- Support for companies requesting bank loans to invest in capital goods, machinery, plant, and digital technologies.
- Tax credit for research and development.
- Special rate of taxation for revenues related to the use of intellectual property rights (e.g. industrial patents).
- Support for innovative start-ups and SMEs.
- Supports for large investments in the industrial, tourism and environmental protection sectors.
- Co-funding of projects related to industrial research and experimental development of new products, processes, services or the relevant improvement of already existing ones.
- Support for the training of employees in the areas of sales and marketing, computer science and techniques, production technologies.

¹⁹<http://www.fabbricaintelligente.it/english/>.

²⁰<http://www.sviluppoeconomico.gov.it/index.php/it/industria40>.

Among the ongoing initiatives coordinated by MISE it is possible to mention the Lighthouse Plants, i.e. greenfield or brownfield production plants that are designed to make extensive use of Industry 4.0 technologies. A lighthouse plant is characterized by a significant innovation project (10 million euro or more) that continuously provides results to be implemented into the production plant. Therefore, the lighthouse plant is designed to evolve through the years while becoming a national and international reference to show best practices for technological development. The Cluster Intelligent Factories supports MISE to identify and propose lighthouse plants and later to coordinate the awareness and dissemination of their results. Currently, four Lighthouse plants have already been approved by MISE and two of them started their activities (cf. Chap. 21 for a detailed description of the Lighthouse plants initiative [27]).

1.5 Flagship Project Factories of the Future

The Italian Flagship Project *Factories of the Future*²¹ (*La Fabbrica del Futuro – Piattaforma manifatturiera nazionale*) is one of the 14 Flagship Projects (Sect. 1.4.1) that started in January 2012 and lasted till December 2018 with a total funding of 10 million euro. CNR was the coordinator of this flagship project and played a key role both as research body and also as facilitator and integrator of the various actors involved in the activities: research institutes, universities, government institutions, manufacturing companies and industrial consortia.

The flagship project defined five strategic macro-objectives (Sect. 1.5.1) for factories of the future to be pursued thanks to the development, enhancement, and application of key enabling technologies (Sect. 1.5.2). The strategic macro-objectives took inspiration from the research priorities identified at international level (Sect. 1.3), while considering the evolution of the global industrial contexts (Sect. 1.1) and, above all, the peculiarities of the Italian manufacturing context (Sect. 1.2).

The flagship project was organised into two subprojects to create a stable national community characterized by scientific excellence of research. *Subproject 1*²² aimed at establishing a multi-disciplinary cooperation among research organisations operating in specific scientific domains to exploit synergies for the development of integrated solutions. The goal of *Subproject 2*²³ was to strengthen the systemic cooperation among national research centres and universities with complementary competences.

Each subproject published a call for proposals based on the strategic macro-objectives to increase the competitiveness of the Italian manufacturing industry, paying particular attention to *Made in Italy* products in the global context. Section 1.5.3 presents the calls for proposals and the evaluation process that led to the selection

²¹<http://www.fabbricadelfuturo-fdf.it/?lang=en>.

²²<http://www.fabbricadelfuturo-fdf.it/projects/subproject-1/?lang=en>.

²³<http://www.fabbricadelfuturo-fdf.it/projects/subproject-2/?lang=en>.

of 18 small-sized research projects. The key results of the funded research projects together with the main dissemination activities of the flagship project are presented in Sect. 1.5.4.

1.5.1 Strategic Macro-objectives

Five strategic macro-objectives were defined for factories of the future:

- Evolutionary and Reconfigurable Factory (Sect. 1.5.1.1)
- Sustainable Factory (Sect. 1.5.1.2)
- Factory for the People (Sect. 1.5.1.3)
- Factory for Customised and Personalised Products (Sect. 1.5.1.4)
- Advanced-Performance Factory (Sect. 1.5.1.5)

These objectives are not disjoint and must be intended as complementary perspectives concurring together to build the holistic concept of *Factories of the Future*.

1.5.1.1 Evolutionary and Reconfigurable Factory

A relevant characteristic of high-tech *Made in Italy* products (e.g. machinery, medical equipment, mechanical products, textile and wearing apparel) is the continuous reduction of product life cycles, because of the fast innovation of materials, ICT, artificial intelligence, mechatronics, and the fast evolving needs of the client.

Complex and variable market demands combined with the technological evolution of products and processes lead to the need of factories that are able to react and evolve themselves by exploiting flexibility [28], reconfigurability [29], changeability [30–32], and scalability [33] to stay competitive in dynamic production contexts [34].

Enabling technologies (Sect. 1.5.2) such as high automation, ICT tools, digital twins, and an integrated and efficient logistics can provide factories with the ability to change processes and configurations in a fast and cost effective way.

Hence, production systems must be endowed with operational flexibility and a high reconfigurability to cope with the co-evolution of product-process-manufacturing systems [35]. Production systems will be required to evolve and reconfigure themselves at various factory levels, from the global logistics network to the single production resource. The factory evolution will consist of changes and reconfiguration of production resources and system layout, and changes in planning and production management policies.

Specific research and innovation topics for *evolutionary and reconfigurable factories* will cover:

- Development of new methodologies and tools to model and design flexible and reconfigurable production systems [29], control systems, automation systems [36], machines and fixtures [37].

- Development of methodologies to support the integrated design of products-processes-systems in evolution [35].
- Design of optimisation approaches to reduce set-up and ramp-up times in production systems [38].

1.5.1.2 Sustainable Factory

The concept of *green products* has a strong impact on the global scenario and involves also *Made in Italy* products. According to the Life Cycle Assessment (LCA) approach, *green products* must be characterized by a limited environmental impact during their whole life cycle, including the production phase [39, 40]. Therefore, sustainable production requires factories to guarantee limited energy consumption of industrial plants, systems, and processes, while producing limited industrial waste and consuming a reduced amount of natural resources [41].

Factories will have to be compliant with stricter and stricter energy consumption and emissions regulations, considering both the consumption of the workstations and the lighting and conditioning systems of the building. Factories will be able to reduce their environmental impact also by exploiting clean energy sources, cogeneration, industrial symbiosis [42] as well as re-using any available source. In addition, factories will have to be sustainable also from a societal perspective, integrating worker skills and contributing to the growth of the local economies [43]. Furthermore, besides being sustainable in the production, there is the need of a new generation of factories able to manage the final stages of the product life cycle by implementing product de-manufacturing, re-manufacturing, reuse, recycling and recovery, thus generating new opportunities and resources (de-production factories) [44]. Both production and de-production factories must be part of a network that is sustainable as a whole in terms of supply chain management and overall business model [45].

Research and innovation lines for *sustainable factories* include:

- new materials and production technologies exploiting renewable and green sources of energy and wastes of production processes [46];
- ICT tools and digital twins supporting the integrated control and management of factories, considering energy and environmental aspects of both productions systems and buildings [47];
- methodologies and tools for the modeling, design and management of processes, machines, systems and factories characterized by an efficient consumption of resources [41];
- methodologies and tools to model and design new products endowed with many lives since their conception;
- human-robot interaction and artificial intelligence to disassemble products after their use [48];
- new business models for an efficient exploitation of production resources, through the offer of targeted services [49];

- methodologies and tools for the modeling, design and management of factories for de-manufacturing able to regain the functions of the products and their components [50].

1.5.1.3 Factory for the People

Factories of the future must be designed and managed taking in due consideration societal and demographic changes such as the increase in the retirement age of workers and the global aging of the population (see Sect. 1.1). Technologies, machine tools and workplaces will be designed not only for young employees but also for workers with relevant accumulated knowledge [51]. The complexity and evolution of the working environment will require continuous training of the workforce [52].

Indeed, manufacturing history shows that culture, know-how and skills of the workers play a key role in the success of manufacturing companies. Therefore, decisions regarding the factory design and location cannot be taken while considering only short-term cost minimisation, but it is necessary to fully evaluate the socio-economic impacts of phenomena like industrial de-localization [43].

The continuous improvement of robotics and automation technologies will make human-machine interaction even more relevant in the future of manufacturing. New forms of interactions must be investigated to better exploit human-machine cooperation in a shared and safe manufacturing environment [53].

Safety and ergonomics have a strong impact on productivity and profitability, therefore they should be addressed in a proactive way and not only in reaction to regulations [54].

New factories will provide an environment where people can face difficult production contexts characterized by products with short life cycles and high variability, thus requiring a quick adaptation of the production systems and the generation of new knowledge. Operators must be trained in a multidisciplinary way to flexibly manage the planning and execution of complex production plants. Furthermore, the high rate of technological obsolescence requires more and more attention to the ease of use of production resources, placing people in a central position within the factory environment. Specific research and innovation topics to develop *factories for the people* will include:

- study of socio-economic aspects to assess the impact and exploitation of knowledge and technology, considering standardisation and ethical issues;
- development of technologies that can improve working conditions thanks to ergonomic studies, reduction of risks related to dangerous processes by means of higher automation and remote control [55], more effective training using augmented and virtual reality [56], reduction of noise emissions [57] and air pollution, and telework;
- interactive human-intelligent machines cooperation in the factory environment to better exploit human intuition and skills in changing working conditions [48];

- development of adaptive and reactive human-machine interfaces (voice recognition, gesture recognition, autonomous moving machines) to better support an effective collaboration.

1.5.1.4 Factory for Customised and Personalised Products

The offer of personalised products and services that are difficult to replicate allows competing with high value-added products in the global market. This represents an important strategic opportunity for the Italian manufacturing industry that is traditionally focused on meeting the customer requirements by exploiting process and product know-how together with an attitude for innovation. This is particularly relevant in sectors such as textiles, wearing apparel, footwear, glasses and accessories, luxury goods, and furniture.

A full personalisation based on the specific customer needs (e.g. biometric characteristics, non-standard size and shape) represents an evolution of the *mass customization* concept offering products in pre-defined variants [58]. This asks for shifting the focus from high production volumes, process capability, component standardisation and modularity to factories able to offer *one-of-a-kind* products [59]. The production of personalised products asks for factories implementing fast innovation cycles thanks to modern technologies and approaches that can further increase flexibility, efficiency and ability to offer highly personalised products in a very short time [60].

Customer-driven factories can be designed thanks to a close cooperation with end users. Indeed, the collection and analysis of customer preferences through innovative technologies and the testing of product prototypes can help to improve the customer experience along all the phases of the product life cycle [61].

Factories for customised and personalised products will have to address the following research and innovation lines.

- ICT tools to support product personalisation (e.g. augmented and virtual reality [62], design and simulation of human-product interaction);
- new business models to optimise production and logistics supporting the *one-of-a-kind* paradigm;
- new approaches for the design, management and cooperation of supply chains and single manufacturing companies aimed at the production of personalised products [63];
- new tools and services based on innovative monitoring and maintenance techniques to support the use of products along their life cycle [64].

1.5.1.5 Advanced-Performance Factory

The production of customised and evolving products in a sustainable and human-oriented way poses serious challenges for the factory performance. High-performance factories will meet the demand by minimising all the inefficiencies

associated with internal and external logistics, management of inter-operational buffers, transformation processes and their parameters, management and maintenance policies, software and hardware tools, quality inspection and control techniques. Both production systems and production processes can concur to increase the factory performance if monitoring data are properly collected [65]. Necessary enabling technologies include advanced sensors, innovative mechatronic components, ICT platforms [66], and digital twins [67–69].

The elaboration of data collected from the field with innovative techniques including data fusion and artificial intelligence, will enable advanced-performance factories to autonomously identify the causes of anomalies, failures and disturbances, implement adaptive strategies (e.g. predictive maintenance) modify operating modes so that the factory can constantly operate in conditions of high efficiency and zero defects [47].

Increasingly efficient transformation processes will reduce cycle times of the transformation operations, thus improving also the factory service level. New transformation processes will be needed to produce new products making use of innovative materials.

Specific research and innovation topics to develop *advanced-performance factories* will include:

- new high-performance transformation and transportation processes and systems;
- digital twins of processes, machines and systems [70] together with model predictive control and multicriteria optimization.
- models and platforms for the collection and fusion of shop floor data aimed at improving the technical efficiency of the production systems also by means of artificial intelligence [71];
- methodologies to support the design and modeling of quality control systems, management policies [47], and maintenance policies;
- new hardware and software solutions, data fusion, digital twins and artificial intelligence to continuously monitor and optimize manufacturing systems performance.

1.5.2 Enabling Technologies

Enabling technologies are technologies with a high content of knowledge and capital that are associated with intense research and development activities, involving highly skilled employment [72]. These technologies are characterized by rapid and integrated innovation cycles and *enable* innovation in a wide range of applications involving products, services, processes, and systems. Enabling technologies are of strategic importance at the systemic, multidisciplinary and trans-sectoral levels, because they incorporate skills deriving from different scientific-technological areas to induce structural changes and disruptive solutions with respect to the state of the art.

The list of enabling technologies has evolved during the last ten years depending on the technological progress. The list proposed by EFFRA in 2013 [21] included:

- advanced manufacturing processes;
- information and communication technologies;
- mechatronics for advanced manufacturing systems;
- modelling, simulation and forecasting methods and tools;
- manufacturing strategies;
- knowledge-workers.

Enabling technologies represent the basis for the innovation of *Made in Italy* production, providing solutions for a large number of applications and sectors that will offer new products and services. Herein, the following *enabling technologies* have been identified as relevant for factories of the future:

- Artificial Intelligence, digital twins, and digital factory technologies for intelligent factories;
- production technologies;
- de-manufacturing and material recovery technologies;
- factory reconfiguration technologies;
- control technologies of production resources and systems;
- resource management and maintenance technologies;
- technologies for monitoring and quality control;
- human-machine interaction technologies.

The wide adoption of ICT in manufacturing industry can help to improve the overall efficiency, adaptability and sustainability of the production systems. The interoperability among software tools and digital twins [67, 69] is crucial for sharing and transferring data along all the phases of the factory life cycle. For instance, integrated and interoperable solutions could include software tools for:

- Product Life-cycle Management (PLM) and platforms for Life-Cycle Assessment (LCA), at product level [40];
- wireless sensors and solutions for remote resources monitoring [65], CAD (Computer Aided Design), CAE (Computer Aided Engineering), Computer Aided Process Planning (CAPP), Computer Aided Manufacturing (CAM), at process level;
- evaluating the production system performance [73], multi-level simulation of reconfigurable factories, collaborative factory design in Virtual Reality (VR) [66] and Augmented Reality (AR) environments, ontologies for the conceptual modeling of the factory and its elements [74], at production system level.

Modern ICT offers new solutions (e.g. Cyber Physical Systems—CPS [75], Internet of Things—IoT [76], and Big Data Analytics [77]) with high potential impact on manufacturing. However, new digital technologies are associated with relevant challenges and risks for manufacturing companies because it is necessary to acquire or outsource advanced services, cyber security is under threat [78], and reference technical standard are still under development.

Factories of the future will have to adopt production technologies that enable the efficient use of resources [41] and are based on *clean* processes. Therefore, it is necessary to search for new processes characterized by low energy consumption, exploitation of renewable resources, increased efficiency and reduced emissions. New modular and flexible technologies will be needed for the production of non-standard products, even in small batches. Examples of enabling production technologies are high-speed machining, high performance tools, modular and reconfigurable handling technologies, non-conventional manufacturing processes (e.g. water jet, plasma, laser, ultrasonic machining—USM), micro-machining, micro-assembly and micro-factories [79].

Sustainable manufacturing involves both the production process and the management of the life cycle and reuse of materials and components [80]. Production technologies will have to minimise energy, materials' use, as well as the production of waste. The contribution of robotic disassembly technologies, advanced automation and human-robot cooperation will be fundamental to enable efficient re-use and re-manufacturing applications [48]. Finally, a key role is played by advanced technologies for the shredding and separation of materials to recover and recycle materials with commercial value.

New system and machine architectures enabling fast hardware and automation systems will provide competitive advantages to the factories of the future. Methodologies and tools to support the reconfiguration of machines and production systems will have to model uncertain information about the production context.

The design of control systems distributed over a network of heterogeneous devices is enabled by the introduction of advanced fieldbus communication techniques and intelligent devices endowed with microprocessors and programmable hardware. Traditional modelling techniques (e.g. based on IEC 61131 standard and programmable logic controllers - PLCs) are inadequate for distributed systems, since they can hardly meet the requirements of reusability, reconfigurability and flexibility for the development of control applications. Research on distributed and reconfigurable controls will rely on technical standards such as IEC 61499.

Production planning, scheduling and maintenance planning will have a strong impact on the performance of the factories of the future that are coping with changes in the market (e.g. demand) and the production environment (e.g. reconfiguration of the production system, availability of resources, etc.). An effective management of production resources can be supported by techniques such as reactive and robust production planning [81, 82], preventive and predictive maintenance [83], integrated production and maintenance planning, condition based maintenance (CBM), self-learning and self-organization algorithms for self-repair of systems.

Zero-defect production will enable factories of the future to increase their efficiency thanks to proactive improvement processes and intelligent measurement systems. The acquisition of data from the field requires designing accurate and low-cost sensor networks, whereas the elaboration of monitoring data asks for multi-resolution and multi-scale algorithms. Factory operations will be assisted by integrated methods that are able to process monitoring data and evaluate the system performance depending on possible adaptive reconfigurations.

Table 1.2 Calls for proposals

Call for proposals	N. submitted proposals	N. funded projects	Total cost [million euro]	Duration	Participants
Subproject 1	22	9	5.8	2 years	CNR institutes
Subproject 2	21	9	3	1 year and 4 months	CNR institutes and universities
Prototypes	15	14	1.4	4 months	CNR institutes and universities

Factories of the future will need to cope with the continuous increase of factory automation. Efficient and reactive technologies for human/machine interactions in advanced production environments will guarantee employment levels and ergonomics [53]. Innovative industrial robots will perform a wide range of tasks in spite of significant knowledge gaps. Advanced graphical interfaces will enable the use of increasingly complex software tools. Virtual and digital environment will be used to support training and enhance human skills [56].

1.5.3 Calls for Proposals and Research Projects

Each call for proposals of the two subprojects included four macro-objectives selected among the ones defined in Sect. 1.5.1 to demonstrate how enabling technologies (Sect. 1.5.2) can be developed and applied to innovate manufacturing processes. The project proposals had to follow a template consisting of project description, partnership, and impact. An additional call for proposals was published to enhance the result of the previously funded research projects through the development of hardware/software prototypes.²⁴

Table 1.2 reports the summary of the three calls for proposals, pointing out the total cost of the research projects (including co-funding), the number of submitted and funded proposals, the duration of the projects and the admissible participants. Manufacturing companies could not be funded, but each proposal had to include an Industrial Interest Group to prove that manufacturing companies are interested in the proposed research topics.

Table 1.3 and Table 1.4 report the topics included in the call of Subproject 1 and Subproject 2, respectively.

The submission and evaluation of the project proposals were managed through a third-party informative system provided by CINECA²⁵ (Italian consortium of universities and research centres) to guarantee robustness and maintain anonymity along the

²⁴<http://www.fabbricadelfuturo-fdf.it/projects/prototypes/?lang=en>.

²⁵<https://www.cineca.it/en>.

Table 1.3 Topics of the Subproject 1 call for proposals

Macro-objective	Call topic
Advanced-Performance Factory	Mechatronic devices for high-performance factories
	Innovative technologies to realise components with advanced functional properties
Evolutionary and Reconfigurable Factory	Evolving and reconfigurable control
Factory for the People	Design and development of robotics systems cooperating with human operators
Sustainable Factory	Sustainable and interoperable factories
	De-manufacturing factories

Table 1.4 Topics of the Subproject 2 call for proposals

Macro-objective	Call topic
Factory for Customised and Personalised Products	Methodologies for the joint design of customised and personalised products, processes and productions systems
Evolutionary and Reconfigurable Factory	Optimisation of co-evolution of production systems
Factory for the People	Human-machine interaction technologies
Sustainable Factory	Technologies and methodologies for sustainable factories

Table 1.5 Reviewers and reviews

Call	N. national reviewers	N. international reviewers	N. reviews
Subproject 1	19	8	66
Subproject 2	17	9	63

process. The proposals were evaluated by a set of independent national and international reviewers selected from a pool of 167 experts registered in the MIUR database. The reviewers for each proposal were automatically selected by an algorithm based on matching between the call topic and the expertise of the reviewer, both of them identified by ERC (European Research Council)²⁶ keywords. Three reviewers (two national and one international) were assigned to each proposal and each reviewer evaluated a maximum of three proposals (Table 1.5).

The project proposals were evaluated by the reviewers according to the following criteria:

- Technical-scientific quality (max 5 points, threshold 4 points)
- Project organization and planning of activities (max 5 points, threshold 3 points)
- Scientific and industrial impacts (max 5 points, threshold 3 points)

²⁶<https://erc.europa.eu/>.

Table 1.6 Subproject 1 research projects

Acronym	Research project title	Macro-objective
GECKO [84]	Generic Evolutionary Control Knowledge-based mOdule	Evolutionary and Reconfigurable Factory
Zero Waste PCBs [85]	Integrated Technological Solutions for Zero Waste Recycling of Printed Circuit Boards (PCBs)	Sustainable Factory
FACTOTHUMS [86]	FACTORY Technologies for HUMans Safety	Factory for the People
SNAPP [87]	Surface Nano-structured Coating for Improved Performance of Axial Piston Pumps	Advanced-Performance Factory
NanoTWICE [88]	composite Nanofibres for Treatment of air and Water by an Industrial Conception of Electrospinning	Advanced-Performance Factory
PLUS [89]	Plastic Lab-on-chips for the optical manipULATION of Single-cells	Advanced-Performance Factory
MaCISte [90]	Mature CIGS-based solar cells technology	Advanced-Performance Factory
MECAGEOPOLY [91]	Mechano-chemistry: an innovative process in the industrial production of poly-sialate and poly-silanoxosialate geopolymeric binders used in building construction	Advanced-Performance Factory
SILK.IT [92]	Silk Italian Technology for Industrial Biomanufacturing	Advanced-Performance Factory

Finally, the Executive Committee (consisting of Director, vice-Director, Subproject 1 coordinator and Subproject 2 coordinator) of the flagship project approved the ranking of the proposals based on the evaluation of the reviewers and published the list of funded projects. Table 1.6, Table 1.7, and Table 1.8 report the list of funded projects after the Subproject 1, Subproject 2, and Prototypes calls, respectively.

1.5.4 Results of the Flagship Project

A total of 21 CNR institutes and six universities participated in the 18 funded research projects. In addition, 55 private companies joined the various Industrial Interest

Table 1.7 Subproject 2 research projects

Acronym	Research project title	Macro-objective
IMET2AL [93]	genomIc Model prEdictive ConTrol Tools for evolutionAry pLants	Evolutionary and Reconfigurable Factory
Pro2Evo [94]	Product and Process Co-Evolution Management via Modular Pallet configuration	Evolutionary and Reconfigurable Factory
WEEE Reflex [95]	Highly Evolvable E-waste Recycling Technologies and Systems	Evolutionary and Reconfigurable Factory
PROBIOPOL [96]	Innovative and Sustainable Production of Biopolymers	Sustainable Factory
Xdrone [97]	Haptic teleoperation of UAV equipped with X-ray spectrometer for detection and identification of radio-active materials in industrial plants.	Factory for the People
Made4Foot [98]	Innovative Methodologies, ADvanced processes and systEms for Fashion and Wellbeing in Footwear	Factory for Customised and Personalised Products
Fab@Hospital [99]	Hospital Factory for Manufacturing Customized, Patient Specific 3D Anatomico-Functional Model and Prostheses	Factory for Customised and Personalised Products
POLYPHAB [100]	POLYmer nanostructuring by two-PHoton Absorption	Factory for Customised and Personalised Products
CHINA [101]	Customized Heat exchanger with Improved Nano-coated surface for earth moving machines Applications	Factory for Customised and Personalised Products

Groups, thus effectively creating a large community working on topics for factories of the future.

The main scientific results of the research projects are summarised in Table 1.9 in terms of publications on international journals, proceedings of international conferences, and chapters of international books. The citations of the journal articles demonstrate how the results of the research have already achieved a scientific impact, even though the publication date is still recent. In addition, two patents were successfully published.

The flagship project as a whole was disseminated during more than 20 national and international events related to manufacturing industry and research. In particular, synergies were established with the Italian Cluster Intelligent Factories (Sect. 1.4.2) and with European initiatives such as *Manufuture* and *EFFRA* (Sect. 1.3).

Table 1.8 Prototype projects

Acronym	Prototype title	Related research project
AUTOSPIN	Automated electrospinning plant for industrial manufacturing of functional composite nanofibres	NanoTWICE
APPOS	Axial Piston Pump Prototype Assembled with Oleophobic Surfaces Components	SNAPP
AWESOME	Advanced and WEearable SOLUTIONS for human Machine interaction with Enhanced capabilities	FACTOTHUMS
CD-NET	Tool for Customer-driven Supply Networks configuration	Made4Foot
F@H for 3D plates	Fab@Hospital for bone plate fabrication and patient anatomy reconstruction using rapid prototyping technologies	Fab@Hospital
IC+	Imaging Citometry in Plastic Ultra-mobile Systems	PLUS
PCB-ID	In-line automated device for the identification of components and the characterization of materials and value in waste PCBs	Zero Waste PCBs
Pro2ReFix	Product and Process Co-Evolution Management via Reconfigurable Fixtures	Pro2Evo
ProBioType	Prototyping ProBioPol results	PROBIOPOL
ProBioType II	Prototyping ProBioPol Results II (UV/TiO ₂ Photocatalytic Reactor)	PROBIOPOL
Rolling CIGS	Roll-to-roll deposition of flexible CIGS-based solar cells	MaCIS _{Te}
ShredIT	Self-Optimizing Shredding Station for Demanufacturing Plants	Zero Waste PCBs
THESIS	Thermally Improved Heat Exchangers prototypes with Superhydrophobic Internal Surfaces: new assembly procedures and materials	CHINA
WEEE ReFlex CPS	Cyber-Physical System (CPS) for reconfigurable e-waste recycling processes	Weee ReFlex
X-Drone2	Improved Haptic-guided UAV for detection and identification of radioactive materials	XDrone

Table 1.9 Scientific results of the research projects

Research project	Int'l journal articles	Citations of int'l journal articles ^a	Int'l conference articles	Int'l book chapters	Presentations at conferences and workshops
IMET2AL	2	9	1	1	1
Pro2Evo	5	78	7	2	4
GECKO	3	34	20	1	3
WEEE Reflex	1	0	8	1	8
PROBIOPOL	2	14	11	1	11
Zero Waste PCBs	0	0	5	1	7
FACTOTHUMS	7	28	38	1	2
Xdrone	1	1	2	1	5
Made4Foot	2	7	7	1	6
Fab@Hospital	10	36	6	2	6
POLYPHAB	3	8	4	1	1
CHINA	5	33	5	1	2
SNAPP	5	35	8	1	6
NanoTWICE	6	78	15	1	12
PLUS	15	398	12	1	15
MaCISte	6	30	5	1	2
MECAGEOPOLY	1	6	3	1	4
SILK.IT	11	102	2	1	9
Total	85	897	159	20	104

^aRetrieved on 13th July 2018

The flagship project participated in the BI-MU²⁷ 2016 exhibition in Milan. BIMU is the largest Italian fair of machine tools and other capital goods related to manufacturing and is the second largest exhibition in this field in Europe. The Flagship Project *Factories of the Future* presented the results to the selected public attending the exhibition by organising a stand (Figs. 1.2 and 1.3) of 170 m² dedicated to the 14 prototypes (Table 1.8) resulting from the activities of various research projects (Fig. 1.4).

Four conferences of the flagship project were organised in 2012, 2013, 2016 and 2018. During these conferences the calls for proposals and/or the results of the research projects were presented.

The Final Event of the Flagship Project was conceived as a one-week national research road-show (26–30 November, 2018) visiting laboratories of institutes and universities that are active on advanced manufacturing research. Forty young researchers participated in the final event to work on new ideas for factories of the future in a creative and multi-disciplinary environment.²⁸

²⁷<http://www.bimu.it/en/>.

²⁸<http://eventofinale.fabbricadelfuturo-ffd.it/>



Fig. 1.2 *Factories of the Future* stand (left side) at BI-MU 2016 exhibition



Fig. 1.3 *Factories of the Future* stand (right side) at BI-MU 2016 exhibition

The flagship project promoted an international collaboration with *Automotive Partnership Canada* after a memorandum of understanding between CNR and the Natural Sciences and Engineering Research Council of Canada (NSERC). In this



Fig. 1.4 Examples of the Prototypes at the *Factories of the Future* stand: **a** ShredIT, **b** X-Drone2 (left) and IC+ (right), **c** ProBioType II (left) and Pro2ReFix (right), **d** ProBioType

framework a concurrent call for joint research projects²⁹ was launched in the area of manufacturing research, with the Canadian side focusing on automotive manufacturing. The collaboration resulted in one joint research project [86].

Finally, this very book represents a contribution to the dissemination of the whole flagship project. The following chapters will present in details the scientific and industrial results of the 18 research projects (see Tables 1.6 and 1.7) [84–101]. Grounding on the experience and results of the flagship project, the final two chapters of this book present an outlook on future manufacturing research by proposing *missions* aimed at fostering growth and innovation [102] and discussing research infrastructures and funding mechanisms [27].

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²⁹http://www.apc-pac.ca/Apply-Demande/CanIta-CanIta_eng.asp.

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