Defining a Collaborative Framework for Roadmapping Activities

Rosanna Fornasiero and Tullio A. M. Tolio

Abstract Today, more than ever, it urges to increase effort for monitoring and investigating changes in environment, particularly in relation to events in the social, economic, political and ecological landscapes as well as new technologies. Roadmapping activities are based on techniques and practices to analyse the "state" of a system and to identify evolution of emerging drivers. Roadmapping methodologies can support in understanding the impact of drivers on the competitive position of system under consideration and on the advantage of answering to these drivers. This chapter proposes a collaborative framework, designing it with the aim to involve several stakeholders with an iterative approach to consult and validate the results collected from literature and state-of-the-art and to share knowledge in a context where system competitiveness is considered as a precondition for individual benefit. Overall, this work contributes to improve the effectiveness of strategic roadmapping and to increase its value added to the planning process of clusters and in general of large groups of interest, while providing helpful insight to public organizations that promote the competitiveness of related sector under consideration.

Keywords Roadmapping · Collaboration · Manufacturing · Systemic approach

1 Introduction

Literature recognises the relevance of technological roadmapping activities as fundamental elements supporting strategic decisions for R&D policy definition both at private and public level. In particular, the aim of roadmapping is to identify development paths to help a system to acquire competitive advantage facing exogenous factors while implementing reactive and pro-active actions. Trends and weak signals

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R. Fornasiero and T. A. M. Tolio (eds.), *The Future of Manufacturing: The Italian Roadmap*, Springer Tracts in Mechanical Engineering,
https://doi.org/10.1007/978-3-031-60560-4_1

detection become of strategic importance in a context of turbulent environment and increasing complexity. Technological changes like acceleration in digital transformation, production systems innovation, social changes like increase in aging people, evolution of consumer tastes, etc., and political changes like protectionism, trade barriers etc. are only some of the possible factors to be taken into consideration when starting a roadmapping activity.

The roadmapping activities represent a process to be implemented both by single company willing to re-position itself in the market as well as by heterogenous group (i.e. associations, clusters, production networks) willing to understand environment and to position in a macro-scenario where several factors need to be taken into consideration. In this last case (heterogeneous group of interest), it is necessary to have a wide and comprehensive approach that involve many different actors and stakeholders each bringing to the discussion specific interests to balance appropriately these contributions. The perspective is different from the single company and the aim is to define strategies to be taken for the overall group and to bring to the attention of the policy makers a strategic view which is necessary to be shared.

The creation of the roadmap is a structured process based on visions of the future addressing multiple influencing factors and their inter-relationships. From the methodological point of view, there are several papers proposing review of methods and tools to be applied in the fields of future studies, foresight, forecasting, strategy for the future, etc. There is no standard classification of these methods, but when designing a roadmap framework, it is important to consider trade-offs in roadmapping like: top-down versus bottom-up, explorative versus normative, quantitative versus qualitative, and expert-based versus assumption-based.

A multi-stage approach should assure the coverage of different dimensions through quantitative and qualitative methodologies to integrate and cover the following aspects (Popping 2008):

- Evidence: collect evidence using methods based on codified information, data and indicators etc. like literature review, scanning, benchmarking to get the status of the things;
- Interaction: assure interaction using methods based on participation and shared views of technical experts and market experts, like workshops, multi-criteria methods, stakeholder analysis;
- Creativity: enhance creativity of experts by methods relying heavily on the inventiveness of individuals with strategic vision on the future (like general managers, highly qualified researchers);
- Expertise: gathering Expertise using methods to extrapolate tacit knowledge of people to gain relevant information with tools like expert panels, surveys, qualitative and quantitative scenarios.

Therefore, in the last years, the Cluster of Intelligent Factories has defined and tested a collaborative framework where methodologies like online consultation, scenario definition, expert panels, literature review and others have been set in an integrated way to support the development of a roadmap applied to an heterogenous

group of interest. This pool of methodologies was used as a strategic guideline for the medium-long term roadmapping not only at National but also at regional level.

The path followed by the Cluster to define the roadmap is based on honing a framework that—by integrating different approaches that have also been acknowledged in scientific literature—has allowed to gather and formalize the opinions of the various actors within the actual Cluster or operating within its orbit.

An analysis of the current landscape has been a necessary preparatory phase providing a snapshot of the Italian and global situation and an insight into how manufacturing is reacting to shifting market conditions, in an attempt to extrapolate the industry's strengths and weaknesses. In terms of empirical data, a number of databases, such as the World Bank, OECD, Eurostat, ISTAT, have been used to support the analysis of the general situation, and data from Italian manufacturers associations Federmacchine and UCIMU have been used for a more focused look at the machine tools sector.

In terms of policies, the roadmap's reference points are European documents (such as Next Generation EU, Manufuture's SRIA, and programming documents from the Made in Europe partnership), Italy's national PNR and PNRR documents, and the Regional Specialization Strategies.

This phase also drew on trend analysis documents and grey literature such as consultancy reports (e.g. Roland Berger, McKinsey, Deloitte, PwC and EY), and reports from associations (e.g. Confindustria think tank-CSC, Edison Foundation, trade associations) to understand what the social, economic, environmental and political trajectories look like, and define reference scenarios that include a number of major radical changes in the landscape that are inextricably linked to manufacturing.

The definition of scenarios is a starting point for understanding what the society and global economic structure change factors are and how they affect the industry. They also highlight that the combined effects of certain trends—such as an aging population, the shortage of resources and their overexploitation, climate change, technological acceleration, and opening up of new markets—create unprecedented challenges that call for a transformation of the Italian manufacturing system.

In light of these scenarios, the technological roadmapping activities conducted by the CFI Cluster to identify the priorities and technology trajectories of the area of specialization have been based on findings that have emerged from interaction over the last two years with all the actors within the Cluster's own ranks.

2 The Collaborative Framework

The management structure of the Cluster of intelligent Factories is based on the collaboration of several bodies that have been involved in the various phases of the roadmap's definition (Fig. 1) which are:

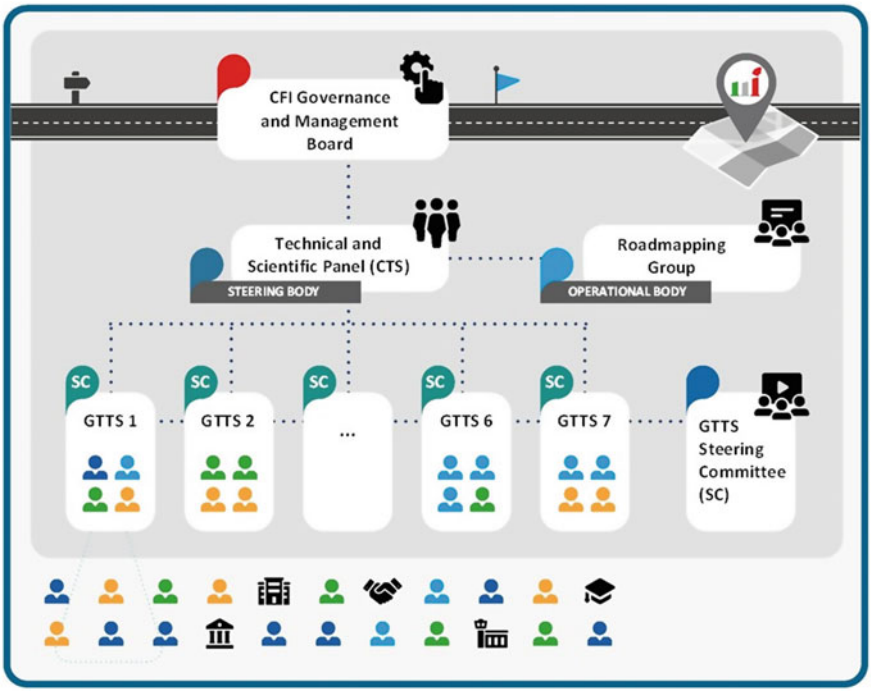

Fig. 1 Organisation structure of the cluster of intelligent factories

- Technical and Scientific Panel (CTS) with the role to orient and coordinate the scientific activities of the roadmap group and the technical groups (GTTS). In addition, CTS aligns with the Cluster's coordination and management board (OCG) for the purpose of document validation and to activate the process of member consultations.
- Roadmap group (GRM) with the role to support CTS in the definition and development of the methodology to be used in the roadmapping process, and provide operational support to the steering committees and GTTS in identifying the themes to be developed and in compiling the document.
- Technical groups (GTTS): 7 groups organized along the different themes identified by the Cluster. Comprising the Cluster's members, these groups are involved in the roadmapping activities through seminars, consultations, brainstorming sessions and workshops to determine the challenges and research and innovation themes.
- Companies with Lighthouse plant projects: Emblematic companies that, with the Cluster's support, develop Lighthouse projects (financed by Ministry of Economic Development and regional funding) based on cutting-edge plants powered by industry 4.0 technologies.

- Pathfinders: companies with a prominent position on the national and international stage for the development of enabling technologies for manufacturing. They are involved in the roadmapping processes to help identify the development trajectories of a specific technology in which they are leaders, and in the demonstration of those enabling technologies as part of the Lighthouse project and associated Supply Chain and Open Innovation activities.
- Members and supporting members involved on a regular basis through a variety of initiatives across the roadmap's various development phases, such as consultations, online surveys, workshops and seminars.
- Coordination and management board (OCG), in addition to its role of managing the Cluster from a strategic point of view, is also tasked for this specific exercise with approving and orienting roadmapping activities, coordinating with CTS on an ongoing basis.

More specifically, a significant role in drawing up the roadmap's strategic action lines was played by the 7 Steering Committees of the GTTS, which have guided the specific theme definition process. In particular, each Steering Committee is composed of 7–10 members appointed by their respective institutions to represent them based on a selection process involving stakeholders like industry (through the industry confederations Confindustria and Confartigianato), research bodies (through Deans and directors of Universities and Research organisations) and regional bodies (through regional associations and clusters).

The collaborative framework is based on several iterative steps like (Fig. 2):

- Periodic consultation with members, initiatives with Pathfinders and Lighthouse plants with methods like online surveys, interviews and focus groups;
- Analysis and elaboration of scenarios, analysis of industrial statistics; analysis of international, national and regional policy documents;
- Document preparation where GRM and steering committees of the 7 GTTS elaborate the contribution collected from the consultation and from the analysis to deliver reports to the CTS of the Cluster;
- Webinars and meetings with members to dissemination contents like through open innovation mechanisms or through meetings with regional authorities;
- Review and validation where the CTS reviews the content produced, interact with GRM and steering committees to improve content and to refine it for final validation by OCG.

The Table 1 below illustrates the most important steps of the collaborative framework taken over this two-year period (2020–2022), which have involved the actors listed.

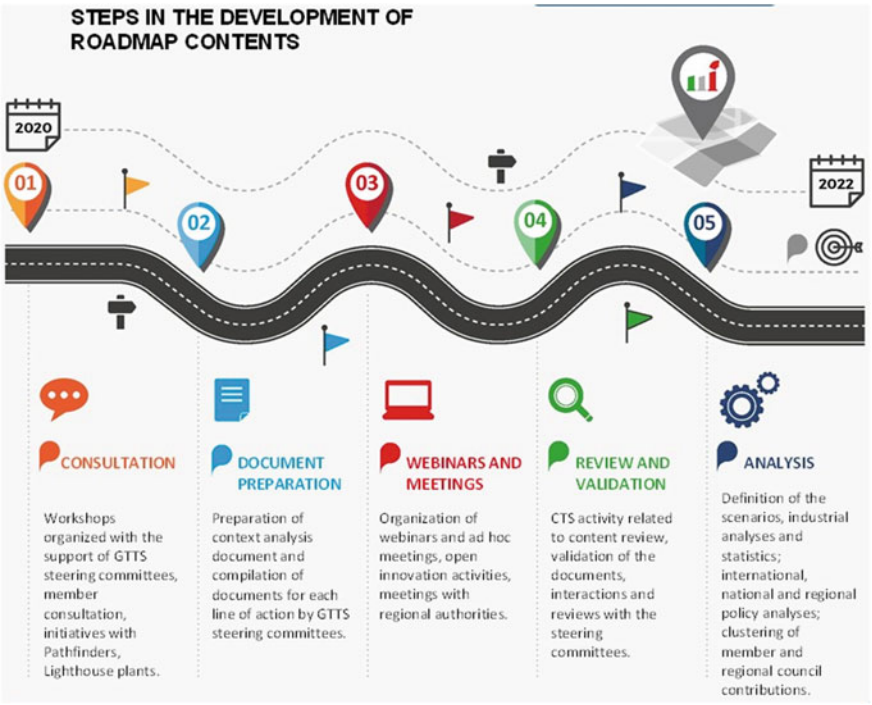

Fig. 2 Steps of the collaborative approach for the roadmap definition

3 Roadmap Structure for the Cluster of Intelligent Factories

The roadmap of the Intelligent Factories is set upon 7 strategic action lines that represent the paths along which Italian manufacturing's research and innovation priorities are developed. The objective of the strategic action lines is to respond to specific challenges generated by the market and by the acceleration of technological development.

More specifically, they represent trajectories against which companies can measure their own progress and develop research and innovation pathways, also taking into account the context scenarios, such as new consumption models, circular economy, electric mobility, knowledge management, digital platforms and climate change.

Each strategic action line comprises research and innovation priorities (PRI) within which research and development goals are defined that can help with the planning of short-, medium- and long-term actions both at company and at supply chain level and, above all, at the coordinated country level.

A number of strategic action lines has been identified that have been informed by the market and by the need to research and develop new models, methods and

Table 1 Steps and actors involved along the collaborative approach

Timing	Main actors involved	*n. people involved*	*Activities*
Q1-2020	Steering Committees, CTS and roadmapping group	*60*	*Meeting for the definition of work structure, planning and timing*
Q1-2020	Cluster members	*200*	*Online consultation for gathering of research and innovation ideas and needs*
Q1-2020	Initiatives with Pathfinders	*50*	*Webinars for the definition of technology trajectories*
Q2-0.2020	Initiatives with Lighthouse Plants	50	*Webinars on their ongoing projects for the definition of the market trajectories*
Q2-2020	Steering Committees of the GTTS groups	*60*	*Content analysis and clustering of research needs gathered from members and formulation of research and innovation priorities (PRI)*
Q3-2020	Cluster Members and GTTS groups	*200*	*Meetings and webinars to present PRIs and gather other research needs*
Q3-2020	Roadmap group and CTS	*15*	*Analysis of statistics on manufacturing sector*
Q3-2020	Steering Committees of the GTTS groups	*60*	*Formulation of documents for each action line*
Q1-2021	CTS and Steering Committee meetings	*70*	*Discussion of documents and revision proposals by CTS*
Q1-2021	Roadmap group and CTS	*15*	*Definition of reference scenarios and analysis of European, national and regional strategies*
Q2-2021	Cluster members and GTTS groups	*200*	*Online consultation and validation of action lines and PRIs*
Q2-2021	Regional bodies and Roadmapping group	*20*	*Sharing of PRI contents with bodies representing the Regional Councils*
Q2-2021	Pathfinders and Lighthouse plants	*100*	*Sharing of PRIs through open innovation*
Q3-2021	Regional bodies and Roadmapping group	*20*	*Mapping of regional Smart Specialization priorities with Cluster's PRIs*
Q3-2021	CTS and Roadmapping group	*15*	*Final review of documents by CTS*
Q1- 2022	CTS and Roadmapping group	*15*	*Review of the reference scenarios*

(continued)

Table 1 (continued)

Timing	Main actors involved	*n. people involved*	*Activities*
Q1-2022	Roadmap group and Steering Committees	*70*	*Final review and tuning the document*
Q3-2022	Cluster Management Board	20	*Release of the final document*
Q1-2023	Cluster Management Board	20	*Issue printed version of the roadmap*

technologies to meet the society challenges that companies find themselves facing (Fig. 3). The 4 action Lines are as follows:

- LI1: Personalised production
- LI2: Industrial sustainability
- LI3: Enhancing human resources
- LI4: High efficiency and zero-defect

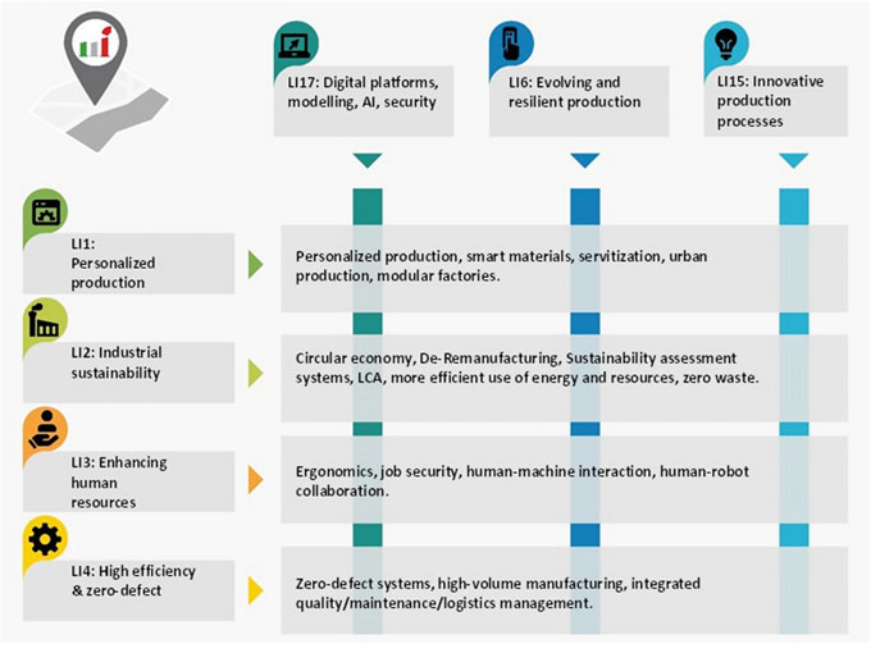

Fig. 3 Intersection of market oriented strategic action lines

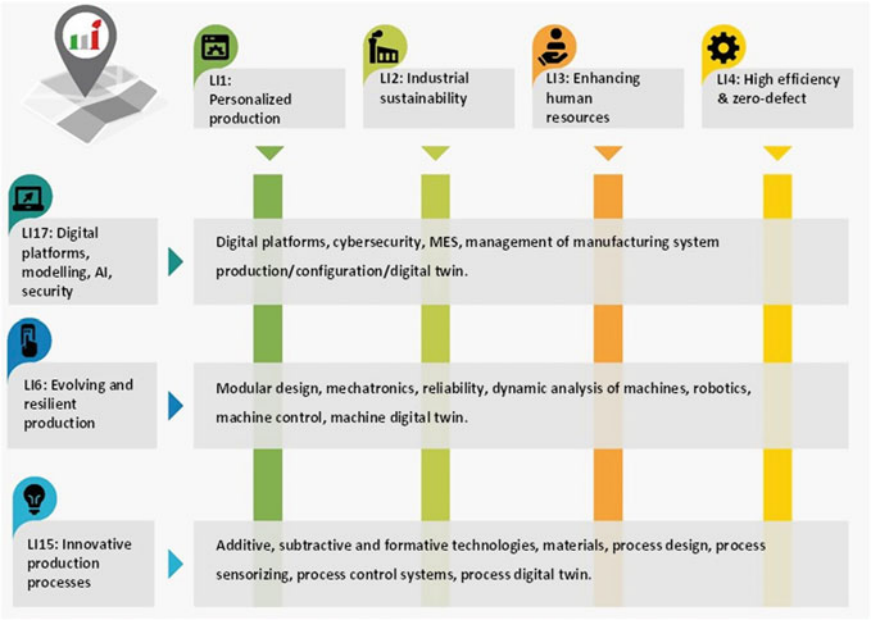

Fig. 4 Intersections of the technology push strategic action lines

The other 3 strategic actions lines have been identified as stemming from the need to research and develop new technologies that support the manufacturing sector at different levels (Fig. 4), namely:

- LI5: Innovative production processes
- LI6: Evolving and resilient production
- LI7: Digital platforms, modelling, AI, security

Below is a brief summary of the objectives of each strategic action line and the relevant research and innovation priorities.

LI1-Personalized production: the objective of this action line is to propose research and innovation priorities aimed at promoting industrial systems and models for the efficient manufacture of customized products that can be reconfigured with fast turnarounds to meet specific requests fielded from individual customers or small groups, and that deliver a high level of integration with the customers in order to ensure they become the main actors of the resulting solution. These design and production systems must be conceived to have the capacity to be reconfigured for the manufacture of products that can be required in certain times of emergency (such as health emergencies) or in response to events that can cause a sudden shift in system priorities and require the industrial system to transfer its focus to different categories of products to those usually made. In this action line, it will be important to research new supply chain management models and local manufacturing models as well as smart materials.

LI2-Industrial sustainability: the objective of this action line is to propose research and innovation priorities aimed at transforming the industrial processes involved in the design and manufacture of new products of the future in line with circular economy principles, in order to significantly reduce carbon emissions and improve energy efficiency, reduce and rationalize consumption of resources, facilitate and promote their recovery and recycling. In addition to recovering and recycling materials, it is important to orient future production models towards product re-purposing and the recovery and recycling of raw materials. These actions must be aimed at preserving the value of activities involved in transforming raw materials into products. These changes require the introduction of new processes, new machinery and new systems, resulting in a thorough overhaul of the national manufacturing base, opening up new capital goods markets that will see Italy claim a leadership position.

LI3-Enhancing human resources: the objective of this action line is to propose research and innovation priorities aimed at designing and developing new solutions to enhance the role of human resources and their skills, and contribute to their satisfaction and wellbeing; research and experimentation of new technologies for reducing physical exertion, cooperation with advanced support systems, with collaborative robots and with AI-powered technologies; mapping of knowledge generated on the job, especially implicit knowledge, in a way that is compatible with privacy requirements, introducing advantages both on the human wellbeing front—whether the individuals are users, operators or managers—and in terms of business strategies and procedures. In this regard, innovative factories will need to be increasingly inclusive, strongly geared towards the engagement and participation of individuals (users, operators and managers). These models must take a human-centric approach to look into/investigate new technologies and all the dimensions through which the new factory is defined.

LI4-High efficiency and zero-defect: the objective of this action line is to propose research and innovation priorities aimed at researching models for efficiency in terms of: zero-defect technologies designed to reduce non-conformances, monitoring of processes during the various phases, quality management, maintenance and internal logistics of a manufacturing system, upgrading and improving the capacity of equipment and industrial goods; robustness/flexibility as the capacity to face disruptions, due to the precarious supply of incoming materials and parts, and to the specific properties of the material (anisotropy, low rigidity, etc.); smart systems for optimized use of available resources (equipment, human operator, knowledge) and for the control and management of production systems through models (CPS, empirical models, etc.).

LI5: Innovative production processes: the objective of this action line is to propose research and innovation priorities across various aspects of production processes, such as: digitization of conventional production processes in order to improve their interactions and handle different types of processing, even by means of hybrid processes; the growing role of additive manufacturing and its ensuing challenges in terms of both design and production; processing of standard and innovative materials, or materials with meso/macro geometries, including also nano- and

micro-manufacturing. In addition, process innovation also needs to take the shape of innovation in support of re- and de-manufacturing processes, to start with, through to the development of bio-inspired transformation models.

LI6-Evolving and resilient production: the objective of this action line is to propose research and innovation priorities aimed at researching and developing evolving and resilient production systems by exploiting a high degree of machine automation and self-learning, with levels of autonomy and adaptive intelligence designed to facilitate the operators' job. The priority research topics concern: modelling and simulation for the design and management of production systems, and hardware and software technologies for production system reconfigurability. The technology enablers are linked to the availability of smart modular devices that can be integrated wireless in a transparent, autonomous way, capable of monitoring and controlling manufacturing assets and products, and supporting decision-making, ensuring ready access to all necessary operational, configuration, fault and maintenance data.

LI7-Digital platforms, modelling, AI, security: the objective of this action line is to propose research and innovation priorities aimed at researching and developing innovative digital architectures for the monitoring, control and management of manufacturing activities and related assets, modelling new products/services and production processes, use of Al, Big Data and adequate Cybersecurity systems. More specifically, the LI7 line research and innovation priorities assume 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.

It is expected that the impact derived from the implementation of the roadmap's contents embraces a number of different aspects, such as:

- Creation of new jobs in manufacturing and greater attractiveness of these positions, thanks to improved security, ergonomics and inclusion; the integration of industry into the urban environment will be facilitated to focus on specific consumer needs like comfort, health and wellbeing.
- Increase in the value added of manufacturing activities, through improved positioning of Italian businesses in the global value chain to cater to the needs of emerging markets, improving the competitive positioning of the companies in question.
- Reduction of manufacturing's environmental impact through reduced greenhouse gas emissions caused by manufacturing activities; reduced energy consumption and consumption of materials generated by manufacturing activities; reduced product waste from manufacturing activities; and the creation of green products and green technologies.
- Growth in R&D investments in manufacturing, exploiting the opportunities offered by the current technological acceleration mainly linked to the development and integration of digital technologies. The creation of integrated research

and innovation paths will also be promoted: starting with fundamental research, they will progress through research and innovation to lead to the development of knowledge in industrial fields.
- The development of specific local skills through the integration of actions at a national and regional level.

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