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Strategic Research Agenda

Report of the High-Level Group
September 2006

Assuring the future of manufacturing in Europe

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PREFACE

"Strong reasons make strong actions."
William Shakespeare

Manufacturing is the dominant sector of the European economy. Since each job in manufacturing is linked to two additional jobs in high quality services, Furthermore, it also exerts a strong technology pull on research and innovation – so the EU depends strongly on the dynamism of its manufacturing industry! Putting knowledge and innovation at the heart of European growth is therefore a must.

Speeding up the rate of industrial transformation to high-added-value products, processes and services was the key message from a recent meeting of a group of leading European industrialists. This document presents a concise strategic master-plan for realising that goal, and thus keeping Europe at the forefront in manufacturing.

I would like to thank all the members of the High Level Group, and, especially the Support Group members, for the time and attention they have devoted to this exercise. I also wish to thank the European Commission services of the Enterprise, Information Society and Research Directorates-General for their support to the Manu*future* initiative

Finally, I would like to express gratitude to those numerous contributors who have commented on the draft versions of this document.

Heinrich FLEGEL
DaimlerChrysler, Chairman of Manu*future* High Level Group

MANU*FUTURE* PLATFORM

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MANUFUTURE SRA

BACKGROUND

The Manu*future* European Technology Platform was launched in December 2004 in Enschede, the Netherlands, with the publication of 'Manu*future* – a Vision for 2020'. This document resulted from detailed analyses carried out by a High Level Group formed a year earlier, composed of high-ranking representatives from European industry and the scientific community. The vision document recommended the preparation of a more detailed Strategic Research Agenda (SRA), paving the way for the definition of research priorities to be implemented via the EU's future RTD Framework Programmes, in coordination with initiatives at Member State, regional and individual stakeholder levels.

Produced with the help of a specially convened Support Group, the resultant SRA recommends employing the Seventh Framework Programme (FP7) as the means to move towards a new manufacturing paradigm and to outline a roadmap for industrial transformation, making synergistic use of all available resources. Its proposed solutions and research priorities – the so-called 'pillars' – are anchored in a number of recent strategic foresight studies, reports and workshops. Among the most significant are MANVIS (Manufacturing Visions – integrating diverse perspectives into pan-European foresight) and FuTMaN (Future of manufacturing in Europe 2015-2020 – the challenge for sustainable development).

The SRA is intended as a tool for further action, rather than an implementable roadmap in itself. A first version was presented at the Manu*future* 2005 conference in Derby, UK, forming the basis for on-going consultation with all interested stakeholders in the run-up to the launch of FP7. This process was completed in June 2006.

The present document summarises the consensus reached, taking into account all of the received comments. Its findings, collated by the Support Group with the help of Commission staff, constitute an ambitious plan inviting European organisations to invest in a set of targeted research, innovation and education activities that could transform the competitive basis of producing and delivering products and services that reach a new level in satisfying society's desires and expectations.

The Manu*future* initiative stems from the understanding that Europe's future will depend on the retention of a healthy manufacturing industry. There is thus an urgent need to take advantage of the historic opportunity provided by FP7 to help shape this future. As a next step, it is therefore recommended that the described methodology be used to produce specific technology roadmaps, both horizontal and sectoral, to define priorities for the first calls for proposals.

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EXECUTIVE SUMMARY

The Manu*future* Technology Platform aims to provide an analysis and methodology leading to a transformation of European manufacturing industry into a knowledge-based sector capable of competing successfully in the globalised marketplace.

The economic importance of sustaining a strong manufacturing base in Europe is evident from the fact that it provides jobs for around 34 million people, and produces an added value exceeding €1 500 billion from 230 000 enterprises with 20 and more employees. Today, however, it faces intense and growing competitive pressure on several fronts. In the high-tech sector, other developed economies pose the greatest threat. On the other hand, manufacturing in more mature traditional sectors is increasingly migrating to low-wage countries such as China and India. And these, too, are rapidly modernising their production methods and enhancing their technological capabilities.

Moreover, the short-range perspective of some shareholder considerations leads to a disproportionate loss of European technology to outside countries, causing a destruction of work-places that cannot be repaired by technology alone

A step further

A number of 'vertical' technology- or sector-specific action plans and Technology Platforms have already been established, or are in the course of preparation. Manu*future* goes a step further by addressing underlying 'horizontal' approaches applicable across a broad spectrum of industries.

It advocates the use of existing and new science-based solutions to transform European industry in ways that will strengthen its ability to compete in terms of high added value, since purely cost-based competition is unsustainable. By formulating synergistic fields of action and research, it also pursues the goal of maintaining the Community's social and sustainability standards, while making efficient use of Europe's remaining resources.

In this SRA, the priorities for maximising added value are outlined in a strategic perspective linking the principal drivers of change with a series of 'pillars' of activity spanning the short- to long-term timeframe.

The SRA identifies the key drivers as:

- competition, especially from emerging economies;
- the shortening life cycle of enabling technologies;
- environmental and sustainability issues;
- socio-economic environment;
- regulatory climate; and,
- values and public acceptance.

The countermeasures for competitive and sustainable reaction to these challenges are seen in terms of five priority pillars and their associated enabling technologies:

- new, high- added-value products and services;
- new business models;
- new manufacturing engineering;
- emerging manufacturing science and technologies;
- transformation of existing RTD and educational infrastructures to support world-class manufacturing, fostering researcher mobility, multidisciplinarity and lifelong learning.

Concentration on these actions will attract high value manufacturing industry, as well as the other fundamental actors such as universities and research centres, even from outside Europe.

Role for collective research

Collective research will certainly have a central part to play in realising the transformation, but technology alone will not meet the objectives of the Lisbon and Barcelona Councils. Understanding of business and financial mechanisms, implementation of new business models and restrengthening of the ethical and social core values of European enterprises will all be required – as will the realisation of scientific innovation in traditional technology areas. Only by involving the largest possible number of stakeholders – notably the existing and proposed Technology Platforms, whether applied at EU or national/regional level, and the innovative SMEs and other independent enterprises that figure largely in the structure of all manufacturing sectors – can today's knowledge be applied to structure manufacturing as a new engineering science bringing sustainable results for Europe.

Traditionally, European products are associated with high quality, appealing design and cutting-edge technology. The effectiveness of the Manu*future* research agenda in transforming industry will depend upon manufacturers' readiness to leverage these strengths, while adapting continuously to the changes necessary in an open, fast-moving global industrial marketplace.

Developments in enabling technologies such as innovative materials, nanotechnologies, ICT and mechatronics give almost limitless possibilities to develop new products or add functionality to existing products. European industry must have access to these technologies and to the tools for incorporating them into product designs.

Research topics to be supported should nevertheless have real industrial relevance and produce measurable impact in terms of marketable products/services or more efficient manufacturing methods. Programmes should therefore be conceived in order to reward results rather than efforts – which implies a substantial parallel investment in the improvement of existing technologies.

From products to product/services

The market increasingly demands products that are customised, yet available with short delivery times. Consequently, the business focus must shift from designing and selling physical products, to supplying a system of products and services ('product/services' or 'extended products') that are jointly capable of fulfilling users' demands, while also reducing total life-cycle costs and environmental impacts.

Innovating production

A fundamental concept of the Manu*future* vision is that of 'innovating production', which embraces new business models, new modes of 'manufacturing engineering' and an ability to profit from ground-breaking manufacturing sciences and technologies.

The 'virtual factory' of the future will manufacture in adaptable networks linking medium- and large-sized OEMs (original equipment manufacturers) with value-chain partners and suppliers of factory equipment/services selected according to needs at a given time. Its composition will not be limited by the presumption of physical co-location, nor by a need to maintain rigid long-term relationships.

This will demand a tremendous and concerted effort. At the heart of the new enterprises will be knowledge management, network management, and relationship management based on trust and ethics. The understanding that Europe and its population cannot forever live on a cushion of welfare underlines the fact that there is no other way into the *future* but to network globally in a reliable way.

Favourable climate

Reaching these objectives will depend on the implementation of supportive fiscal and legislative framework conditions at EU market level. A consensus of support for the Manu*future* vision will naturally enable a European Manufacturing Innovation and Research Area (EMIRA) to be created as an integral part of the European Research Area. It will promote the interests of European manufacturing industry, take account of regional and national needs, promote participation in European programmes (Framework Programmes, Eureka and other initiatives) and recognise Europe's wider role in the global RTD network.

1. The new global industrial revolution: a challenge for Europe

Globalisation is bringing about a new industrial revolution, leading to unprecedented worldwide distribution of production, products and services. It is affecting all countries and economical regions, with the new emerging countries (NECs) seeming to take the greatest advantage by exploiting their low labour costs. The advanced nations find increasing difficulty in competing on this ground.

At the same time a new knowledge-based economy is emerging, with profound effects on markets, society and technology. This calls for a new approach to manufacturing, based on high value addition and the incorporation of knowledge content at all levels The paradigm was described in 'Manu*future* – a Vision for 2020', and is the basis of this SRA.

Both developed and developing countries are already addressing this challenge. But it is advanced nations – such as those in Europe – that, for the time being, are in a better position to develop, implement and exploit the new concepts embodied in Manu*future*. They have an outstanding record in scientific and technological achievements related to knowledge-based manufacturing, and show the highest concentration of universities, institutes and research centres involved in it.

The move to Manu*future* should be seen as a transition from a traditional economy (land, labour and capital) to a knowledge-based economy (knowledge, reliable networks and capital) and, in turn, from an economy of use and waste to sustainable economy and development.

The above will require a radical and timely transformation of manufacturing industry and the related research and education infrastructures.

The transition from manufacture to Manu*future* can help the developed countries to play a leading role within the new and global industrial revolution. This approach, over time, would also be followed by NECs, thus bringing about progressive, balanced global economic growth and a sustainable development of all countries.

Because of the demographic trend towards an ageing population in Europe, the available workforce is declining, and only a small window of opportunity remains for change through closer cooperation. Such a transition process requires the involvement of all stakeholders, from industry to research, education, public institutions and the financial sector.

This science, technology and innovation plan is designed to foster a call for European organisations to invest in a joint effort to create a manufacturing industry capable of generating strong and sustainable economic growth for the EU in the globalised marketplace. It seeks to direct investment towards an ambitious but realistic set of targeted research, innovation and educational activities that would transform the competitive basis of producing and delivering products and services for a society with rising expectations.

The present report is not meant to be a specific work programme, but rather proposes a generic methodology whereby medium- to long-term strategic and innovative measures can be undertaken using the available means in a synergistic way to accomplish the required transformation of European industry.

Contribution to Global Output Shares of World Manufacturing Output by Civilization or Country, 1750-2000 (in percentages. World=100%)

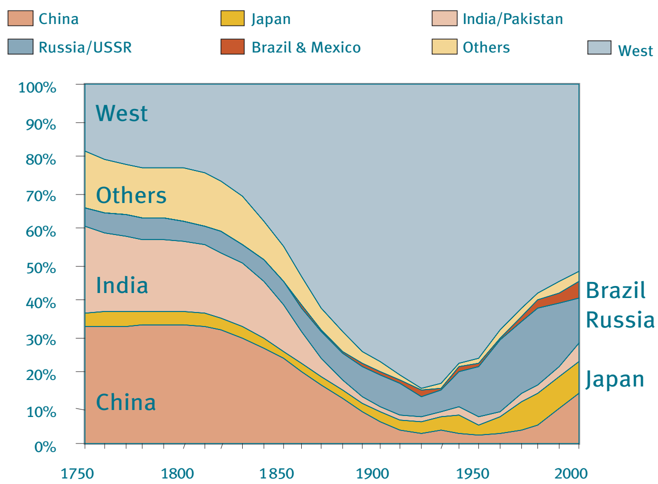


Figure 1: Output share from the first industrial revolution (around 1800) to the emerging global industrial revolution

(Source: Tseng Mitchell M., "Industry development perspectives: Global Distribution of Work and Market", CIRP 53rd General Assembly, Montreal - Canada, 2003)

2. Economic importance and the Manu*future* process implementation

Around 230 000 European manufacturing enterprises with 20 and more employees provide 34 million people with jobs. In 2004, the value added by manufacturing amounted to more than ¤1 500 billion. Some 70% of this total was derived from six main areas – automotive engineering, electrical and optical equipment, foodstuffs, chemicals, basic and fabricated metal products, and mechanical engineering. Moreover, each job in manufacturing creates two more in manufacturing-related services.

Apart from its economic and social importance, the location of manufacturing industry in Europe contributes to sustainable development through more efficient production and reduced transport costs, thus supporting the aim of decoupling growth from increased resource use.

Another important argument, as advanced in the *FuTMaN* report (Future of manufacturing in Europe 2015-2020 – the challenge for sustainable development), is that: 'Not only does RTD drive new developments in manufacturing, but more importantly, manufacturing is the contextual driver for more RTD'.

Within management discussions, the conviction is growing that the trend to move manufacturing physically abroad leads to destruction of vital business interests. It not only means loss of revenue, but also places strains upon the communication channel between manufacturing and RTD centres. The development base will decline progressively, and with it, the ability to develop added-value products and services.

The short-range perspective of some shareholder considerations leads to a disproportionate transfer of European technology to outside countries, causing a destruction of work-places that cannot be repaired by a purely technological perception of business. To appreciate the error of such short-termism, it is important to note that there are highly profitable companies operating within Europe whose core businesses are in sectors long deemed lost to the region.

Leading the world

So far, European manufacturing remains a dominant force in international trade. In 2004, the EU's share of total global manufacturing trade was 18%, while the US had 12% and Japan 8%. In some key sectors such as automobiles, mechanical engineering, agricultural engineering and certain categories of telecommunications equipment, EU companies have even achieved global leadership. These show world-class competitiveness and account for 42% of total manufacturing exports, although mechanical engineering and chemicals alone account for 31%.

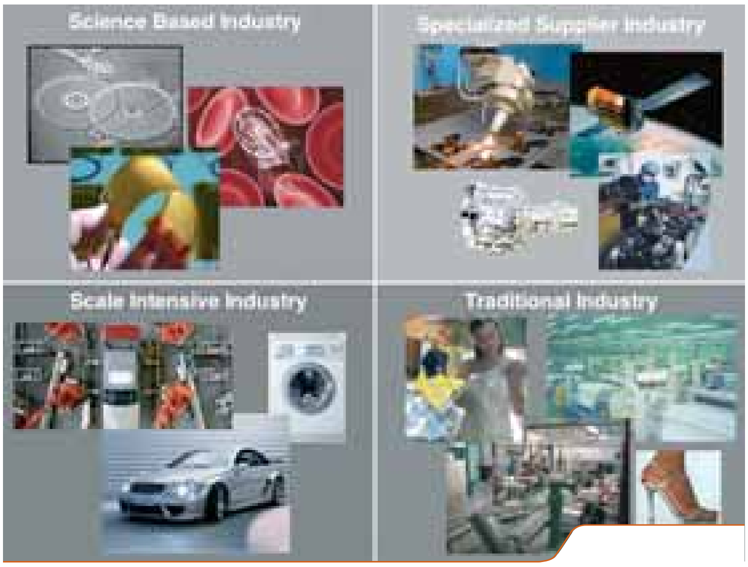


Figure 2: Manufacturing multisectoral industrial domains, following Pavitts classification

European Industry is concentrated in sectors whose added-value growth at global level will occur at a moderate rate. To ensure consistent returns, European industry must lead in those sectors. This requires adoption of the Manu*future* paradigm, which focuses on the realisation of a set of four strategic objectives:

- competitiveness in manufacturing industries;
- leadership in manufacturing technologies;
- eco-efficient products and manufacturing;
- leadership in products and processes, as well as in cultural, ethical and social values.

The inherent value of RTD for investors such as industries, research institutes, governmental and non-governmental organisations will be optimised through an infrastructure that permits open and inclusive pan-European communication in medium- and long-term activities. The goals are to encourage collaborative approaches towards high-level objectives; and, without relating directly to governments' policies, to gather the resources necessary to identify and unblock shared scientific and technological bottlenecks.

(1) Eurostat Business Statistics 2004
(2) http://europa.eu.int/comm/research/industrial_technologies/pdf/pro-futman-doc1-final-report-16-4-03.pdf

3. Response based on strategic analysis

To address the challenges facing European manufacturing, industry and policy-makers need to reconcile policies and approaches with the objectives of improved competitiveness and sustainable development.

Dramatic changes can occur over a time span of 10 to 15 years. Today, it is not only industrial labour that is cheaper in some regions outside Europe, but also engineering and management. Europe still has the possibility and means to counter this situation, but it must do so in a decisive, concentrated manner based on sound strategic analysis.

The research priorities proposed in this document are anchored in a number of recent strategic foresight studies, reports and workshops. Among the most significant are *MANVIS* (Manufacturing Visions – Integrating Diverse perspectives into Pan-European Foresight) and *FuTMaN*.
A common thread extracted from these studies points the way forward, via a new 'knowledge-based' manufacturing paradigm, the requisite roadmap for industrial transformation and its principal technology-, business- and framework-enablers. Adopting fresh views may, in some cases, even turn threats into new opportunities, leading to the birth of new (often mini) European multinational companies generating knowledge and retaining know-how in Europe.

3.1 Knowledge-based manufacturing

European manufacturing has huge potential to generate wealth, jobs and a better quality of life. It is generally knowledge-intensive, embracing many different sectors, from capital equipment, through intermediate-tech traditional products, to more labour-intensive industries. As the mainstay of the European economy and employment, however, manufacturing industry must continually adapt in order to survive in a globalised economy.

New paradigm needed

The current industrial paradigm is no longer adequate. On the one hand, the EU faces continuing competition from other developed economies (e.g. Korea), particularly in the high-tech sector. On the other, manufacturing in more traditional sectors is increasingly taking place in low-wage countries such as China and India. The real dangers for Europe lie in the growing technical competence and rapid take-up of automation in these countries. Indeed, the thoughtless draining of intellectual resources and manufacturing capabilities to such locations, in the pursuit of short-term profit maximisation motives, is one of the greatest threats to the future of EU manufacturing.

Europe must respond by strengthening its ability to compete by adding value (Fig. 3) as the route to dominance, since purely cost-based competition is not compatible with the goal of maintaining the Community's social and sustainability values. Even for less technology-oriented industries that are physically tied to the European region, RTD must support continuous gains in productivity and efficiency, in order to maintain their competitiveness.

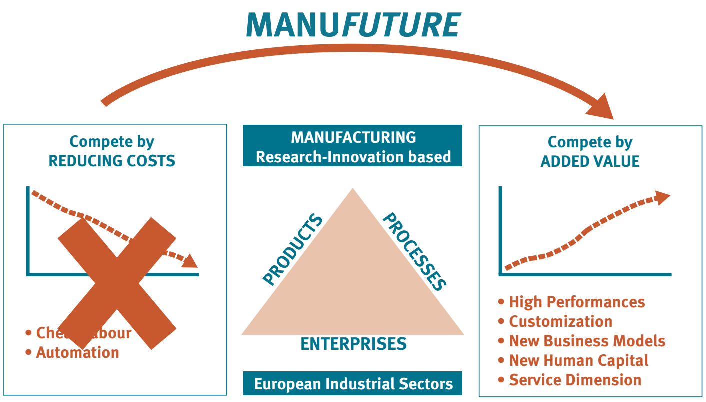


Figure 3: Competition shift – from cost reduction to high added value: Manu*future* (*Source ITIA-Series 2004*)

(3) http://www.manufacturing-visions.org/ManVis_Report_2_Final.pdf

3.2 A roadmap for industrial transformation

In the medium-term – i.e. up to the 2020 time horizon of the Manu*future* vision – foresight studies indicate both demand and opportunities for manufacturing. In summary, the main **drivers** of change are:

- competition, especially from emerging economies;
- the shortening life cycle of enabling technologies ;
- environmental and sustainability issues;
- socio-economic environment;
- regulatory climate;
- values and public acceptance.

The competitive and sustainable reaction to such challenges is seen in terms of **five pillars** and their associated **enabling technologies**:

1. added-value products and services;
2. new business models;
3. advanced manufacturing engineering;
4. emerging manufacturing science and technologies;
5. transformation of existing RTD and education infrastructures to support world-class manufacturing.

Appropriate knowledge-based solutions can be derived using the **industrial transformation reference model** shown in Fig. 4, with research areas and targets prioritised on the basis of criteria such as the expected value addition. This document proposes a framework for the necessary transformation of European industry and of the related RTD and educational infrastructures, under headings that correspond to each of the five pillars. The approaches used and the results obtained can be transferred to sectoral domains, according to their specific needs.

3.3 Multi-level action

For Europe to move towards knowledge-based manufacturing, it is essential to combine the interests of the various sectors of industry, and to coordinate their RTD efforts. Collective research will evidently have a central part to play in this process – reinforcing the European fabric by building networks of medium- and large-sized OEMs and other independent enterprises such as innovative SME suppliers, and technology and service providers – thus creating new kinds of supply chain, establishing RTD centres, etc.

Attaining the objectives of the Lisbon and Barcelona Councils will only be possible by involving as many as possible of the stakeholders and adopting best practices along the value chain. In this context, the benefit of co-operation between Manu*future* and the various existing and proposed Technology Platforms focusing on common goals and action plans – whether applied at EU or national/regional level, and whether sectoral or technological in scope – relates to the process of sharing the Manu*future* concepts and results, together with assessing a common 'core' of business areas of interest.

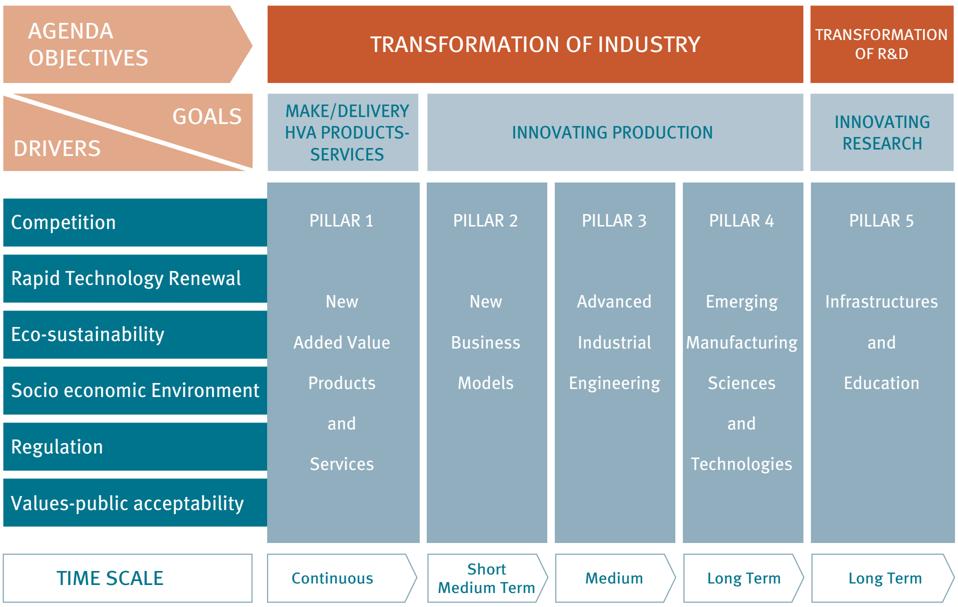


Figure 4: Industrial transformation reference model, guided by drivers and based on five priority pillars, to achieve an innovating environment for European enterprises. The time-scale indicates when impact should start to be realised.

The main recommendation of this SRA is the restructuring or transformation of manufacturing industry in Europe by adopting new business models that may require a completely new understanding of the function of products and services. It proposes a remodelling of manufacturing processes to introduce new forms of knowledge-management and engineering technology, in order to change from purely cost-based competition to the paradigm of high added value.

4. New added-value products and product/services

Traditionally, European products are associated with high quality, appealing design and cutting-edge technology. In many industrial sectors, they continue to compete successfully in the marketplace. However, it is becoming increasingly difficult for Europe to contend in those areas where labour charges form a significant part of the overall manufacturing costs. In addition, the window for generating profits is becoming smaller and smaller as competitors are fast to get on-board. Often, they are able to undercut the price of the market pioneer – unless copying of the idea is too difficult (by design of the product/service, coupled with strong protection of intellectual property) to allow market entry.

Although the European manufacturers can make significant headway in improving the competitiveness of their manufacturing processes, competing on cost, quality and delivery alone will not provide a viable solution – therefore products made in Europe must evolve into high-added-value product/services.

While the importance of high-added-value products is indisputable, it must be emphasised that **continuous innovation in manufacturing processes as well as in products** will be central to tomorrow's dynamic businesses. Europe must keep investing in fundamental scientific research, as many of the modern-day industries have emerged from a science base.

High-added-value products are created by a synergistic combination of various attributes and technologies, which together make them stand out from global competitors. A promising product, in itself, is only one part of the equation. Without the right business model, a highly developed production process and a competitive production system, it cannot succeed.

Fitness for purpose is the key to success. **Engineering** and **manufacturing** are two traditional European strengths, and this tradition must continue in order to keep European products at the forefront.

Apart from aesthetics, **design** can contribute significantly to utility value, and is often a decisive factor when choosing between different options. Although design is already a strongpoint of many European products, the EU needs to leverage its strengths in this area, since other countries are not lagging behind in technological innovation. Every product nevertheless also requires a USP (unique selling proposition), in order to avoid the need to compete on cost alone.
Europe must capitalise on its proven ability to handle complexity, and ensure continuing access to developments in **enabling technologies** such as holistic user-centred design, innovative materials, nanotechnologies, ICT and mechatronics. These will give almost limitless possibilities to develop new products, achieve faster manufacturing, or add functionality to existing product concepts.

For the present, Europe still has a huge volume of scientific results at its command on which to draw when innovating in manufacturing. At the same time, it has the knowledge to judge which enabling technologies are relevant, and how they can be developed further in the near future to support on-going growth.

The market increasingly demands products that are **customised**, yet available with **short delivery times**. Urgent attention to **knowledge engineering** is necessary to decrease time-to-market and cut delivery delays. Furthermore, 'rapid manufacturing' technologies will be needed to manufacture customised products. In addition, the structures of the products themselves must be better adapted to the new modes of manufacturing.

The outcome will be products and services made in factories designed and built by Europeans: factories which themselves can be regarded as new products on the world market.

Research under FP7 and at national/regional level will produce the technologies to be used in these plants, and will thus contribute to a sustainable European society.

It is essential that European companies be able to understand and satisfy the needs of customers, regardless of their geographical location. In this context, the business focus will increasingly shift from simply designing and selling physical products, to selling a system of products and services ('product/ services' or 'extended products') that are jointly capable of fulfilling specific users' demands. This concept is equally valid for the products and for the machines used to manufacture them.

Through the provision of product/services and a manufacturing approach that takes into account the **whole life cycle**, European companies will gain:

- more opportunities for innovation and market development;
- more and longer-term customer relationships;
- better feedback from consumers;
- demonstrable improvements in environmental performance.

Product/services will offer greater satisfaction of customers' needs, reduce total life-cycle costs and avoid sustainability problems associated with the conventional purchase, use, maintenance and eventual replacement of goods.

5. Innovating production

A successfully innovating European manufacturing industry will be **adaptive, digital, networked** and **knowledge based**. These attributes not only refer to the more efficient running of factories with the aid of knowledge-management tools such as software interlinked to the physical reality by new types of feedback mechanism, but also to a new social and ethical network that is a basis for lasting success.

Adaptive manufacturing focuses on agility and anticipation to permit flexible, small-scale or even single-batch production, through integration of affordable intelligent technologies and process control for optimal efficiency, in which human experience can properly be formalised and integrated. It responds automatically to changes in the operating environment, and handles the transfer of manufacturing know-how into totally new manufacturing-related methods and systems. It embraces manufacturing systems and equipment incorporating automation and robotics, cognitive information processing, signal processing and production control by high-speed information and communication systems.

Digital manufacturing brings dramatic time and cost savings in the implementation of new production facilities, through virtual representation of factories, buildings, resources, machine systems, equipment, the workforce and its skills – as well as permitting closer integration of product and process development through modelling and simulation; By the same means, planners and designers are able to optimise reliability and minimise environmental impacts.

Networked and integrated manufacturing replaces the conventional linear sequencing of processes with complex manufacturing networks that often operate across multiple companies and countries. This mode of production makes it possible to insert processes and manufacturing systems into dynamic, value-adding co-operatives, and also to restructure them as needs change.

Knowledge-based manufacturing strives for seamless integration of scientific, technical and organisational knowledge from all fields of production, such as process industries, advanced functional products, micro- and nano-scale engineering, and intelligent mechatronics systems for high performance design, engineering and production. This will demand more research into modelling and simulation as the means of integrating the inter-related aspects. Today, simulations are used for the engineering of logistics, machines and kinematics – and partly for processes. Future engineers will need multi-scale simulation, with high-performance computing and the ability to adapt to real or forecast system behaviour. New basic models of processes and simulation techniques must be developed, extended by automated planning and programming and, possibly, by provision for cognition and learning features – as well as the integration into unified models of diverse simulation aspects such as mechanics, control and process physics. Learning and reasoning will even enable the systems to cope with effects that exceed simulation capacities.

Two further trends that will have a significant impact on future manufacturing operations are **converging technologies** and **miniaturisation**.

Converging technologies will exploit the convergence of nano-, bio-, info- and cognitive technologies to develop the next generation of high-added-value products and engineering concepts, with the prospect of stimulating the birth of new science-based industries.

Miniaturisation and serial manufacture of multi-material micro-engineering components will facilitate the conception of products that combine sensing, signal processing and actuation on a microscopic scale, with application fields as diverse as consumer electronics and medicine.

In fact, **innovating production** is a much broader concept than this short description implies. It also needs to embrace:

- new solutions in business;
- new advanced industrial engineering processes;
- research and exploitation of trans-sectoral technologies/products;
- pushing existing technologies beyond present frontiers.

5.1 New business models

Strategic business models define the way companies generate revenue. They are often framed in response to particular competitive circumstances, such as the length of a product's life cycle, or the length of the sector life cycle and its maturity. However, the underlying drivers are the same for all businesses. Companies are seeking to maximise added value; profit from a differentiated capability; devolve risk; minimise exposure, headcount and capital expenditure; and thus optimise value for shareholders and other key stakeholders.

Visible changes over recent years have included:
- a transition from products to services;
- the reduction of vertical integration in large businesses;
- a diffusion of intellectual property across company and national borders;
- an increase in the importance of networks of smaller businesses working in open collaboration to form a value system.

With the continuing globalisation of manufacture and the political integration of an enlarged EU, there is a need for European manufacturing Industry to enhance its business models, to:
- identify and exploit new opportunities for maximising value in the product life cycle;
- embrace global change in industry and business structures and their value systems;
- establish partnerships for economically sustainable manufacturing in an enlarged Europe that works with the rest of the world;
- understand how to realise and supply manufacturing and other technology/knowledge-based services;
- embrace innovation and entrepreneurship as the routes to successful and secure business growth;
- recognise the product opportunities that emerging markets and new global science offer for the growth of manufacturing businesses.

Some national traditions will be challenged by business models arising solely from an Anglo-Saxon economic perspective. There are unique opportunities to build new brands and product-led businesses based on other European cultures, ethical traditions and aesthetics.

Networking along the value chain

Rapid formation of open networks in both traditional and emerging sectors will bring significant increases in capability, profitability and productivity for all European businesses. The establishment of environmentally benign product-based service companies will create a net increase in employment This objective requires action over three time horizons.

In the **short term**, it will be necessary to expose SMEs and other businesses to the changes and opportunities, and to support of the exchange of best practices among OEMs and SMEs, by which businesses can sustain themselves through those changes.

Medium-term research must define new hard and soft 'business-process' technologies that can be applied to modify the framework conditions for innovation and business growth. Subsequently, the Community should look towards the **long term** by exploring approaches that will permit the growth of new manufacturing and product-based service industries from the science base. RTD should be directed towards the artefacts of innovating production and their deployment in a knowledge-based European manufacturing environment, in which ICT and related technologies are fully integrated and the social and cultural systems are drivers of continuous adaptation and innovation.

5.2 Advanced industrial engineering

For European industry to play a leading role at global level based on the RTD-to-market value chain, the factory itself has to be approached as a new and complex type of product, having a long life cycle but able to adapt continuously to the needs and requirements of markets and economic efficiency.

New complex products and processes, together with production systems, will be developed through efficient reuse of technical/scientific, business and process knowledge to make accurate decisions. Shared knowledge of the properties and interactions of materials and processes will support optimised process design and total understanding of complex transformations and interactions at the micro- and macro-levels.

5.2.1 Knowledge-based factories as products

The development of future knowledge-based factories requires research into adaptive structures and solutions that make provision for continuous change, by:

- management models and systems following the objectives of self-organisation and self-optimisation;
- reconfigurable technical systems and integrated processes/systems;
- technical intelligence in process control systems, with efficient human-machine interfaces;
- efficient networking in systems based on standards and open system architectures.

Development directions

The mainstream of future development will be characterised by:

Life-cycle orientation Factories and their components will be linked in manufacturing networks extending from engineering to end-of-life, as the basis for enhanced customer relations and value addition by product-oriented services. This implies a clear understanding of the requirements and usage of products (customisation), their manufacture and associated services; and of how to control, manage and use the vast amounts of data and knowledge that are created within and between companies when products are designed and supported through their life cycles. Europeans have the human skills to activate value in the life cycle by online support and communication with the user population. Acquiring such abilities will enable EU industries to stabilise and strengthen their positions in world markets.

Product-integrated knowledge and intelligence Knowledge is the resource of the future. Its efficient use in the engineering and manufacturing aspects of factories, as well as in the implementation of control and management systems, offers the way towards intelligent knowledge-based manufacturing, and permits tracking of relevant information during the whole product life cycle. This will be accomplished by the use of process modelling, on-line simulation, planning, reasoning, software embedded in mechatronics systems integrating sensors and actuators, intelligent processing of smart materials, and cognitive or learning systems adapting process information to human cognition. It will give the potential to sell knowledge as a product or parts of a product in which the knowledge is encapsulated.

Product-integrated services The majority of technical products, and of manufacturing systems themselves, need the support of services during their life cycles. Services can be made globally available by linking manufacturing systems to the networks of manufacturers, and by incorporating intelligent diagnostics into machines and processes. In this way, Europe can add value by supporting users around the world in solving technical, organisational and financial problems.

European standards for manufacturing Prominent among essential supporting elements is the framing of high-level European manufacturing standards. Standards do not serve simply for the technical definition of specifics. They represent the philosophy of manufacturing: the management of innovation, implementation of best practices, protection of the human workforce and responsibility for the environment. In addition, the adoption of European standards will enforce the integration and interoperation of digital engineering tools, which are now sourced from a small number of individual system suppliers. Intelligent machines and systems Internal automation and modular design is needed. To reconfigure systems, standards are required for real-time digital control and information management.

Leadership in this field will depend on the development of a European real-time platform resembling a **'Windows for manufacturing'**, with well defined IT standards and the flexibility to allow sectors to apply their own specific solutions. Intense research into robotics and flexible manufacturing will be needed to deliver 'plug-and-produce' systems with integral automated services. This, in turn, will influence the way that people work. A new methodology for the organisation of human labour, taking into account the European culture and work standards, will also be required.

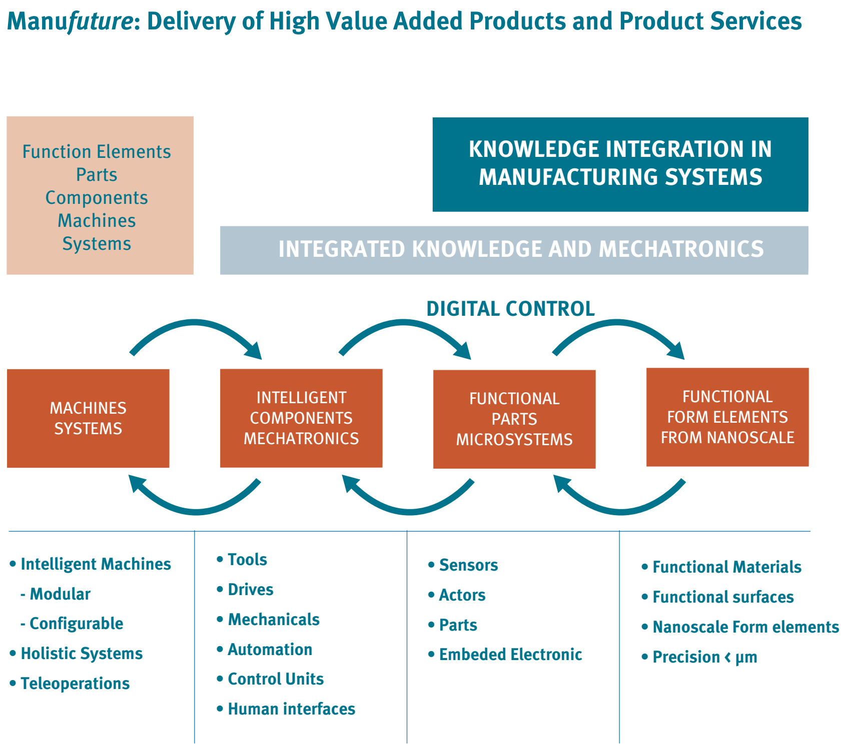


Figure 5: One key element facilitating delivery of high-added-value products and product/services is the integration of knowledge in manufacturing systems at all levels, cascading from intelligent machine systems down to knowledge-based engineering of functional elements at nano-scale.

New Taylorism

Taylor defined the basic paradigm for manufacturing management more than 80 years ago. Tayloristic organisation underlies the models of the manufacturing processes and systems still used in nearly all areas of industry. It specifies the tasks of workers, based on elementary processes. The tasks are planned in detail using basic methodologies such as MTM (Methods-Time-Measurement) or REFA (Association for Work Design/Work Structure, Industrial Organisation and Corporate Development). Global operating companies in the automotive and other sectors employ this methodology to calculate, compare and standardise processes worldwide.

Taylorism is contradictory to the paradigm of a socio-technical system characterised by knowledge-based manufacturing, manufacturing in networks, or principles of self-organisation and self-optimisation. The concept of integration of knowledge into machines and systems is not compatible with detailed process planning. As a consequence, manufacturers need to adopt a new type of Taylorism, which takes into account dynamic change and adaptation, specific human skills and the requirements of co-operation in networks.

The factors accounting for the success of European manufacturing industries to date are mainly related to the great diversity and skills of personnel at all levels. Harnessing these abilities in the factories of the future will be vital to the economies of the Member States. The keys to growth and leadership are rapid evaluation of change under practical conditions, monitoring success in meeting the demands of markets, and exchanging knowledge.

5.2.2 Manufacturing engineering and services

The concept of **manufacturing engineering** – the way that processes and production are organised in novel production patterns within factory units able to respond flexibly to global demand – is the core of manufacturing development. This inevitably implies significant changes in manufacturing processes along the whole product value chain within the networked enterprise.

It will require both engineering competence and the tools to support engineers working in distributed and open networks. Their role will be to implement new technologies and to design manufacturing systems by employing an intimate blend of virtual and real-world techniques. As a consequence, there is a need for European industry to progress towards simultaneous development of product/services and processes within the enterprise/network organisations.

The challenge to industry

The research field of advanced industrial engineering(4) arises from the need to enhance the concept with new models, methods and deployed tools. It has to reflect the new way of operation, the so-called 'digital business', which represents a more effective mode of developing businesses suitable for any industrial sector, using state-of-the-art ICT across the supply chain. A second requirement is to approach the factory as a new kind of transformable and adaptable product.

Digital manufacturing engineering, as a key component of manufacturing engineering, uses a wide range of engineering and planning tools, software applications and ICT for efficient and effective integration of new technologies into manufacturing processes. The main area of research is the development of integrated tools for industrial engineering and adaptation of manufacturing, taking into account the configurability of systems.

This will give factory engineers a representation of a factory as it is today, and enable them to project its future reality by deploying virtual manufacturing technologies consisting of simulation tools and specific applications/systems.

Current development and innovation of industrial products and processes are still experience-oriented. Experiments and experience are the basics for reliability. In tomorrow's knowledge-based industry, the 'costs of experience' – loss of productivity and time – can be reduced by the modelling of all manufacturing processes, in combination with automated planning and programming.

Virtual factories will integrate flexible supply chains for:

- engineering and designing products to match market needs;
- logistics, from customer orders to final delivery;
- consumable materials and waste treatment;
- factory machines; and,
- equipment and tools.

The constituent parts making up the virtual factory will be created from basic components, supporting transformability/changeability. Fast response at all scales, from individual processes to complete networks, will take place within a digital infrastructure relying on a high level of knowledge, and making extensive use of RTD for:

- incorporation of functional and structural materials into machines, tools and other equipment;
- implementation of ICT and cognition-based solutions for control and management of all processes;
- application of micro- and nanotechnologies;
- enhancement of human/machine interfaces, and
- integration of methodologies from different disciplines for human work and management.

Product design is the activity concerning the product-system: the integrated body of products, services and communication strategies that the actors conceive and develop so as to obtain a set of specific strategic results.
This will be based on such requirements as:

- response to life-cycle processes and contextual conditions;
- compliance with competitiveness and sustainability goals, while pursuing the added-value approach;

and will require:

- the acquisition of enabling technologies covering architecture and components, structural and functional materials, and processing;
- an increasing incorporation of new technologies as they emerge from research.

Process design will address processes throughout the whole product life cycle – production, distribution, use and maintenance, recycling. – as well as the life cycles of individual processes, whose phases are design, implementation, use and maintenance, and reconfiguration. It will be based on such requirements as:

- interrelation with other product life-cycle processes and the product itself;
- compliance with competitiveness and sustainability goals, while pursuing the added-value approach;

and will require an increasing incorporation of new technologies as they emerge from research.

Manufacturing systems engineering will embrace the development of machines, equipment and the technical factory supply systems (energy, air, water, information), with integrated tools for design, analysis and simulation under real conditions.

There is a strong requirement to formulate the data management standards for all objects and elements of the factories. A specific objective is the real-time management of the effects of set-up, wear, maintenance and end of life of machines and equipment.

Reconfigurable manufacturing Rapid and adaptive design, production and delivery of highly customised goods will establish closer coordination between demand and supply sides. Continuous change will require improvement in modelling and simulation of new complex phenomena such

(4) Advanced Industrial Engineering AIE, aims at combining the basic knowledge in production and process planning "i.e. Industrial Engineering" with the methods, models and procedures used to enhance the transformability, and thus to advance industrial engineering by adding: a) collaborative and team-based planning, b) integrated planning approaches,including interfaces to product design and distribution, c) digital tools and methods, d) the potentials of technology management and e) the analysis of continuous process chains.

as uncertainty management and multi-domain support. Enterprises will create networks and virtual factories, achieving reduced time-to market, reduced order quantities, mass and full-customisation, just-in-time production and reduced need to transport components and products. New paradigms such as ambient intelligence will facilitate the integration and adaptation of people and manufacturing devices into flexible networks.

Lean, efficient enterprises: Businesses will develop efficient processes to create, manage and control the entire production chain and life cycle of products. RTD will address the development of intelligent controls, expert systems and improved supply chain management; while exploitation of emerging technologies will dramatically reduce the cost and time of designing, manufacturing, delivering, and supporting products.

Technology-innovative manufacturing: Future manufacturing enterprises will leverage revolutionary technologies that radically change the way they design, build and support products. The trend will be towards the generation of robust design and planning systems giving higher quality solutions in relation to the quantity of input information.

In order to obtain knowledge-based systems, great attention must be devoted to the development of 'self-learning' capability, to:

- use experience and histories of development processes in processing real-time data to extrapolate information or predict behaviour;
- generate new knowledge by proposing several solution options.

Knowledge-based systems will facilitate the rapid transfer of data across product-process domains and life-cycle phases. European manufacturing service industries have the potential to realise an open engineering platform, for which many different applications can be envisaged. In fact, the platform itself represents a future market, in addition to those for the products and factories it will produce.

A characteristic of next-generation manufacturing systems will be their 'evolvability'. Here, the term is intended to indicate change that goes far beyond simple re-configurability. As yet, this remains an unattained goal. Its realisation will depend on engineering technology with the ability to strengthen and speed the innovation process, support the progression from traditional to life-cycle-orientated paradigms, and contribute to the science-based modelling of processes to realise science-based artefacts.

5.3 Emerging manufacturing sciences and technologies

The history of industrial technological development can be traced in permanent innovations and solutions that have had advantages over former generations by being better, faster, cheaper, more convenient, more flexible or smarter.

Continuing to exploit emerging sciences and pursue specific objectives of RTD in emerging technologies will lead to:

- desirable new product characteristics;
- improved or new manufacturing technologies;
- intensive integration;
- new industries able to cope with global markets;
- radically enhanced efficiency in labour-intensive manufacturing.

Many thousands of publicly and privately employed researchers in Europe could be engaged intensively in the continuous development of enabling technologies, blazing a new European trail towards implementation of the science-to-market knowledge-production value chain. They make up the most strategic asset of Europe: the knowledge base of an industry that can launch and sustain high-added-value manufacturing engineering.

The main objective is the acceleration of technological innovation in manufacturing by the development of high-end machines and systems.

In the medium term, added value is likely to come primarily from some of the most revolutionary technologies: machine intelligence (or artificial cognition), microelectronics, nanotechnology and biotechnology. However, the potential also exists to break new ground in the majority of traditional manufacturing technologies.

To achieve these objectives, innovation processes centred on single competences will increasingly give way to a multidisciplinary convergence of: physics, mathematics, social sciences, biology, chemistry, medical sciences, etc.

The contribution of extended technologies to environmental objectives is likely to be extremely high. A sustainable reduction of energy consumption by manufacturing processes and products over their whole life cycles would have a high impact on society. However, even modest advances will demand higher skill levels among workers and technicians in the factories.

6. Infrastructure and education

New business models, products and manufacturing processes will transform traditional industry through the intervention of enabling technologies via both top-down and bottom-up approaches.

Progress of knowledge-based manufacturing from breakthrough research to market innovation will be realised by considering this breakthrough research, together with enabling technology research, product/process development and industrial innovation, as a set of integrated activities.

The top-down RTD approach of radical Innovation is a science-driven process, leading to new high-added-value products/processes 'looking' for potential use.

The bottom-up route to incremental innovation, going from market towards RTD-based development results in upgraded products and processes responding to shorter term contextual challenges and opportunities with improved science-driven products.

Both approaches are capable of delivering new products for existing and new markets.

The present European RTD system comprises:
- universities;
- research centres;
- applied research organisations;
- knowledge-intensive SMEs;
- manufacturing enterprises;
- networked SME intermediaries.

According to the Eurostat Business Statistics 2004, 981, 209 professional researchers and research managers are employed within this system in the EU-15 countries.

Building a world-class RTD infrastructure will only be possible against the background of a favourable economic and regulatory climate that encourages research investment and entrepreneurialism. Further harmonisation of national regulatory and taxation frameworks will be required, particularly to support companies pursuing high-risk strategies when operating in highly competitive environments (e.g. high-tech IT). The aim should be for the national frameworks to merge on a common basis at European level, thereby promoting equal opportunities for competition. A knowledge-based economy will also necessitate a restructuring of education and training to reflect the lifelong learning needs of tomorrow's 'knowledge workers', for whom variety must be seen as opportunity

Another essential to ensure the availability of a suitably qualified workforce will be to increase public awareness of the value of science, of the rewarding career opportunities that will arise in knowledge-based manufacturing and of the importance of sustainable production/consumption patterns.

However, it is also crucial to consider the social dimension. To cope with demographic change and the ageing population in many western European countries, new forms of work organisation should be developed to permit full integration of the elderly – including those with low qualification levels – into the workforce.

6.1 Innovating SMEs

SMEs make up the majority of the European industrial manufacturing landscape for which the Manu*future* SRA represents a means of achieving market success and ensuring a viable future. Securing that future depends upon developing a scalable approach based on a single platform following the principles of co-operation in a networked value system for high performance SMEs that are self-organising, self-monitoring, and self-configuring.

Co-operation between academia and industry is vital. This is especially true for the large majority of European SMEs that want or need to innovate, but can not afford an adequate internal RTD capacity.

Transformable SMEs will build their technical and organisational processes around the strategy of innovating production, employing optimised inputs of materials, energy and information. They will continuously develop operational, organisational and financial solutions that answer day-to-day challenges, while also taking account of a planning perspective aimed at improving their competitive position in the medium to long term.

Value-based internal and external developments will be identified at an early stage by means of risk analysis of future developments and their impact on investment decisions. Systems and methods enabling SMEs to react swiftly to dynamic situations should be capable of defining action alternatives in the fields of strategy, structure, human and technical resources – as well as determining points of leverage whereby strategic management can increase transformability.

When conflicts of interest arise as a result of process changes, integrated management control systems should be in place to guide decision-making through systematic classification of relevant options and indicators.

For systems and human resources to act co-operatively throughout the value-adding chain, and to enable an SME to negotiate independently with partners at its own and other hierarchical levels, new theories and methods must be proposed. These would ensure a dynamic process through which the enterprise could acquire the desired degree of freedom in both tactical and strategic decision, empowering it to pursue and self-regulate its goals.

Structural concepts with standardised interfaces for rapid configuration by 'plug and play' will be central to the common platform – as will digital tools and human-centred approaches to coaching, facilitating and empowering SMEs, enabling them to maintain a forward-looking stance and optimise the configuration of their operational processes, performance units and networks.

Relevant framework conditions are:

- managers' education and awareness of the relevance of science-based innovation;
- existence and recognition of the 'innovation management' function;
- workers' education and training;
- access to the national and European scientific and technological systems, and to the results of their activities and projects;
- organisation of sectoral or thematic co-operation networks, RTD and innovation investment funding.

Test-beds for innovating production

The research output of innovating SMEs is a key value-adding component of the SRA. It will be used to test, validate and demonstrate solutions suitable for small enterprises in general, moving towards innovating production in tomorrow's virtual factories – and thus permitting rapid deployment of new technical knowledge by the SME community.

Proving that networked transformable SMEs can function as full working participants in a new knowledge-based world would thus show that the virtual factory concept represents a real opportunity for would-be investors.

6.2 RTD system and RTD management changes

The transformation of manufacturing requires new and dynamic research and innovation networks that must be nurtured to stimulate knowledge generation and ensure efficient transfer of its benefits to the sector. It involves clear recognition of the mutual value in an intimate collaboration between industry, the academic community and knowledge-transfer intermediaries.

This demands a clear understanding of the respective roles of research partners on the one hand and of industrial partners on the other. Each has a different viewpoint in evaluating results. That difference must be recognised and reconciled if collaboration is to lead to optimum outcomes in which innovation is translated into new products and processes.

Manufacturing industries can derive added value from the knowledge created within knowledge-intensive SMEs and from applied research organisations. This will enable them to focus on their own core activities, while leaving tasks that require specialised skills to the SMEs that have direct links with universities and RTD centres. As a result of their extensive networking, SMEs will thus become important reference points for manufacturing enterprises seeking frontier knowledge and innovative services. They will also form fertile breeding grounds in which personal growth and creative talent are strongly stimulated.

6.3 Skills and educational strategy

The challenge for European manufacturing is to increase skills and capabilities of the EU workforce by developing the competences needed by new generations of 'knowledge workers' combining technological expertise with entrepreneurial spirit. Ensuring continual training will produce a workforce capable of working in volatile business networks, and facilitate the mobility of researchers and engineers.

Further important challenges for manufacturing education include overcoming the fragmentation of manufacturing knowledge and research in Europe, embedding innovative spirit within the education system to counter the risk-averse approach that characterises Europe, and providing the means by which the loss of a large number of low-skilled jobs can be balanced by educating high-level personnel for new manufacturing jobs (e.g. shift from production to pre- and post production, focus on after-sales services, etc.).

A basic need is to align the differing national educational systems with the demands of future manufacturing, taking into consideration that the responsibility for those systems lies within different departments in each of the Member States.

Knowledge-based production requires the support of new kinds of education and training schemes integrating research with technology and manufacturing. The priorities are to:

- **develop an effectively resourced landscape of innovation**, together with a training mechanism for its emerging job profiles;
- **reorganise educational programmes** around new engineering disciplines;
- **establish Europe-wide educational systems** by introducing an EU credit system allowing students of manufacturing engineering and other disciplines to complete parts of their education in other regions and countries; and
- **address the workforce as a societal issue**, focusing on attracting and keeping adequately trained people to make European manufacturing more competitive and sustainable.

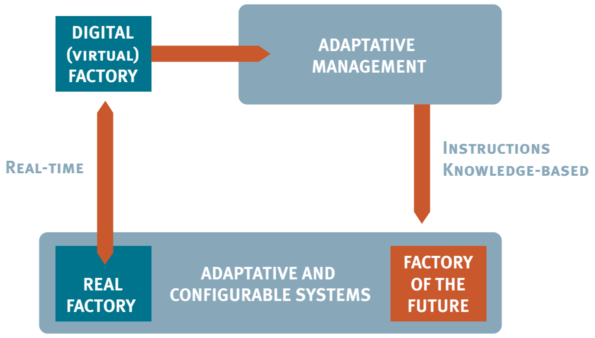
Integrating education and industry

During the 1990s, universities were faced with significant pressure to produce innovative results that could be exploited more effectively by industry. This was mostly due to the fact that the European innovation gap was deemed to result from insufficient and inefficient scientific and technological transfer.

Despite the efforts of the academic community, development of educational curricula has failed to keep pace with either the growing complexity of industry or the economy, and even less with the rapid development of new technologies. Studies are often too lengthy and too general. Furthermore, it can be argued that manufacturing is a subject that cannot be handled efficiently inside a university classroom alone.

A highly promising approach would be to integrate the factory environment with the classroom, to create the **'learning factory'**, in which academic study is combined with practical work experience and exposure to the needs of industry. This concept has its origins in the medical sciences, and specifically in the paradigm of the teaching hospitals, where medical schools operate in parallel with hospitals. In a similar way, aiming to become a new paradigm in education and training for manufacturing technology, the teaching factory will combine research, innovation and educational activities within a single initiative.

New forms of basic and life-long training, moving beyond the traditional disciplinary boundaries with world-class targeted interdisciplinary teaching at university and postgraduate level, should also be envisaged (e.g. academic start-ups and 'venture capital universities').



7. Implementation of the SRA through collective action

The review and integration of critical areas of research and development from all manufacturing-dependent sectors will provide the fundamental means for synergistic co-operative schemes ensuring ease of commercialisation. Such actions can provide a solid foundation for the whole spectrum of manufacturing innovation technologies. They will also address the diffusion of new knowledge to SMEs and the education of the next generation of manufacturing leaders, technologists and workers.

Appropriate actions at the right level

Manu*future* will promote successful Europe-wide implementation of solutions at various levels, facilitating the structuring of effort and funding, and encouraging pan-European convergence between regional centres of industrial competitiveness.

Coordination of policies, high level RTD and standardisation at the European level will provide an 'umbrella' for actions at the level of individual nations – including information dissemination, support of SMEs, education and adaptation of national regulations. These, in turn, will create an environment for local actions such as technology transfer, aid to SMEs and cluster formation at the regional level.

7.1 At European level

With the common purpose of overcoming problems posed by the complexity and diversity of the EU manufacturing scene, European Technology Platforms can be considered as 'collective' stakeholders. They include:

- sectoral European Technology Platforms (ETP): ERRAC, ERTRAC, Waterborne, Forest based, Textile, ACARE, ECTP, SUSCHEM, etc...
- trans-sectoral ETPs: Industrial Safety, EuMat...
- enabling technologies ETPs: Eniac, Artemis, E-Mobility...

To achieve the necessary broader convergence of the many different industrial sectors involved, Manu*future* operates to assess the common core of business or areas of interest, in collaboration with other platforms and European or international initiatives such as EUREKA and IMS.

Intervention through interaction

The objective of collective activities is to define a complete Manu*future* SRA taking into account Europe's overall manufacturing needs from sectoral, trans-sectoral and enabling technologies viewpoints.

For the Sectoral ETPs, Manu*future* provides a generic reference model able to express their manufacturing RTD orientations. Such an approach will greatly facilitate the cross-referencing of common issues by facilitating discussions and exchanges on process commonalities between different sectors.

Where sectors focus exclusively on their own particular products, Manu*future* will play the role of stimulator, initiating the definition of process needs and implementation of suitable actions to retain manufacturing in Europe.

For the trans-sectoral ETPs, Manu*future*'s contribution is in the coordination of interfaces with Manu*future* itself and the sectoral TPs.

For the Enabling Technologies ETPs, Manu*future* will, through the common reference model, pool the needs for manufacturing and act as a supplier of the available and emerging technologies.

The mode of intervention will be to promote the paradigm of high added value and the Manu*future* reference model, in order to use available funds synergistically and efficiently through coordination of manufacturing RTD actions at the industry-wide and sectoral levels.

7.2 At national/regional level

National Technology Platforms related to the Manu*future* ETP must be created in individual EU Member States. All Manu*future* National Technological Platforms should adopt the main development goals identified in both 'Manu*future* – a vision for 2020' and the current document. Other initiatives can also encourage the emergence at regional levels of equivalent concepts promoting competitiveness by stimulation of the synergy between sciences, education and industry. Existing networks of excellence that are completely in accordance with the goals of Manu*future* have also to be taken into account.

National development agencies need to appoint and part-fund national representatives as drivers of the initiative. National Manu*future* initiatives, while adopting different models of organisation, should share the common vision and aim to encourage widening acceptance by, and participation of, European industry via appropriate actions in their respective nations or communities, e.g.:

- alerting public opinion and politicians to the challenges that European manufacturing faces, as well as to industry's critical role in delivering economic output, skilled employment and sustainable growth;
- aligning the interests of the RTD community and technology providers in strong and effective co-operation networks that develop and source knowledge and technology;
- identifying and strengthening the highly competitive local/regional networks of medium- and large-sized

OEMs, suppliers, technological partners, consultants and RTD contractors.

The most important contributions of these national and local initiatives should be in:

- fostering wide SME involvement, as these face greater difficulties than large international companies in participating at European level. To this end, industrial SME associations should be invited to contribute in defining strategies and future needs;
- horizontal integration, coordination and synchronisation of RTD efforts in EU Member States;
- vertical application of competitive technologies, products, methods and processes in both large companies and SMEs – including multidisciplinary networks coordinating RTD activities in new industrial sectors such as medical technologies, telematics, nanotechnologies and mechatronics.

Enlargement adds opportunities

Over the next decade, the integration of new EU Member States will have a significant influence on European manufacturing of products for global markets, and these countries could become world-class suppliers to OEMs.

This can be seen as an EU strategy of transition, to maintain strong national/regional sectors in an interim period. It will create competition between EU members in all areas, even in RTD, as a key factor in promoting excellence and fostering European manufacturing progress.

Aligning the development goals and priorities of the original 15 with those of the 10 is therefore crucial in building a common interest in close co-operation between production companies and RTD organisations as a foundation for expansion into global markets.

National and local initiatives will be particularly important in the new MS. After many years of socialist regulation, their move towards market economy – in RTD, as in other spheres – is a major mental, organisational, technical and financial challenge.

7.3 At SME level

SMEs are main players in the structure of all manufacturing sectors. They are capable of developing, producing and selling innovative products and services to more and more demanding consumers. They are also linked in diverse networks with OEMs in the value chains. They are competent partners to each other as well as to global OEMs, to technology centres and to RTD organisations. Experience has already shown that SMEs certainly represent one of the strongest assets for Europe in maintaining a sustainable competitive advantage against the emergent Asian competitors. Their participation in the integration activities of engineering platforms will engage them in long-term partnerships across Europe, reinforcing the ability of the manufacturing infrastructure to achieve rapid, reliable transfer of research results into marketable products.

7.4 Across frontiers

A number of practical measures can be envisaged for realising Europe's competitiveness goals, while also meeting national/regional needs, e.g.:

- launching specific local network initiatives to establish new RTD infrastructures for technologically innovative and knowledge-driven economies, which would build local market strength and permit entry into global markets;
- developing regional and sectoral maps of technological and manufacturing competencies, RTD centres and universities ;
- creating European networks of suppliers of standard components and adaptable technological systems, including low-cost technologies in the new MS;
- forming virtual institutes and linking them with sectoral manufacturing networks to generate high added value;
- establishing innovative multidisciplinary technology and business centres
- transferring new business models and communicating success stories to SMEs of the new EU countries;
- actively participating in pan-European RTD initiatives within ETPs and EU programmes, especially the Seventh Framework Programme, and EUREKA;
- introducing universities and technology centres to the European system for educating highly qualified engineering staff who are prepared to work in large or small enterprises – entailing the adoption of 'exportable' standards, coverage of innovative technologies encouragement of student mobility.

8. Recommendations for action

1. Manu*future* should be a label for successful research and competitiveness at **EU level**. The Manu*future* initiative advocates the promotion of change towards manufacturing paradigms with high industrial application and value-generation potential, with particular respect to:
- knowledge management and creation of the relevant tools for manufacturing;
- focusing the use of research means in a synergetic way for a sustainable output;
- using research results in creating high added value within the following two years.

2. The favourable **framework conditions** should be set by ensuring:
- a blend of basic, sector-specific and regionally focused application-oriented research in:
  - new business models;
  - advanced industrial engineering;
  - emerging manufacturing science and technologies;
- development of a cost-effective and robust shared research infrastructure capable of delivering results according to the current and future needs of Europe's manufacturing industry.

3. Because RTD processes are long and complex, involving several layers of society, an integrated set of actions is required at **Member State level**. In addition to pan-European efforts, national and regional authorities must participate, either independently or in a complementary manner, by
- fostering the creation of clusters (sector, technological or other) at national and/or regional level, creating research and transfer nodes, and integrating SMEs into networks. These can then join and support the creation of clusters at EU level;
- developing competence in high-end manufacturing technologies; and,
- establishing local centres of excellence in manufacturing, incorporating a Manu*future* network of educational and research communities to permit the involvement of university researchers, knowledge transfer to industry and the formation of spin-off companies.

4. At **educational level**, the Manu*future* recommendations are to:
- build strong links between industry and academia, by establishing joint postgraduate degrees, postgraduate industrial training and industrial 'real-life' courses, as well as manufacturing departments and/or universities driven by industry;
- develop schemes to help to create knowledge-SMEs able to link with research centres and other small and large enterprises;
- integrate all manufacturing qualifications of EU Member States into European engineering curricula;
- introduce new teaching principles and industry-based case studies that will promote concrete expertise in manufacturing;
- re-organise educational programmes around new engineering disciplines with a high potential impact on EU manufacturing competitiveness. Such disciplines need to address all levels of the extended products, systems and embedded services of the manufacturing sector;
- activate an appropriate Manu*future* International School, leading to Masters and PhD qualification in industrial research, based on research institutes and leading manufacturing companies.

Finally, as an industrially-driven platform, Manu*future* defines a **consensus vision** of the research and innovation needs for high-added-value manufacturing. This vision should be used by stakeholders to integrate and coordinate research in a 'European Research and Innovation Area for Manufacturing – EMIRA (Fig 6) within the European Research Area (ERA). This coordination should take account of regional and national needs, and recognise Europe's wider role in the global RTD and innovation network.

SRA Implementation through collective action

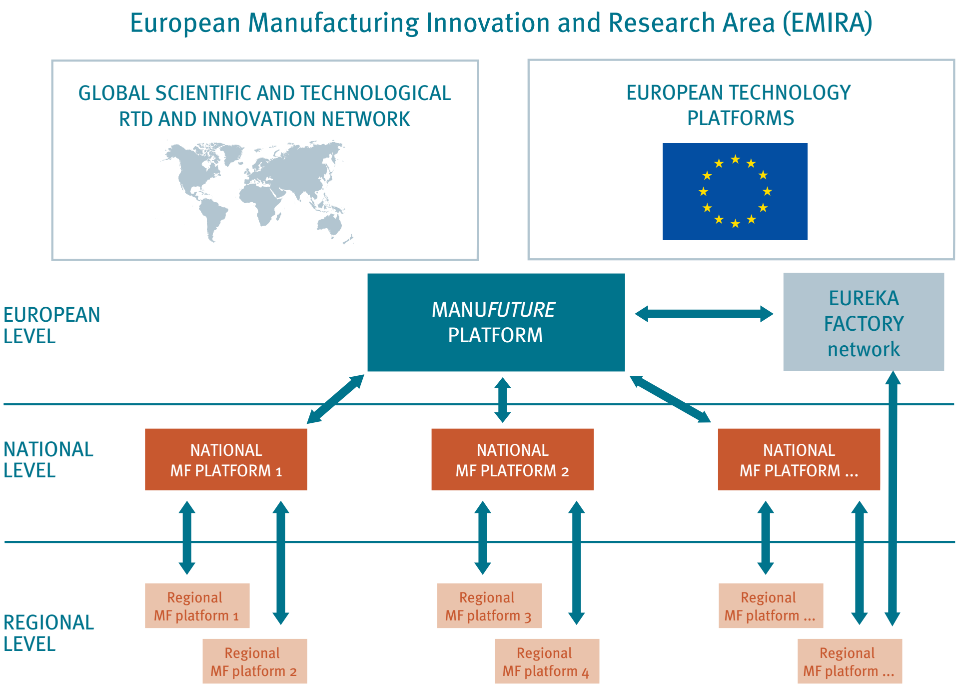


Figure 6: The Manu*future* Platform's role in establishing the European Manufacturing Innovation and Research Area, EMIRA

European Commission

Manu*future*© Platform
STRATEGIC RESEARCH AGENDA
assuring the future of manufacturing in Europe

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