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SPECIFIC SUPPORT ACTION
PRIORITY 3 – NMP

Leadership Deliverable

D 2.5 - Overall Manu*future* Roadmap

Manu*future* Workprogramme "New Production"

High-Priority Call Topics (= Roadmap Elements) proposed to European Research Programmes and Manufacturing Innovation Programmes like FP7 – NMP et. al.

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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	**CO**

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1. INTRODUCTION

The SSA LEADERSHIP aims at providing support for policy makers, industries, researchers and other stakeholders to develop new approaches for assisting European Manufacturing Industry’s transition towards a K-based competitive and sustainable base.

To achieve the scope with related objectives the SSA LEADERSHIP:

1. defines a common roadmapping approach and a framework to develop roadmapping actions and related activities
2. develops roadmaps in Manufacturing high technologies and sectors
3. supports high tech oriented European Technology Platforms
4. elaborates a strategic European Manufacturing Implementation Plan
5. plans and runs dissemination activities and website.

In this frame, this deliverable reports the key result of the intensive and large roadmapping work carried on within **WP2** and concerns the Manu*future* Overall Roadmap in Manufacturing high technologies and sectors (point two above).

The WP2 key result has defined:

1. the **key priorities** macro-areas that lead to a new manufacturing industry knowledge based in short-medium /medium long term,
2. the **key technologies** areas that require European near-long term industry-research investment in the global economy scenario.

The centre of gravity of the SSA LEADERSHIP is the focus on the development, integration and use of RTD roadmaps as strategic tools for innovation management in EU-manufacturing industry, as well as on related activities within the 2020 context of the Manu*future* SRA.

According to the Manu*future* Strategic Research Agenda:

Even the factories themselves are regarded as complex, long-lived products, operating with the latest technologies and adapting continuously to take account of customers’ and market requirements. The ‘virtual factory’ of the future will manufacture in adaptable networks linking OEMs with value-chain partners (often SMEs) and suppliers of factory equipment/services selected according to needs at a given time.

Therefore, Manu*future* Roadmaps would impact the manufacturing technology development by providing a new approach to the advanced technological programmes, namely FP7 New Production programme, ERA, EUREKA!, Country National and Regional Programmes, that – hopefully - will call for proposals and fund collaborative projects to achieve excellence in deploying results related to the horizontal enabling technologies commonly envisaged as a need by production sectors.

According to the Manu*future* Strategic Research Agenda:

For Europe the movement towards knowledge-based manufacturing and, hence, the shift from cost-based to high-added-value competition, 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 mid and large size OEMs and other independent enterprises, suppliers and technology and services providers; creating new kinds of supply chain, establishing R&D centres, etc.

Attaining the objectives of the Lisbon and Barcelona Councils will only be possible by in*volving the largest possible number of stakeholders. In this context, the benefit of cooperation between Manufuture 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 Manufuture concepts and results, together with assessing a common "core" of business or areas of interest.*

The Overall Manu*future* Roadmap presents Manu*future* Pillars' related roadmaps, that - according to the Strategic Research Agenda- aim at the strategic target N. 4.2.3 to achieve - with FP7 New Production Programme and Multi-level programmes - the following:

Factories are treated as socio-technical systems; they are capital intensive, complex and long life products, operating through complex relationships between the material value chain and information chains, involving technical and human elements. In contrast with other complex products, factories have an overall system architecture enabling the continuous adaptation to the needs of customised products, economic environment and objectives. Just as for other complex products, knowledge is the key to maximise the economic success and the dynamics of this socio-technical system…... The overall efficiency of the manufacturing network depends on the efficiency of each system element. European standards for knowledge based manufacturing are able to compensate turbulent environment influences by system based methodologies and intelligent technical solutions.

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At an operative level, WP 2 has fulfilled the objective - with the participation of all the Partners of the Leadership Consortium – of the elaboration of these **Roadmaps capable of defining horizontal technologies in the time horizons trajectory.**

These roadmaps develops a level deeper the Manu*future* strategic **RTD areas** for the selected important European industrial sectors. The sectors have been involved through extended coordination with:

- **key industrial players** in each of 25 manufacturing sectors and the industrial automation industries
- **key RTD areas outcomes** from other Roadmapping initiatives.

So, these roadmaps define RTD packages at one level deeper than described by the Manu*future* SRA and provide topics usable for the definition of RTD areas in Research Programmes at European or national/regional levels, as appropriate.

This WP has strong linkages with WP1 and WP3, where the results are directly used and further elaborated.

With the above mentioned strategic directions, the main steps of the Roadmapping **process** initiated to produce the **Overall Manu*future* Roadmap** can be summarized as follows:

1. In WP1, identified relevant foresight activities, SRAs of other ETPs and FP6 projects have been analysed in respect to Manu*future* relevant RTD targets and contents. The **template** to describe RTD targets has been developed in WP1 and reported in D1.1 and D1.2. The roadmapping process ended with the **catalogue** of the fulfilled Technology Fact Sheets is reported in D2.2. In this process integration from other EU-funded Concerted Actions, namely EUMECHA-Pro, IPmann and MDapient.
2. The Manu*future* SRA strategic vision and Pillars have been related to individual industrial sectors – as being relevant for the future development of sectors. The result is a sectoral overview of potentially relevant technologies as input to the structured **interviews** with sector representatives and experts. These interviews have been performed in Task 2.3 applying the questionnaire developed in WP1 and reported in D1.1 and D1.2.
3. **Sectoral roadmaps (25 sectors)** have been elaborated – based on interviews with selected industrial companies representatives (Key Opinion Leaders) and experts. Information has been gathered by roadmappers with the use of a Leadership structured questionnaire. As result, priorities and expected time lines have be identified and associated to individual and clusters of sectoral targets. **25 sectoral roadmaps** have been produced, as reported in D2.3 and D2.4.
4. These sectoral roadmaps have been analysed to verify the Demand of horizontal technologies in the perspective of identifying common areas and sub-areas of key **trans-sectoral technologies** that constitute the **Overall Trans-sectoral Manu*future* Roadmap**.
5. **Time horizon for the development of these horizontal technologies has been assessed with the interviewed persons.**

   The Manu*future* Pillars broadly defined Short, Medium, Long term horizons for the development of Knowledge based manufacturing. Leadership SSA WP2 presents time expectations at one-year precision level.

   Each roadmap, Trans-sectoral and Sectoral, is mapped on a 9 years time scale that spans from 2007 to 2015, applying the same time scale as in the standard questionnaire for interviews. The one-year precision comes from the sectoral roadmaps, where roadmappers operated at one-year precision.

   Results may easily be converted to a three level (short-medium-long) time scale.

   Conversely, the roadmaps elements for FP7 calls, described in chapter 3, are mapped on a 7 years time scale, applying the same time scale as in FP7, admitting that some other topics may be implemented outside or after the FP7.

2. Manu*future* Workprogramme and Research Topics. Development of trans-sectoral Roadmaps

The Manu*future* Workprogramme represents one of the main scientific outputs of the Manu*future* Research Agenda, aiming at identifying the relevant research topics corresponding to the Manu*future* Pillars and developing their trans-sectoral roadmaps. The Figure 1 presents the overall enabling technologies corresponding to the Manu*future* Pillars, listed on the left side of the figure. The distribution and the employment of these technologies on a generic time scale and prioritisation is drifted on the X dimension of the picture. The implementation strategies envisioned to be followed are:

- Competition and Customisation, with high priority and immediate implementation,
- Leadership and Globalisation, aiming at medium-term deployment with high priority and
- Emerging, focusing on long-term using of enabling technologies which can be approached based on their innovation impact as merging technologies, acting in the so-called emerging industrial sectors.

		Competition Customization →	Leadership →	Globalisation →	Emerging
New Business Models		Beyond Lean… Life Cycle Services Survival Strategies	European Production System Knowledge & Service	Real-Time Enterprises New Taylorism	Invest in R&D Enterpreneurship
adv. Industrial Engineering	Adaptive Manufacturing	Adaptive Automation Modular Products Configurable Systems	Adaptive Factories Real-Time Adaptation Adaptive Systems	Real-Time Factories Disruptive Factories	Knowledge-based Factories
	Networking in Manufacturing	Network Engineering Interoperable Networks Customisation	Manufacturing on Demand Networking Standards	Supply Chain Mgt.: - Real-Time - Global	Knowledge-based Order Management
	Digital Engineering	3D PLM and Tools Fast Engineering Digital Prototyping	Multi-Scale Simulation Digital Factory Material Engineering	Process standards Smart Factory Cognitive Simulation	Knowledge-based Engineering
Emergent Technologies		Intelligent Products High Performance Energy Saving	Gen. Technologies Adaptive Materials Micro & Nanotechn.	Reliability Process Models and Simulation	In-Situ Process Control beyond Borders
ICT for Manufacturing		Configuration Systems Embedded Systems	Multimodal Interfacing Software Engineering	Grid Manufacturing Ubiq. Computing	ICT Environment Manufacturing

Figure 1. Manu*future* Enabling Technologies for the Next-Generation Manufacturing and European Production Systems

2.1. New Business Models

Current manufacturing systems, the typical instantiations of modern socio-technical systems called factories, have to solve highly complex tasks under increasing demands for adaptability, economic performance, maintainability, reliability, scalability and safety. The "Next Generation European Factory", approached as a complex long life product, has to be adapted continuously to the needs and requirements of the market and economic efficiency. Furthermore the "factory" will have to take into consideration more and more social responsibility and, in particular, environmental sustainability. Based on these challenges the need of development and validation of new industrial models and strategies, shortly named New Business Models is more and more relevant for the purposes of the European Industrial Transformation. A collection of enabling business and management models, methodologies, technologies and tools have been identified and then strongly harmonised in order to support the implementation of the desired "Management of European Production Systems" in the following so called "**Manu*future* Trans-sectoral Roadmap: New Business Models** Roadmap" (Figure 2). Graphically presented, the Management System of European Production represents the synergy of several main enabling business and management models, technologies and tools, structured in the following main clusters: European answers for Production Systems, European Management Systems, Innovative management models, methodologies and tools and Service and Consumer-oriented business models. In this chapter, high-adding value and innovative research and technological development areas are shortly presented from a technical point of view, respective according the content, the scientifically objectives and potential results of each identified area or field. The Roadmap graphically presents on time dimension and priority scales, several research directions as the following:

- **On short term with high priority** innovative methodologies supporting the manufacturing enterprises to survive or to stay competitive in the turbulent environment of global and high wage economies, coming from two areas which are relevant: Strategies for transformation management, part of the cluster "Management of European Factories" and Survival production strategies, as a contribution to the "European answer for Production Systems" field.
- **On medium term with high priority as well,** the directions aim at enabling the European factories towards: Service and consumer-oriented Life Cycle Management and Global networked Virtual and Real-time Factory management. From the European answer for Production System clusters, the research efforts have to be directed towards the investigation of Beyond Lean Manufacturing, the employment of New Taylorism as a base of increasing the efficiency of people and of the manufacturing processes. The synchronisation and harmonisation of all these, has to be conducted towards the implementation of the "Factories as Products" new industrial paradigms and business models.
- In **long terms** the envisioned new business models and methodologies and tools have to support the conception and implementation of European Production Systems and Standards, which are highly enabled by innovative, finance-based

entrepreneurships, required as foundation for the next-generation "Factories as products", having the required features: digital, adaptive and real- time.

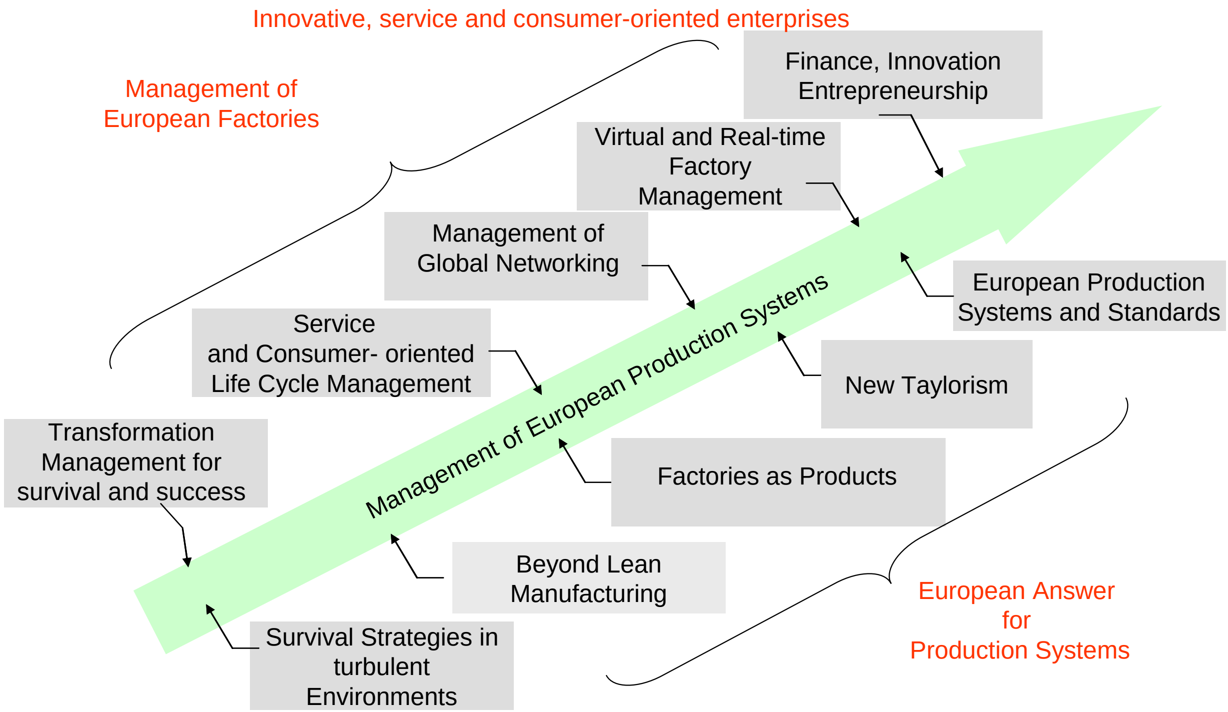

Figure 2. Manu*future* Trans-sectoral Roadmap: New Business Models

2.1.1. European answers for Production Systems

Europe has a long tradition in manufacturing of technical products, based on inventions and innovations: Manufacturing in Europe has a human orientation with high skills and qualification, including scientific-based social standards of work. The so-called "European Production System" has been attacked by Far East "Production Systems" known as "Lean Manufacturing" or the "Toyota Production System" (TPS), - permanent fighting for efficiency with a concentration on value processes and logistics, simplification and standardisation, elimination of waste, loss of time and quality and fast reaction on disturbances. The automotive manufacturers implemented the TPS, being at the moment still far behind the efficiency of competitors. Today's practices of "Production Systems" are the quasi international standard of manufacturing. To overcome this standard with the European way of manufacturing, a very intensive and well focused long term research and technological developments are necessary. On time dimension and priority scale, several research directions have to be mentioned:

- **Short term and high priority** have the acceleration of the diffusion process of the knowledge of lean manufacturing in all sectors of manufacturing, through survival strategies and innovative methodologies supporting the manufacturing enterprises to survive or to stay competitive in the turbulent environment of global and high wage economies.

- **Mid term activities** should focus on several main directions as:
  - Definition of an European way of manufacturing, based on European Culture, Innovation and Knowledge and the implementation of "Factories made in Europe", by
  - Implementation in all manufacturing industrial sectors, the principles and new philosophy of "Ney Taylorism", and by
  - Integration of new industrial paradigms for manufacturing fitness, balancing reactivity and efficiency.
- Long term implementation of the European Production System as a foundation for the next-generation Information and Communication Technologies (ICT) for manufacturing, giving to the new industrial paradigm "Factories are products" the required features: digital, adaptive and real- time.

The fast diffusion of lean manufacturing knowledge and best practices in manufacturing industries can be achieved through new and innovative education and technology and knowledge transfer models, methodologies and tools.

Survival strategies in turbulent industrial environments

The development of the market depends mainly on economic factors. In many industrial sectors and especially in investment sectors, the usual good cyclic fluctuations with strong growth and falls, represent main factors of market turbulences. Many enterprises are not capable to remain competitive or at worst, they do not survive in these cyclic phases. Other high challenges are issued by market strategies of competitors, which operate in areas characterised by lower wages and higher flexibility of the work force (hire and fire). European human-oriented culture and social standards on the one side and high fix costs caused by capital intensive production on the other side, highly reduce the chances of surviving. European manufacturing industries, operating under the increasing pressure of making short time profits, represent another turbulence factor. All these factors reduce the employment and sustainability of many industrial sectors. The current economic models are mainly oriented towards growth and are following the preventive strategies coming from product innovations. There is a requirement for manufacturing strategies and methods for:

- Balancing the load in mid term cyclic markets
- Overcome critical short term situations
- Dynamic forecast
- Adaptation of fix costs (dynamic systems)
- Dynamic work force models
- Financing of critical phases.

These represent the main directions on which research and technological development activities have to be oriented, with high priority on short term horizons.

New product and process life cycle-oriented industrial paradigms

The new paradigm of manufacturing is oriented towards the optimization and value creation of products along their whole life. This assumes the prediction and understanding of the future user requirements and design of products (customisation), the manufacturing, product-near services and end-of-life. The global market is registering an increasing demand towards customized products, which have a short delivery time: in parallel, a continuous shift of business is taking place towards the development of a new and innovative system of products and services, capable of fulfilling specific user demands. Under this perspective, the analysis and the best orientation of the product life cycle, to achieve maximisation of potential and of related business opportunities, are crucial elements that have to be exploited. Furthermore, the integration of new technological developments in products and consequent modifications in the production process are driving the manufacturing sector towards complex and articulated dynamics that require strategic intelligence and a New Taylor approach. To properly face these challenges, the production process shall be analyzed and optimized in its structural and functional aspects, considering the total life cycle, in order to identify qualitative aspects which have to be enhanced, new performance factors, networked integration and interaction aspects, and environmental factors which have to be achieved.

Innovative and new combinations of the following elements – customization – production – service – end-of-life , including within each element the solution of “what, how and when” in order to introduce knowledge, know-how and technologies, represent valuable solutions to the above stated challenges. They should be addressed at network and factory level, as follows:

Network level: *The shift to the new industrial revolution*

Factory level: *"Factories as a product" - the factory is anticipated to be a product in its own right*

Several main development issues and targets at network and factory level have to be mentioned:

- Methodologies for regulating the new paradigm with strategic intelligence on markets, products, technologies and human resources (success stories, best practices, innovation laboratories)
- Methodologies and tools for understanding product/service potentials and for identifying new business opportunities with respect to new market/consumer demands, in terms of product enhancement and new consumer oriented services
- Process architectural analysis, process functional analysis and performance calculation, multi level simulation, process performance optimization product/service related
- Tool and methodological support for the integration of state-of-the-art industrial paradigms for manufacturing fitness, balancing reactivity and efficiency;
- Tool and methodological support for integrating systems and processes of suppliers and customers capable of supporting continuous adaptation; systems based on European “standards” and open architectures;
- Tool support for dynamic systems and process modelling, providing improved synchronization between reality and model;

- Tools for highly responsive manufacturing design systems, delivering systems with optimum complexity, capable of meeting mass customisation requirements;

Integration of industrial paradigms for manufacturing fitness, balancing reactivity and efficiency

Industrial manufacturing is oriented in achieving the main objectives of time, cost and quality. Industrial paradigms follow strictly conventional paradigms like balancing the capacity or management of resources with high rates of utilization. The next-generation manufacturing is characterised by customisation, which reduces the lot sizes and increases the variants and specific products, manufactured in a short time. Another specificity of next-generation manufacturing is the increasing complexity of products. This challenge can be overcome through actions as the development of methodologies for future manufacturing management, based on new and innovative paradigms, mainly aiming at achieving following goals: single customer order, flexible work time and high reactivity, especially in the sectors of customised products. Market influences and changing customised products by reducing the lot sizes to 1 with increasing un-efficiencies, requires new methodologies for the balancing of capacities in turbulent markets. These are intended to support the:

- Flexibility of resources and flexible work management
- Situation, based on balancing of the capacity load
- Self-organisation and self-optimisation, self-controlling with autonomous work groups and business units
- In-situ Management
- Learning organisation

Beyond lean manufacturing

See 1st call

European Production System

Production Systems represent the recognised and well-accepted frame for the management of manufacturing engineering. They comprise the set of models, methodologies, technologies and tools for efficient engineering, planning, production and operations of products and factories. An accepted and available collection of about 80 methods is used to systemize the management of manufacturing processes. They include specific aspects like quality management, management of orders in logistic chains, planning of processes, resources or optimisation of time and cost. Many of them are implemented by using the modern ICT technologies and tools. The basic foundations of these methodologies are partly old, as time or cost management or the optimisation of workplaces by ergonomic basics.

Systematisation by use of basic methods brings manufacturing enterprises advantages in cost and value per capital, estimated at about 30 %. Behind these traditional paradigms as rationalisation, analysis of human work, division of labour, equal and incentive payment can be mentioned. They got new elements by methodologies for lean management.

These methodologies have to be oriented towards development and implementation of the so-called European Production System, which is characterised by the culture of work responsibility for sustainability (resources, management) and economic efficiency. Solutions are mainly influenced by the fact of permanent adaptation to changing conditions, activation of the potentials of global communication, global standards in logistics and technologies as well as global competition. Therefore the set of methodologies has to be extended and advanced towards the leadership of European Manufacturing in efficiency and human work. This can only be realised by interdisciplinary research and the development of basics for a holistic view and the knowledge of a community. Interdisciplinarity is an essential aspect, by synchronising and harmonising areas as: Economy, Ecology, Technology, Communication, Social areas and cultural aspects of work of millions of people. The European Production System is intended to become the standard of production around the world.

European manufacturing standards

Technical standards are usual and have a broad spectrum. The development of standards for efficient and sustainable manufacturing management should be a part of the strategic development of the European manufacturing. Several main standardization activities and required standards should be mentioned:

- Standards of the European Manufacturing Management
    - Management of Sustainability
    - Actualisation of Quality and Environmental Management
    - Certification in global production and work: social areas, ergonomics, management systems, IP, Security
    - Standards for the exchange of data and information in networked production

The activity should be launched to define the requirements of standards, based on existing regulations

Factories as Products

European manufacturers of capital intensive products play a significant role in the manufacturing world market. There are some hidden champions which have leading positions. Following the Strategic Research Agenda Manu*future* towards global leadership in the market of manufacturing with “Factories made in Europe” the research and technological development in manufacturing has to focus on:

- Understanding factories as the complex socio-technical systems for transformation of energy and material by the input and adaptation of resources like buildings, infrastructure, machines, tools, people, information, knowledge etc., most efficient to products and value.
- Understanding that factories have a long life duration from planning to end of life, in which they have to be adapted permanently to the needs of markets, product technologies, manufacturing technologies, human skills and age, changing regulations

- Implementation of methodologies and holistic production systems (beyond lean)
- Implementation of efficient ICT's to support operations and engineering,
- Implementation of efficient technologies (beyond limits)
- Permanent innovation and learning capabilities

Factories seen as products will change the workflow from the customer's request for elements for the operating system to realisation and adaptation (short time, high customisation, and delivery), the models of cooperation between manufacturer and end-user, the information and management system and they can activate high potentials in the world market.

It is essential to design, develop, implement and evaluate a new brand "Factories made in Europe", based on best practices and implementation of the European state-of-the-art, as the best in the world.

A specific element of factories as products is the learning element, which supports the implementation of the so-called "Learning Factory". Main features and requirements of the Learning Factory are:

- **Learning from the past** requires education and training and usage of experiences supported by ICT
- **Learning from the best** requires the mobility of people and exchange of knowledge
- **Learning of Machines** requires the implementation of cognitive elements in the control systems

Learning from the future can be realised by the implementation of simulation systems in all scales of the factory, from network to manufacturing processes.

New Taylor, increasing the effectiveness of people and processes

Turbulent factors of influence on networked, knowledge-based and complex manufacturing engineering, highly integrated machines/equipment and extreme requirements concerning quality and precision, raise the question whether modern manufacturing can be developed according to tayloristic/scientific management principles. Currently, new methods of work planning have been developed and a far higher qualification level of work force is given than decades ago. Based on new methods, technologies and tools, the scientific management of manual working systems can be transferred to the scientific management of machines, automation manufacturing processes and can therefore be used for the comprehensive and holistic planning of manufacturing systems. The operation of such systems delivers continuous real-time information, which represents a valuable base of analysis for the re-planning and adaptation tasks of the factory as a whole, by using methods and tools of scientific management systems. The continuing iteration of the flow of activities, regarding the scientific management of manufacturing systems, guarantees their permanent operation under optimal parameters (time, cost, quality). Therefore the new methodical doctrine of "Scientific Management" according to Taylor, called "New Taylorism", focuses on studying the fundamental methods of factory design, optimization and adaptation, of process, system and resource engineering. The efficiency and effectiveness of work force (people), involved in manufacturing activities, represent main focuses of New Taylorism, as well.

Taylor's impact on manufacturing systems mainly resides on methodology development for work design, work-measurement, and production control. The strong criticism of Taylor's theory is that it focuses on work measurement and on methods for increasing the efficiency of work force (people), actively involved in the manufacturing process, by addressing only efficiency and not addressing the effectiveness of manufacturing processes and peoples' activities as well. From this perspective, the manufacturing organisations, called factories, have to face two main challenges:

- Change of the nature of work, performed by people in manufacturing organisations as an effect of changed nature of manufacturing processes through automation and fewer people carrying out routine work;
- Poor productivity gains through the employment of ICT in assisting people in manufacturing activities, based on reduced harmonisation of manufacturing industry requirements, peoples' abilities and skills and ICT system/application performances.

To overcome the above mentioned challenges, the research efforts should focus on:

Development of methods to improve the effectiveness:

- in the way people are working in manufacturing organisations, taking into account both the tasks they currently perform in manufacturing and the systems/tools they use e.g. turn reading emails into collaborative and constructive work and,
- of manufacturing processes, machines/equipment and manufacturing systems closely based and employing the new ICT, e.g. collaborative and multi-scale modelling and simulation, cognitive applications and human-machine interfaces, etc.

Training and Specific Actions for the implementation of European Production Systems

The increase of the rate of diffusion of the new and innovative methods and tools for the manufacturing optimisation is highly supported by the regional transfer centres, which take over the education in environments near research and near application. A concrete mode of giving reality to these transfer units represents the development of the "Learning Labs" equipped with innovative and modern infrastructure, which is required by digital/virtual factories.

Another main element is the realisation of an Internet-based European Platform for Manufacturing Knowledge, now envisioned as a potential "Google for Manufacturing".

2.1.2. European management systems

Transformation management strategies for survival and success in turbulent environments

Manufacturing enterprises are influenced by multiple dynamic external factors concerning the products behaviour in global markets, the strategies of competitors, the regional level of wage and reward systems including management of employee healthcare cost, regional infrastructure, the pace of technical innovations, the financial requirements of the investors and the financial constraints of operations, the robust supply of materials and components. Internal business factors such as qualification and capability of employees and the management, the demands and systems required by different customers, the utilization of resources and the capability of processes represent main influence factors as well. The enterprise environment is tough and turbulent. Only those enterprises can survive and be successful in this turbulent environment which are robust enough and have the capability to continuous adaptations and transformations. These challenges are particularly acute for SMEs, which operate in traditional and new technology sectors and do not have the scale and resource to address all the changes in their environment. The technical content of transformation management strategies for survival and success in turbulent environments is the development of such strategies that recognise the evolution of the manufacturing business environment. Research challenges, which are envisioned here, include: identification of methods for small businesses aiming at recognising and responding to external threats; determining and assessing candidate business models for SMEs to assist their survival and transformation; defining mechanisms that allow SMEs to take similar advantages from manufacturing in the enlarged Europe in comparison with those accessible to large companies; determining the required competences and mechanisms for SMEs to form cooperative transient business networks to increase their scale and to respond to opportunities; determining and disseminating best practice survival and transformation mechanisms developed by successful SME businesses or agencies; generating tools and techniques that support transformation; and the development of economic regulations and financial instruments that support transformation.

Extended product services through integration of product life-cycle knowledge into the products themselves

Information, knowledge and documentation about each product is a part of the delivery and is important for product oriented service operations like maintenance or training. The expenditure of documentation increases with the complexity and customising of new and high-value adding products. Product documentations are generated during the engineering process and are adapted by manufacturing and service. They can be combined with diagnostic systems to have a permanent state-of-the-art and the on-line availability (24 h/day within few minutes). Such systems represent prerequisites for global sales and services especially in the machine industries. Together with e-maintenance activities an European way for service support can be implemented. Main challenges on this way are the reliability and security aspects as well as economic aspects of global services. New and enabling technologies for the efficient generation of information and documentation by manufacturers and the integration in the Life Cycle Management represent a fundamental aspect for efficient growth in the "After Sales" business. In the development of Life Cycle Information and Documentation Systems with efficient data management, the integration of Internet technologies and applications should take into account the complexity of IP and security aspects.

Management of complexity

The manufacturing enterprises have to handle new demands arising from the market, from new technologies or restriction by pollution, from the society as a whole, becoming ever more complex in all aspects in the past years. The global economy and the socio-political scenarios are increasingly more intricate, more fragile and difficult to understand and manage.

Management of complexity is a very important issue aiming to harmonise all these demands in a practical way, in a management strategy for coping with complexity. That implies identifying how complexity starts and works in the complete manufacturing and distribution process.

The process of handle and manage complexity has to take into consideration the development of tools for:

- complex visualisations
- interdependent visualisations
- scenario management, if –what analysis
- complex simulations
- reducing and optimizing processes, interdependencies and connections.

The management of complexity will lead to successful manufacturing operations, allowing manufacturing enterprises to be successful in their markets and being more accurately and rational in their manufacturing processes and their product range.

New business models for networked Virtual Factories

Demands from the market, changes much more faster in the future, so companies can only be compatible in these markets, if they develop, produce and distribute new products much faster than today. For all companies this is a problem of resources, especially for SME´s. To combine the strength of different manufacturing enterprises in the whole process and to be much faster – from the idea to the product – represents the main idea of the Virtual Factory. To organize such virtual factories, there is a need to approach all classical functions of enterprises on a higher level – on a virtual level and for networked virtual factories. As a consequence, new organisation models have to be developed, aiming at developing such self-organised and market-driven entities, consisting of models for:

- o Market environment for new businesses (electronics platforms / stock exchange systems)
- o Partner generating modules
- o Optimization - who is the best in which stage of the process
- o Rules and rights
- o Information and knowledge processing
- o Product processing.

The development of a market driven organization structure with specific aspects of indicators for combining competencies, rules and rights, information systems and logistic aspects has to conduct towards the development of a new market model for networked virtual factories.

Management of global networking (link to IMS)

Globalization of work is one of the leading trends in the business world. To transfer the ideas and rules of the European management system helps European companies to cooperate with companies of other parts in the world. The European manufacturing standards can be transferred around the world, so that Europeans can also transfer the use of these standards in management methodologies, production processes and information systems for cooperation and working together to other companies. Global networks are useable for supply chains, networked companies and virtual factories.

Real-time enterprise management

Global businesses are involved in many complex product life cycle relationships in terms of design, engineering, manufacturing, life time service support and final product environmentally friendly disposal. This involves businesses in a vast array of different relationships with various suppliers and customers, each having their own dynamic limitations and requirements. For organisations involved in these partnerships, there is a deep and complex requirement to manage their enterprises on a real-time basis, meeting and managing the conflicts of multiple products, multiple customers in differing supply chain positions and product life cycle stages. For true adaptability, flexibility and ability to improve productivity, these situations must be managed on a real-time basis, using data, information and knowledge, distributed throughout the supply chain and customer environment.

Particular research challenges and barriers which need to be addressed include: a drive towards true inter-operability both within and between enterprise management systems; the availability of inter-enterprise information on a real time and intelligible basis; the ability to agree and make inter-enterprise decisions on the basis of mutual trust and benefit and finally, the ability to distribute new inter-enterprise schedules and agreements. All of the above mentioned abilities can be achieved within the development of changing economic, highly adaptive and increasingly complex business process models.

The development of suitable tools for Enterprise and Supply-Chain Management will support knowledge-driven outsourcing business models on a global scale.

Finance, science-based entrepreneurship is leading to global manufacturing

The science-based models, methodologies and tools provide a rich source of potential products for manufacturing industries. Some products emerging from the science base may even lead to technological innovations of such a scale that they become significant industries in themselves. The liquid crystal display is a historical instance of the latter. The creation of radical new products takes longer than incremental conventional products and it is a higher risk. This requires corresponding radical approaches to investment and the return on investment. Innovators in the science base frequently lack the entrepreneurial skills necessary to focus on getting the best ideas to market and have little understanding of the requirements for enabling process technologies to allow their products to be realised at an acceptable cost.

In order to exploit the new ideas arising from the science base by European businesses, it is critical to understand how such radical product developments can be financed and how values are developed and returned to investors during the early stages of the life of such new and exciting products. Radical physical products will demand new materials and new manufacturing technologies. The new product development process and its leadership demand a new type of entrepreneur, which is capable of interfacing between the enthusiasm of the science base and the pragmatism of the intellectual property protection, finance and manufacturing. New business models for the creation of new generic materials and manufacturing technologies for emerging products are also required. Mechanisms of accelerating the pace of commercialisation of products from the science base and of increasing the knowledge of the science base on the emerging product requirements of the European economy and society must be found:

Machine tools and centric business models

Changes connected to the adoption of New Business Models for Machine Tools have special impacts on the relationship between MT producers and MT users. In particular, the changes have impacts on the responsibility of the results of operations, actually shared between builder and user. In particular, a builder is responsible for aspects which are mainly connected to the machine's safety and performance (precision, speed, reliability), while a user is mainly responsible for the parts which have to be realized (supplying man power, raw parts, tools, testing facilities, etc.).

Adoption of New Business Models, anyway, would affect this traditional model, in almost 3 phases:

1. better defining the "grey areas" in machine tools of the producer-user relationship: some activities are not actually well covered by both of the two, such as machine installation in the job shop, its final testing, the definition of reliability-connected aspects (MTBF, MTTR, TCO); some performance measurements, etc.
2. NBM – oriented technical aspects: the adoption of a new type of relations between customer – MT producers, such as "Pay per use", "Pay per part", etc. will move some responsibility of the production from MT users to MT producers, with consequences from a technical point of view.
3. The more extreme possibility connected to the NBM and MT user-customer relationship is to transfer the complete responsibility of production to machine tool builders. Then, they will be responsible for parts of the design, technological cycles, machine tool definitions and set ups, raw parts procurements, man power; etc. The only difference between this model and the usual activities of Tier 1 is connected to the localization of the production facilities in the end user plant. Then, the machine is owned by the producers, run with the producers' personnel, is maintained by the producer, discarded parts are just cost for MT producers; the end user just pays for finished parts.

Taking into account the above mentioned aspects, a deep reconsideration of the roles and activities of MT builders and users, as well as of the technical, managerial, economical, financial, normative and legal aspects, might be taken into account.

The above mentioned aspects require a deep investigation and modification of the traditional way of working, involving a wide number of scientific and technical disciplines, as well as various industrial sectors. Anyway, this will, be done with the target to use the European machine tool knowledge of manufacturers, acquired in decades of activity. This knowledge can then be used to help the progressive loss of technical specialization coming from many industrial sectors, in which the focus has moved from production to business, from commercial to financial aspects, and to help to reduce the effects of progressive aging of population and of the reduction of interest for technical professions coming from youth.

- Machine tools: the actual machine tool concepts might be reconsidered to be adapted to different applicative contexts. In particular, they might be focused towards a higher flexibility and reconfigurability, in order to be adapted to various operational situations.
- Control and diagnosis: a wide use of ICT techniques can be useful to keep tracking of all the conditions of running machines located at customers' sites, as well as to define the number of manufactured parts and defect ratios, in order to allow the payment by the customer made under "pay per …" strategies
- Project capabilities: Machine tools manufacturers might enlarge their knowledge base in order to cover the development of process and product designs. This would also lead to the integration of activities for a group of SMEs, in order to create a critical mass to face this challenge, helping to increase regional, national and European level collaborations
- Rules and standards: the actual standards and rules, connected to the use and testing of machine tools are focused on a traditional way of using machine tools. New concepts for testing might be developed in order to fulfil the requirements and avoid contrasts.
- Law aspects: the European and national legislations might be reviewed to cover the new kind of relationship that will derive from the new way of cooperation between MT users and producers, avoiding contrasts and respecting rights and commitments for all of them
- Financial and risk reduction aspects: the machine tools producer might deeply change its financial and risk management approach. In fact, in the traditional model, risk is evaluated ex-ante, during the definition of contracts and with market analysis of potential customers, while financial aspects, connected to machine development and production, are covered with own capital or with bank financing or leasing, guaranteed by the contract signed by the MT user. With new types of business relations, a deep involvement of new participants (such as insurance) will be necessary; again, the formation of consortia and association of companies will be necessary to create the critical mass to manage such aspects
- Intellectual property: new kinds of instruments for knowledge defences might be developed, in order to protect the rights of all actors involved in the NBM based

machine tools, giving also instruments that preserve information ownership during the design and commercial discussion phases

- Training activities and social aspects: the machine tool sectors will increase their attractiveness for young workers by multidisciplinary and will represent a very interesting playground for innovative forms of training, based on multimedia, virtual reality and other technologies based on ICT

The development of NBM-oriented machine tools is on the one side, a multidisciplinary and transversal activity and on the other side, it will innovate one of the column of European industrial tissues, making it more fundamental for the worldwide manufacturing and ensuring a base of know how, coming from the cooperation, based on co-design, co-technology and co-manufacturing with a wide number of customers, belonging to all manufacturing sectors worldwide.

Technology monitoring and scanning

In a technology-driven competitive environment, Management of Technology has to steer the build-up and the usage of technological competences in a company. Technology monitoring and scanning are the first of the four central steps of a state-of-the-art Technology Management process. A fully functional Technology Monitoring has to identify candidate technologies for the following steps of assessment, planning and the usage of technologies. Effective Technology Monitoring assures that attractive new technologies are identified early, their development can be predicted and expected discontinuities in the development of technologies are detected faster than the competition in order to be able to react to these insights. Technology Monitoring itself consists of the determination of information needs, of obtaining and analysing information and of communication.

In recent years Technology Monitoring has, especially due to the ever rising efforts that are undertaken in cooperation with other companies or bought externally, become an even more important and complex task for companies. Technological know-how is bought externally in the form of components or technologies. Because of this reason the internal view of the innovation and technology development processes has to be expanded by the external perspective, which consists of external acquisition and the usage of technologies.

As important a process as Technology Monitoring and Scanning is for the mid- and long-term success of any knowledge-based enterprise, as hard it is to implement it efficiently, especially for SMEs who lack the international resources of global players.

The central challenge for SMEs is to, despite of their limited resources, still cover a broad range of interests with a thorough assessment. In most cases this can only be realized through networked co-operations.

Projects answering to this call should focus on the development of toolboxes that enable European SMEs to monitor and scan technologies with a networking approach. Based on this, the specific needs of knowledge-based European SMEs need to be assessed and new methods that are tailored towards these needs have to be developed. The industrial involvement should be strong and results need to be validated through quantifiable positive effects in industrial trial applications.

IP security in networked manufacturing

The activation of synergy potential in networked manufacturing is one of the strategic aspects of manufacturing industries. The exchange of knowledge is one of the critical factors in the collaboration and needs the protection of knowledge. The specific actions of IP-Security have to be elaborated in a coordinated action.

2.1.3. Innovative management models, methodologies and tools

Innovation and transformation processes

The transformation from a basic research to an application is essential for the effectiveness of the research system and market success. Many companies invest only a small part of their turnover in the development of new products, based on new results of basic researches. It is known that aggressive technology leaders, who combine product-production and marketing strategies, have more success than followers. This has a structural background in the research system but even in questions of reliability of the transformation process. The main constraints from industrial perspectives are:

- missing models for technology management and the integration of manufacturing strategies in the strategic planning processes.
- missing methodologies for the integration of new technologies in the resource planning processes.
- uncertainness about the potential and the effects in manufacturing.
- missing experiences of practical points for reliability
- process chains from research to practice

To overcome the above stated challenges and to accelerate the transfer of knowledge for innovation purposes, the research and technological implementations aim at the development and evaluation of methods for the technology evaluation, the integration of manufacturing strategies in the business planning and information on time about knowledge of new technologies. This includes the economic potential analysis of new technologies by practical procedures: feasibility and reliability studies, forecast and simulation, organisational integration of operations like simultaneous strategy planning.

Preventive Quality Management

The quality and reliability of products, services and industrial operations (Business Processes) are preconditions for High Added Values and the growth of demanding manufacturing sectors. Following the trends towards customised products and build to order strategies in manufacturing, new and efficient methods are required in all manufacturing sectors, in order to assure quality and reliability. Preventive quality management approaches are required. They include innovative methodologies for the introduction and management of the life cycle of new generations of products, such as those including mechatronics. There should be a focus on design of quality and reliability and the design process should include the ability to forecast and predict the utilisation and life time of complex products. Methodologies have to take into account the development of products by cooperative and networked engineering, the capability of the design, manufacturing and measurement processes and the influences of manufacturing technology choices. They should also be linked to the product data and execution management systems and emerging requirements that may require capture of information over the flow of manufacturing from the product's concept to the end of its life and that will necessarily cross commercial boundaries. Documentation systems, which collect data including experience in the use phase and address the responsibilities of manufacturers for their products and the management of the controlled substances used in the product and its manufacturing, will also be required:

Several main results can be envisioned: (1) Basic methodologies for preventive and life cycle oriented quality management including improved design (2) Increased reliability of complex products (3) Development of an European product documentation system (4) Reduced losses caused by quality problems (5) trans-sectoral implementation for pushing the High Adding Value in the manufacturing of complex products.

Change and Modification Management

Due to increasing dynamics in the markets and decreasing product lifecycles at the same time production ramp-ups have to be performed both more often and within shorter time intervals in many high volume industries. Especially suppliers are facing time and cost problems in serving different original equipment manufacturers. In order to reduce development time, avoid late product changes, and improve the coordination of development, engineering and production, the "simultaneous engineering" approach has been developed and diversely applied. As a result of increasing product variety and augmenting fragmentation of the value chain amongst many companies, the traditional SE-approaches do not suffice so that new approaches are required.

The results of a performed research in this field aim at expanding original SE-approaches in three dimensions. Firstly, a company must be harmonised along its supply chain, supporting the fast and flexible dissemination of technical changes in products over all participants of the value chain.

Secondly, while an increasing variety of products use the same resources, solutions for handling changes shall be developed. Thirdly, a company has to be able to propagate ramp-up activities throughout its global production network (e.g. start-up and launch of a pilot line at site A, afterwards shifting of series production to site B). Projects should address improvements especially for suppliers on all levels of the value chain, e.g. in automotive industry.

Competition in global manufacturing

In today's global marketplace, companies face intense competition and increasingly sophisticated consumer demands. Innovation lies mainly within manufacturing networks, constituted by OEMs and SMEs, which compete on the market.

The supply value chains are shifting from *internal* process management and cost reduction, typical of Lean Production, to value *external* collaboration, flexibility, and risk management (including continuity of supply), in order to achieve multiple sources of higher value. New business models are fundamentally for being able to compete in global manufacturing, making SMEs which constitute to the European manufacturing success, reconsidering the nature of OEMs – SMEs, suppliers and partners.

The technical content of these special investigations is focused on competition in global manufacturing to identify and exploit new opportunities for maximizing values in manufacturing networks for European strategic sectors, such as Automotive and Aerospace. The challenges are to evolve the supply chain concept into a new net-centric approach; deploy a network approach to manage business processes and technologies; to develop a virtual "network" extension of organizations' internal capabilities; to build new levels of visibility and interoperability into organization extended operations. These investigations aim at identifying the actual situation of key OEM-SME networks, regarding the product life cycle in the enlarged Europe; in order to identify the major European barriers to achieve a competitive network-centric manufacturing environment; to recognize the different role of partners in different OEM-SME networks; encourage diverse public and private stakeholders as high value partners in the OEM-SMEs network manufacturing to increase capability.

These special investigations in global manufacturing competition aim at: analyzing the Europeans best practices in the manufacturing network-centric for consumer goods, semi-finished and capital goods; benchmark by USA (NACFAM) to understand "how" organizations collaborate and not "how much"; identifying the OEM internal and external business transformations, including "reactive" and "proactive" integration in product development. Possible results have to: deepen the knowledge of the weak parts of the OEM-SMEs in order to provide an impact on SME networks: outline new business strategies, new tools and techniques to comply with product inside the OEM-SME networks; empower the European manufacturers, within OEM-SME networks, in order to avoid, reduce and fill the gap with the U.S.A., Japanese and world counterparts.

ICT enabled business models for manufacturing

The reach and richness of the information and knowledge, available through global ICT services should significantly impact and support the transformation of European manufacturing industry. In particular, the service sector has adopted the use of this technology in interesting and competitive ways. Therefore, if European Manufacturing is to embrace concepts such as the extended product service paradigm, in ways that would allow it having a pre-emptive position within global manufacturing, then it must adopt and understand new business models. These new models will almost certainly use ICT in novel and innovative ways.

However, with regard to ICT, manufacturing has unique and individual challenges. The knowledge can be more complex and requires much higher accuracy than traditional paper-based transactional data. For example, product and process data must be timely, completely accurate and have to take account of many historical configurations if they support the full life-cycle. In addition, this complex data must be available as contextual data in easy-to-use formats to support business processes as diverse as product design, process design, manufacturing, training, service and marketing functions. Finally, it should also capture the tacit knowledge, locked into products and processes in ways that allow effective, repeatable and systematic business models and processes to be developed and make it freely available.

The research activities in this field aim at building on the strategic concepts of Europe at the centre of a global manufacturing capability, tacit knowledge capture and exploitation, lifecycle data management and new business paradigms supported by the reach and richness of state-of-the-art ICT. The conception and development activities should address a full transition/change cycle and include definition, design, development, testing and prototyping phases.

2.1.4. Service and consumer-oriented business models

New consumer-oriented business models for Product Life Cycle

Integrating systems and processes of suppliers and customers, which are capable of supporting continuous adaptation to market needs are needed to strengthen the competitiveness of European manufacturing and logistic companies, facing new opportunities and threats due to continuing globalisation. The main development issues and targets are a further transition from products to solutions (services), improved and increased involvement of the consumer in more parts of the value chain and managing the consequences of the reduction of the vertical integration traditional in larger businesses. Further, environmental drivers and an increasing recognition that manufacturing businesses do not benefit sufficiently from the value that they create, emphasizes the need for the development of a whole new life cycle based business model that minimises environmental impacts while maintaining economic sustainability. The focus should be to resolve the challenges that need to be addressed to encourage businesses to work in open collaborations within a production and logistic network across the whole life cycle; the development of new cross-company business models, addressing aspects of cost, benefit and risk, sharing within coherent financial and intellectual property frameworks which give mutual benefits; and to define and create the supporting technologies and tools, which are necessary. These new business models should cope with new product concepts, also including aspects of dismantling and recycling, and providing a set of services and functionalities, including a potential to upgrade products by “after sales” through their life. The projects are expected to have a successful technology demonstration, technology transfers and training activities.

The performed research aims at achieving the following main results: an increase in added value, productivity and economic sustainability in Europe through an industrial stakeholder involvement. New industrial strategies will increase and sustain production capability & capacity and responsiveness, improve manufacturability, quality and reliability as well as decrease the consumption of raw materials and energy.

Innovative and efficient networking of supplier and customer systems and processes

Concentration on the core competences and on outsourcing is parts of strategic orientations in series production. In this area, the logistic chains are industrialized and efficient. Companies with small series and high diversity of variants have high problems in the management of the chains: low volume, last minute changes, complexity of products, special technologies. In consequence to this, a high potential of synergy is not activated and causes uncertainness in the process chains and quality. Deviations from scheduled plans bring high losses in the efficiency and markets. Solutions and methods are required to activate the potential of synergy in the chains of cooperation: engineering, supply of material, supply in manufacturing equipment, and supply in services.

Possible solutions have to be developed and evaluated under real existing conditions:

- Robustness of the cooperation chains
- Reduction of organizational inefficiencies
- Open architectures for information supply
- New methodologies for order management (situation based)
- Work sharing
- Networking and neighbour-ship
- Regional networking in competences and capacity balancing
- Implementation of innovative technologies
- Standards
- Human relations

The focus of this action is the development of new solutions for efficient networking and the implementation in different sectors like machine-industries, manufacturing of capital intensive products.

Built-to-order new models for production design, planning and control in individualized productions

In the course of internationalized competition, production costs and time (e. g. delivery time, adherence to delivery dates) have become more important in relation to traditional quality targets. Especially small series productions with often highly individualised customer products are confronted with the challenge to cope with the conflictive aims of high efficiency, good process reliability and speed. Hereunto new models for production design, planning and control in individualized production is needed.

The main results in this field should provide mechanisms and solutions to improve small series production by overcoming the conflicts between the targets of efficiency, process reliability and speed. The research should aim at improving process designs and operations in a highly customer-individualized market environment, in order to achieve good process reliability, short delivery times and low production costs at a time. The research should focus on small series productions in larger companies and SMEs which are typically struggling with poor economies of scale, high product variety and problematic material availability, as well.

2.2. Adaptive Manufacturing

Manufacturing is a dynamic socio-technical system, which is operating in a turbulent environment, characterized by continuous changes at all levels, from network of manufacturing systems to the factories, production systems, machines, components and technical processes. Adaptive manufacturing envisioned as a new paradigm oriented to continuously and permanent adaptation manufacturing systems by fast implementation of novel solutions. Adaptive manufacturing is knowledge and intelligence-based and operates with the latest state-of-the-art manufacturing and information and communication technologies and socio-technical systems. The adaptive manufacturing innovative models, methodologies and enabling technologies presented in this chapter supports the manufacturing enterprises to face these challenges by promoting new and innovative paradigms clustered under several main groups. The implementation of the so-called "Adaptive Factories" conducts towards a new and enhanced type of factory which has to be more responsive to the turbulent and permanently changing environment through the development of self-learning, self-optimizing and cooperative control systems. The "Adaptive Production Systems, Machines and Processes" aims to the development of adaptive assembly modules, the implementation of the reconfigurability of the machines and the using of smart materials for the fabrication of plug and play components employed in the high precision manufacturing. The embedding of the "Intelligence for enhanced processes" aim at the development of cost-efficient monitoring systems, which improve the prognostic capabilities, the reliability and performance of the monitoring systems. The "Adaptive Tools and Components" as main entities of the adaptive manufacturing systems have a main contribution in the field by the in-situ process simulation used to identify the behaviour of systems under usage constraints, and self-optimizing drives and innovative electric-fluid energy sources. All these innovative and enabling adaptive technologies are in the present chapter shortly presented and graphically represented under the corresponding "**Manu*future* Trans-sectoral Roadmap: Adaptive Manufacturing"** (Figure 3). The employment of them into the manufacturing enterprises at all levels of abstractions for the implementation of the adaptive manufacturing is envisioned as follows:

- **On short term with high priority** the modular systems engineering aims at the development of the so-called modularisation of manufacturing conducting towards a new generation of scalable and interoperable control systems able to cope with the changing market demands,
- **On medium term with high priority as well,** the enabling technologies grouped here aim at implementing the responsive factories through cooperative, self-organised and self-optimised behaviour of the process control systems, and through embedded electronics and sensor-actuators systems, as well.
- On **long terms** the envisioned "Adaptive Factories, Production Systems, machines and Processes" have to include as main components the plug and play elements required for high precision manufacturing and the embedding of the new

knowledge resulted as output of integration of heterogeneous in-situ simulation models of manufacturing processes.

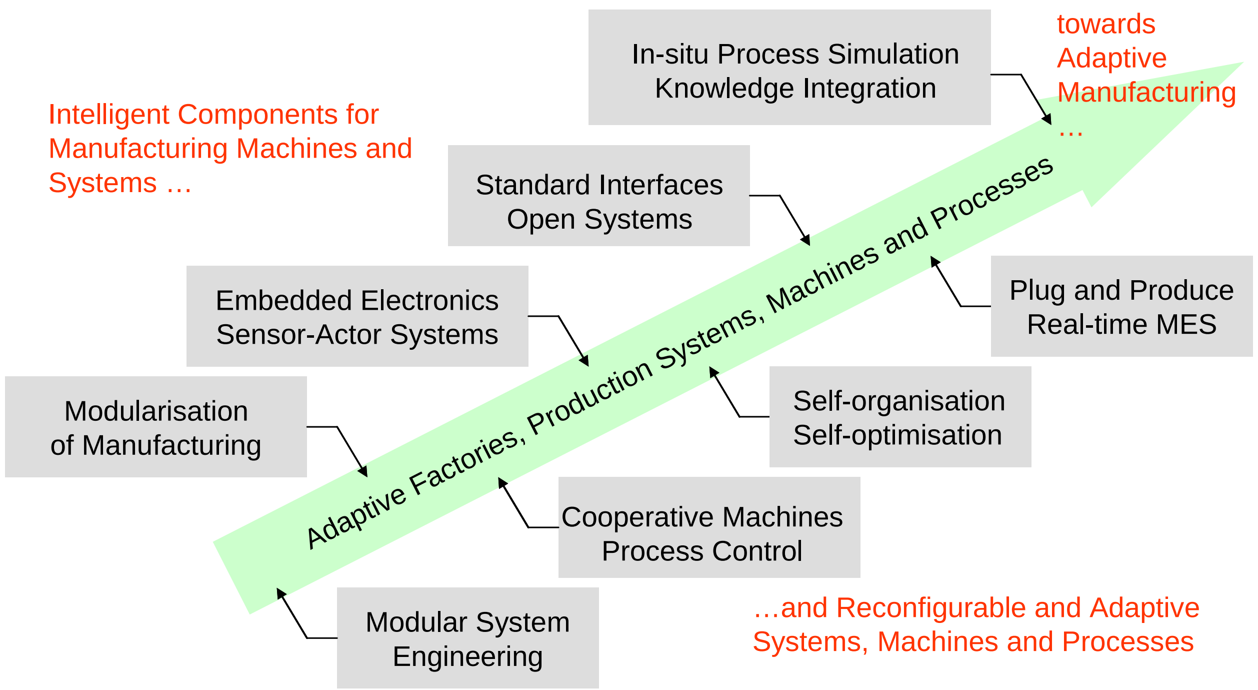

Figure 3. Manu*future* Trans-sectoral Roadmap: **Adaptive Manufacturing**

2.2.1. Adaptive Factories

Adaptive and responsive factories

One of the main strategic goals in manufacturing engineering represents the design and implementation of intelligent factories, which are able to manage complex and reconfigurable production processes.

Distributed multi agent manufacturing technologies and the corresponding solutions will characterize next-generation European factories. Such systems will be constituted by autonomous and collaborative intelligent units (cells, machines and components), capable to self-adapt production operations according to orders and external conditions. In this way reliable and flexible factory automation systems that can be developed or reconfigured with reduced times and costs are able to face the more and more frequent market changes.

In this direction research aims at a fully integrated approach to production systems, achieving:

- modularity of architectures and new flexible and reconfigurable paradigms to be applied to factories. This aspect is mandatory for having a new generation of scalable and interoperable control systems, as a base to create an industry, able to satisfy continuously changing market demands;
- increase of flexibility and performance of knowledge-based processes and automation enabling new agile manufacturing operations. Such features contribute to build new production processes, which are able to adapt to new productive targets and needs with a low impact in terms of costs, development, set-up and ramp-up time;

The main relevant development issues and targets are as follows:

a. Multilayer, interconnected distributed control systems - from product innovation management systems, over factory level control (management information systems, digital factory, simultaneous engineering) down to machine/process level control

b. Multi-agent automation and supervision software will improve distributed intelligence solutions

c. Application and development of digital factory tools and devices, simultaneous engineering and management tools (for optimal use of manufacturing capacity, processes)

Self-learning, self-optimising factory control systems

One of the main objectives of the adaptive production systems is the development of intelligent, scalable and flexible production systems and factories by employing methods of self-learning and self optimizing control and multi-sensor systems.

Modern manufacturing plants are concerned with an increasing complexity, which does not always permit a continuous analyzable development, commissioning and product manufacturing without an increasing amount of uncertainty. At the same time demands for better machines and plant availability, an increase of product throughput as well as of product quality, without neglecting the demand for improved machine profitability, are arising.

Traditional systems are approaching limits which can only be overcome by new philosophies, necessary in the industrial process measurement, control engineering using scalable and adaptive control and multi-sensor systems. So process control systems must be coupled with quality control systems in the sense of automatic quality control loops, in order to be able to react in time to fluctuations during the process, to changes of process parameters and disturbance variables. Furthermore the machines and production systems must be able to react flexibly to different product derivatives as a whole or in parts. Equipment has to be designed to deal with disruptive or not foreseen events without further human intervention. Beyond this one serious has to investigate the question which business models address key factors in this process best. It may very well be that this cannot be restricted to technical questions only.

To reach the above stated objectives the focus of research should lie on the following two points:

- Development of methods for the representation of high-complex production processes in adaptive and scalable tools. That means amongst others are system-open scalable data acquisition and preconditioning techniques, scalable interfaces for data analysis tools (in terms of II) as well as adaptive integration procedures into measurement / control systems and automatic quality control loops. Besides them the usability / intuitional operator guidance must be taken into account.
- Development of data analysis methods / procedures / tools, which are open with respect to the process and necessary analysis algorithm. The procedures should be able to be self-learning and self-optimising. Because of this it must be possible to train the system explicitly by user guidance (i.e. using a human knowledge) as well as by system inherent information (i.e. knowledge derived from process observation, feed back loops, quality records, or quantification of trustable and less trustable sensor signals)

The expected impact should be found in an explicit reduction of development and commissioning time, in an explicit reduction of down times during product exchange and crash situations, as well as in an improvement of product quality, machine availability and profitable efficiency of complex production systems.

Cooperative machines and control systems

The transformation of traditional production line concepts to non-hierarchical agglomerates of autonomous manufacturing units is a key technology for the new European Production. Research and development has to focus on the application of agent control technologies e.g Holonic Manufacturing Systems, Service Oriented Control Architectures for autonomous manufacturing components in the main European manufacturing domains. Novel approaches in these domains shall encompass the life cycle of the production systems from the development of generic manufacturing ontologies, methods and tools for the design of co-operative production systems, integrated engineering systems, monitoring and control systems, HMI for integration of human workforce, re-configurability and behaviour. R&D projects should lead to generic system solutions and demonstrate applicability and current limitations in specific manufacturing domains. The research efforts will demonstrate the feasibility and technological advantage of the New European Production in the core industrial domains. It is expected, that the results will stimulate important industrial innovations in production technology and enhance industrial work environments. The developed technology will drastically improve the international market position of European manufacturers in respect to reactivity on new manufacturing processes and product innovations.

2.2.2. Adaptive production systems, machines and processes

Adaptive assembly modules

The assembly of customised and build to order products is one of the core competences of manufacturing. Short delivery times and an increasing complexity of products requires high flexibility and permanent adaptation of the assembly systems. Hybrid systems with mixed automation, manual operations and assistance by robots are objectives of the technical development. Adaptation without losses of efficiency by set-ups can be realised by modularisation und plug in-technologies. The assembly execution system recognises the actual situation of the system, available resources and orders, which are connected with links to PPC and MRP, in real time. The implementation of principles like self-organisation, self-learning and self-optimisation, which are based on the integration of multi-sensor/actor systems, leads to intelligent systems. But the variety of assemblies in customised manufacturing makes it necessary to change the operations in-situ between automation and human work.

A specific element of this action is the integration of non joining processes and assembly logistics. The system has to be linked to the documentation of assembled parts and components as well as to measurements and physical tests. In-Process Measurement for quality reduces time and costs. Intelligent cognitive elements of adaptive assembly systems are the ability to learn, diagnostic features and in-situ simulations. It can be added by Internet – Information systems and human interfaces with voice processing and tactile feed back.

By the employment of the above presented enabling technologies, several relevant results can be obtained: (1) Configurable systems for assemblies reduce costs and time even in customised manufacturing; (2) Front-Ranking of the European manufacturers of assembly systems; (3) adding value in sectors of assembly suppliers, IT for Manufacturing, Control systems and services; (4)benefits for the users mainly in sectors of automotive, electric and white products; (5) leading the world market by the application of assembly technologies

Flexible machines for rapid reconfigurations

The mechatronic components are widely used in end-products, for example in the automotive and aerospace industries. With increased autonomy they will offer a very effective way to configure robotics and handling units. With increased precision and reliability (including fail-safe hard- and software-interfaces) they will become promising objects for the construction of rapidly reconfigurable manufacturing equipment, suitable to be used in a flexible, agent based production environment. The main objective is then to create radically new, self-adaptive machine structures with online self-optimisation, based on mechatronic modules. The **knowledge-based and/or self-learning intelligent systems** can feature multi-layer control, sensing and actuator structures with a high level of redundancy, which guarantees a high level of reliability and allows optimal performance of a production system under different conditions.

Innovation lies in moving from current 'assembled' sensor, actuator, and control system architectures to truly integrated mechatronic knowledge-based systems.

The main development issues expected in this area are:

1. development of tools for integrated optimised system configurations based on a mechatronic simulation with respect of the resulting performance (including damping characteristics, working envelope, etc.),
2. development of "adaptronic" modules and their integration into intelligent manufacturing equipment

a. active intelligent components (integrating sensors, actuators, control, mechanical structures), adaptronic modules and interfaces, MEMS, MOEMS)
b. enabling the production of micro-systems, micro-technologies (e.g. human machine interfaces dedicated to micro-systems manufacturing, miniaturised manufacturing equipment…)
c. enabling advanced automatic process control

3. enable knowledge-based, self-learning systems through the development of multi-layer controls and model based real-time compensation routines, embedding machining process knowledge
4. development of flexible signal processing methods, and wireless communication mechanisms and flexible system busses with integrated power supply,
5. standardisation of mechanical, electrical and software interfaces.
6. using the above, break the limits of conventional/existing manufacturing processes (machining, tooling, technologies), realising breakthrough of manufacturing methods and processes

Expected results are (i) tools and methods for mechatronic manufacturing systems and components modelling, set-up and use; (ii) demonstrating applications for mechatronic modules and their usage in machines and production systems.

High precision manufacturing by plug and play, components based on adaptive smart materials

The main objective of this topic is to create a new generation of active plug- and-play components, based on intelligent materials or combinations of passive and active materials (engineered materials) to increase the adaptiveness of production systems for changing conditions. The intelligent plug and play systems can feature sensing and actuator structures, adaptive control and energy harvesting to allow a high accuracy of production systems under different conditions and to overcome traditional limitations on dynamics versus precision.

Research should focus on self-sufficient, self-sensing and self-actuating intelligent plug-and-play components based on smart materials. Such systems should easily implement and self-adapt their range of properties, depending on the changing process conditions. Technical key points are the compensation of static and/or thermally induced dislocations, vibration damping and the decoupling of oscillations. Vibrations could be used for energy harvesting processes to transform kinetic energy into electrical energy, to drive the intelligent system and keep European energy resources.

Deliverables include (i) components and methods for intelligent, self-sufficient plug- and-play systems.

Radical new generations of adaptive production systems by means of active, self-optimizing plug and play components based on multifunctional intelligent materials, can be achieved by implementing this innovative technology. Improved dynamics and a higher precision as well as a high level of reliability for changing process conditions represent outcomes of employing the technologies and tools in manufacturing engineering areas.

2.2.3. Intelligence for enhanced processes

The reliability of machines and production systems is paramount for a efficient low cost production. The overall goal is to have a maximum availability of machinery for optimised up time. Firstly a machine user wishes to be assured of the machine's availability. That means it should be ready to use when it is required. This is not a task scheduling matter, but one of a machine consistently being there and being ready to work. Note here that a machine under maintenance is not available and that maintenance times should be reduced as much as possible. A machine which is operating may break down whilst in use and thus become unavailable in an unpredictable way.

A machine may continue to be in use, but fails to meet performance targets (e.g. in terms of desired parameters like tolerances on produced parts), or it has variable outputs (e.g. prone to non-systematic errors). In each case the machine is available, but unreliable.

Machines that are available and initially meet performance targets will stay in use and may thus suffer either a long term degradation of performance or a catastrophic failure. It is thus desirable to provide a prediction of when it will move outside the acceptable envelope of performance. The prognosis of this point allows for maintenance schedules to be planned in periods involving a minimum productivity loss. Rather than a catastrophic failure, it is preferable if machines enter a regime of graceful degradation. In this case their performance degrades in a systematic and predictable manner allowing for a production at reduced rates and eventual shutdown over a period of time (the so-called limp home concept).

Three major research avenues have to be highlighted:

- One that lies in the design of machines, which are inherently more reliable and degrade in predictable ways;
- one which uses condition monitoring (embedded sensing and prognosis engines) and dynamically identifies the current status and predicts timescales for a disruption of the desired performance;
- and finally one which assumes radical new concepts in which the monitoring system is used to modify the behaviour of actuators and to maintain the performance envelope for the longest possible time (self-optimising over a short to mid-tem time period).

The first approach is a short/medium term, the second a medium term and the third a medium/long term. A mechatronic design approach is the key to all three avenues and there are likely to be hybrid integrations of two or more approaches in order to meet cost/performance targets for particular sectors and applications.

The Technical content and scope of this topic is, that generic methodologies, which are applicable to a large variety of complex production machines, are generated. The deliverables should not be component based, e.g. specific for bearings. Bearings could be a specific application case of the developed knowledge.

Cost-efficient condition monitoring systems

The research area should focus on developing systematic condition monitoring methodologies that are robust and cost-efficient, following possible directions:

- Introduction of physical models of the machine's behaviour in condition monitoring systems. This should reduce the required training effort, involved in state-of-the-art condition monitoring systems. The models should match the machine's operations at any state of degradation. To limit the modelling effort, the physical machine model is ideally composed of physical component models, delivered by the component supplier.
- An introduction for cost-effective reasons of new sensors in production machines for condition monitoring should be minimized. This can be achieved by advanced signal processing, that more optimally uses the existing sensors.

The above mentioned scientific research goals can be achieved by:

- combining information of multiple available sensors and controller signals (i.e. sensor fusion) new information can be obtained. A virtual sensor is realised like this.
- Also, sensors can be used more extensively, e.g. in transient modes of the machine. Hence more information can be obtained from already existing sensors.

Condition prognostic capabilities for improved reliability and performance

The research should focus on extending the condition monitoring system with prognostic capabilities. To this end an explicit (physical) and/or implicit (e.g. neural network) model of the degradation behaviour of the machine components over time, in function of the operation conditions, is required. The appropriate format and the methodology to obtain these degeneration models in a cost-efficient way should be established. In particular, different learning approaches for individual machines or classes of machines could be a valuable contribution to this aim.

Revenue optimization through condition monitoring and prognostics

The research should focus on using prognostic capabilities to maximize the revenue of production machines.

In particular, the short to mid-term operation modes of the machines and the maintenance schedule can be optimized for productivity, maintenance costs, energy consumption, etc. Various optimization methods should be compared to determine the optimal way for obtaining the maximum added value from the production equipment. A gradual migration path from operator advisory systems to full self-optimization should be the intent.

Intelligence-based process capability enhancement

Manufacturing processes are instable because of the high number of dynamic influencing factors (deviations of material, wear, dynamic of machines, etc). Manufacturing

Instabilities combined with the inaccuracy of measurement are compensated by the tolerance system. Tolerances are more and more reduced to guarantee the functions of products and to ensure the quality. Additionally tolerances are defined for designing the end of manufacturing, but not the steps of processes (Tolerance channel). To optimise the capability (Cp) of processes today's post process measurement should be displaced by In-Process or Pre-Process measurements. In order to control the process it is essential to integrate process models in the control system. This can include methodologies for signal analytics and machines – self-learning by implementation of cognitive systems.

Specific features are the integration o sensors for measurable parameters under the specific conditions and systems for control and monitoring of the processes. It is the objective to stabilize the process capability towards cp >2.0 even over a long time of usage of machines, taking into account the deviation and wear. All conventional and innovative technologies (casting, forming, cutting, joining, surface protection, laser-assisted technologies) are fields of this research towards intelligent manufacturing.

Main outcomes of the above presented enabling technology represent the push of the manufacturing quality towards zero defects in processes and process chains and realise intelligent self-optimising manufacturing systems.

2.2.4. Adaptive tools and components

Planning tools for open reconfigurable and adaptive manufacturing systems

Process planning and process engineering are parts of the chain from design to manufacturing. Taking into account new solutions for configurable manufacturing systems, it is necessary to develop new and knowledge based tools for the support of planning. The implementation of a knowledge system in this process can be realised by a platform for process planning, which is integrated in the information and execution system of factories. Elements of this Platform should be: actual data of the factories' resources and capabilities, modules and standards of processes, interactive and participative systems for process-planning, design of specific equipments for time and cost calculation, programming of machines, robots and automated systems, communication and distributed work. At the horizon, Virtual-Real workplaces are able to optimise and monitor manufacturing wherever in the world the processes are running at.

Acceleration of planning processes for fast and reliable manufacturing engineering in all manufacturing sectors, should be achieved through implementing this technology.

In-Situ Process Simulation

Simulation is usually an analytic instrument to find out the behaviour of systems under the constraints of usage. It is used for planning and optimising the layout of logistic and manufacturing systems and the design of machines. Future capabilities of real-time control allow the integration of simulation in the systems to analyse the behaviour in relation to situations. This demands the integration of simulation systems in Manufacturing Execution Systems (MES) as well as in machine and process control. Feed by sensorial supervision and monitoring and the actual load, it seems to be possible to look ahead on what happens and to compensate deviations of precision or to control manufacturing processes by learning from the future. The implementation of special methodologies like KNN, MD, Monte-Carlo and discrete models, seems to be of high interest for operating in instable Parameter fields, inducing the increase of the efficiency of manufacturing systems.

Optimal energy consumption by flexible self-optimising drive concepts

The main objective is the flexible adaptation of electric-fluidic energy resources for high performance drives both to production system and to process needs to overcome traditional efficiency limitations of local energy sources (hydraulic and distributed pneumatic power stations) by concepts of generating energy on demand and feed-forward strategies. A higher performance (speed, acceleration) is usually limited by a higher installed electrical power. But energy cost share in product prices increased from 10% to 20% in the last years and energy prices still increase on the market.

Research should focus on flexible drive concepts for altering demands of process conditions. Several such type of drive should be mentioned: a wide range of volume flow or velocity, mass or acceleration and jerk-free movements with regeneration of accumulated potential and kinetic energy (e.g. servo press or direct drive technology); combinations of direct electrical drives with rechargeable batteries providing highly reliable and safe energy and drive concepts. Local energy sources cooperate with production systems on the basis of new mechatronic model-based or knowledge-based motion control and real-time sensor applications to realize forward energy planning demands; co-operation of multiple main or servo drives in motion control and energy regeneration are highlighting the same relevance, as well.

New generations of adaptive production systems with increased drive or process performance of adaptive production systems by 20% and decreased local power consumption by 25% represent one of the valuable outcome in this area. Reducing waste of European energy resources in local industrial energy generation and motion consumption of production systems can be achieved as well. In the wake of drastically dwindling energy and material resources the need for such systems becomes increasingly evident in the field of new and old industrial automation systems.

Self-optimising electric-fluidic energy sources for optimal energy consumption

Innovative technologies for temperature control, power generation and storage in production processes open up a big energy saving potential. They are essential to adapt to manufacturing processes in order to become more and more energy efficient. Taking into account the worldwide increasing energy demands and the increasing greenhouse gas emissions, it is obvious to focus on energy efficiency. Of central importance is the integration of their application into the whole energy concept, including all types of energy, used in the production process. The objective will be the production and the application of innovative energy generating and storing technologies, such as poly-generation plants, organic rankine cycles (ORC), or phase-change materials as energy carriers in production processes and the use of refuse derived fuels (RDF, e.g. from industrial waste streams). The expected projects should perform research integrating cross-cutting technologies for the energy supply of heat, steam, cold and power, aiming at the development and application of innovative temperature control, power generation and storage technologies. Thus, a broad range of competences is needed to organise and accomplish the accordant projects.

The expected benefits especially for manufacturing and production processes are I. substantial energy savings in industrial processes, II. technologies for the closed loop on the second and third level of energy streams, III. new energy efficient production processes, IV. reduction of greenhouse-gas-emissions, V. protection of fossil resources.

2.3. Networking in manufacturing

Due to the present aspiration to conquer new and respectively ensuring existing markets, the number of manufactured product variants is rising steadily, whereas the lifecycles of the products become shorter at the same time. While trying to achieve a cost optimisation, any company is furthermore aiming at creating lean processes along with low inventories. This is why the companies in a supply chain network find themselves in a difficult situation, on the one hand they have to react on very short-term changes of market demands and other events in the network and on the other hand a long-term planning and coordination of the network has to be assured. This situation is still more intensified as even structural marginal conditions as i.e. the network topology or the selection of the network partners, have to be adapted in more and shorter time intervals.

Tomorrow's manufacturing processes will work in complex, integrated and dynamic networks, often operating across borders of companies and countries maximising their shares within the value chain. As the scope and the dynamics of these production networks will increase continuously over the coming years, research and development has to tackle several areas in order to come up with solutions regarding the network integration, the standardization of processes and IT systems, and enabling real-time decision capabilities throughout the network. Looking in more detail on the production network, four different segments of the network can be identified:

- Customer & user network, including all organizations and processes bringing a final product in the hand of the customer or end user

- Product & supplier network, including all manufacturing and service companies creating and delivering parts, components or raw materials and related services for the final product

- Product engineering network, representing all activities across several companies to design and engineer a new or changed final product

- Manufacturing system supplier's network, involving all companies and processes for producing, installing and maintaining the production equipment used for the manufacturing of the products.

With the target of keeping or regaining a competitive advantage of European manufacturing, with the consequences of shortening product life cycles, higher reaction abilities to change customer demands and specific products, the integrative view on all these four network segments is essential for achieving an overall networked production. Several enabling technologies considered as relevant and stringently required for the implementation of this integrative approach of networking manufacturing have been identified and represented according scale time and implementation priority in the following "**Manu*future* Trans-sectoral Roadmap: Networking in Manufacturing" (**Figure 4**)**. The sequence of the technologies deployment is envisioned as:

- **On short term with high priority** the "Innovative Strategies for Networking Manufacturing" new and innovative methodologies and technologies aiming at improving the network engineering and the interoperability of production enterprise interlinked in a production network.

- **On medium term with high priority as well,** the "Real-time Logistics Network" has to investigate and recommend new management models for the global and real-time manufacturing networks towards the implementation of the network visibility and supply chain integration for real-time decision making in non-hierarchical networks.
- On **long terms** the envisioned "Global Environment for networked Manufacturing" aims at implement the knowledge-based and adaptive manufacturing through intelligent order management and factories and logistics on demand concepts.

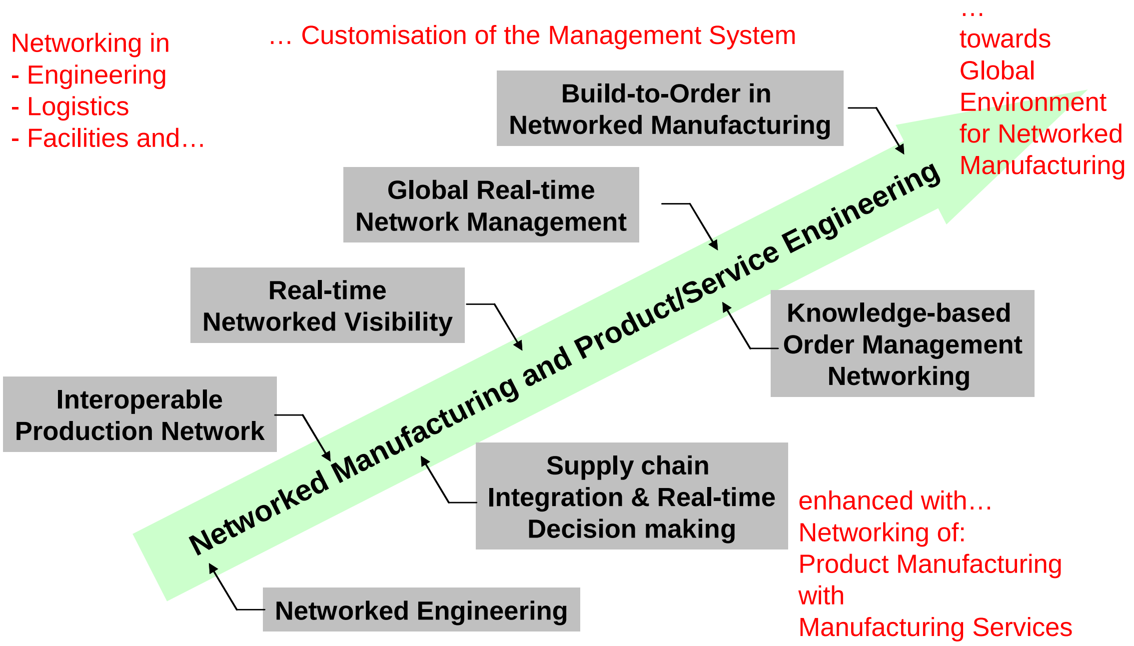

Figure 4. Manu*future* Trans-sectoral Roadmap: Networking in Manufacturing

2.3.1. Innovative strategies for networked manufacturing

Networked engineering

An important factor for the successful operation of production networks is the design of the network structure and the inter-enterprise processes of it. Adequate models, methodologies, technologies and supporting infrastructures for the network design can guarantee technological, strategic and business goal alignments among business partners in a collaborative networked business environment. Furthermore the network engineering must consider the production and service capabilities of the involved companies as well as the market demands and the life-cycle aspects of the products. This engineering also includes the approach of how the product's value can be maximized collaboratively, by selecting the right partners for the joint product and service offers as well as the optimal distribution of the different value-adding steps within the network. In order to qualify the capabilities and costs of a network and different alternative designs, a network engineering methodology also has to include ways to evaluate the performance of a network on different levels of details. This includes the definition of common key performance indicators for the different network segments as well as the ways how these indicators can be calculated. The network engineering process has due to the complexity of the networks to be supported by tools, allowing a detailed analysis of the network, from a static and from a dynamic viewpoint through simulation, and offering functionalities for the optimization of network structures and processes.

The changed and still changing market demands require the frequent if not permanent design and re-design of production and logistic networks. Due to decreased product life cycles, the design of the production network has to change often: Important parameters, including production strategies such as Make-To-Order and Make-To-Stock, production and warehousing locations, mode of transport, lead times and stock levels, have to be adapted frequently. The production networks must strive for both cost-efficiency and for agility to quickly adapt to the changing customer demands. Current network engineering approaches do not fulfil the new requirements: Today's network design methods for new processes and structures take too much time and effort. The time-to-market for new products is prolonged and the network design is not adjusted to the changing market demands. Consequent aspects like the market demands, company production and service capabilities as well as life-cycle aspects of products have to be considered in a network engineering methodology, enabling companies to quickly assess their current network structure and identify improving areas. This engineering also includes the approach of how the product's value can be maximized collaboratively, by selecting the right partners for the joint product and service offer as well as the optimal distribution of the different value-adding steps within the network. In order to qualify the capabilities and costs of a network and different alternative designs this engineering methodology also has to include ways to evaluate the performance of a network on different levels of details. This includes the definition of common key performance indicators for the different network segments as well as the ways how these indicators can be calculated. The results will take the form of new network engineering methods, demonstrated and evaluated in industrial settings.

Interoperable and standardised production networks

Companies can be part of several production networks at the same time thus making the planning, management and optimisation of these networks a very complex task. Research tasks originating from this, are the development of organizational concepts, processes and methods for the collaborative planning, management and optimisation of production and logistic resources, including the production planning and capacity management in non-hierarchical company networks. These processes have to be standardised across industries in order to come up with the necessary speed and flexibility in the network integration. Non-hierarchical networks and the resulting decentralized planning and control processes also indicate that the supporting ICT systems for planning, scheduling and control have to be decentralised and based on distributed models and tools. The necessary seamless integration of the business processes and the supporting ICT systems require a common understanding of the exchanged information and the shared functions. Therefore the interoperability of production networks requires a common semantic of shared information and exchanged services. With these development systems unifying the monitoring, operations and planning across a network, while in the same time providing the specific functionalities for the needs of a company, are possible. Therefore, new value added logistic services, delivered by network companies, will be designed and enabled throughout a product life-cycle. Widespread innovation in reverse logistics services is also expected.

The formation and operation of production networks covers the production, distribution, after sales services, and reverse logistics. This requires a strong interoperability between the different business processes, organisational structures but also technical solutions applied by all of the companies in these networks. The main development issues and targets are the creation of interoperable production networks – in respect to reference processes, the semantics of the exchanged information and shared services as well as the application of supporting ICT infrastructures. The reference processes include the planning and execution tasks for the sourcing of materials, the production of semi-finished and finished goods, and the distribution of the finished goods to the customers. Interoperable production networks aim at enhancing the competitiveness of European manufacturing sectors by increasing the capacity of industrial SMEs to operate globally in an agile manner, in order to adapt to the rapid evolutions of existing and future markets. Deliverables will take the form of pilot implementations in industrial settings of European production networks as well as the contribution to standardisation of exchanged information and shared processes.

Simultaneous engineering in open networks

More and more decreasing innovation cycles have been established in almost all types of businesses and markets. The emerging pressure on products as well as production and logistic planning, regarding time and quality, can be encountered by a solid parallelization and reorganization of the engineering processes, the so-called »Simultaneous Engineering«. As a consequence, the involved parties are facing immense challenges, particularly in the field of design and planning processes and the appropriate organization as well as at the use of modern technical planning methods. These needs are intensified by market and company globalization, together with major enterprises´ strategic decisions under the heading of »outsourcing«. The respective engineering processes are distributed over departments of a single enterprise as well as across enterprise borders. Thus, the engineering in networks has to be performed in a collaborative fashion. In this regard concepts such as the Digital Mock-Up (DMU) for the product development as well as the Virtual Factory and the Digital Logistics for the production and logistic planning gain importance. The main requirement of such a collaborative planning is the ensuring of the interoperability over the complete engineering process.

The trend towards an international division of labour within production networks will significantly change the engineering of products and the design of the respective production processes. Therefore, the respective engineering departments of the network's enterprise have to collaborate closer and faster in order to meet the increase requirements, especially in respect to time-to-market and product customization.

This collaboration of different engineering disciplines requires interoperable methods supported by appropriate tools. Thereon clear organizational structures and processes of the collaborative engineering must be developed by defining activities, responsibilities as well as rights and duties of the ones involved.

Build-to-order in manufacturing networks

European manufacturing enterprises have to compete based on a range of performance objectives such as quality, price, delivery, responsiveness and flexibility. Whilst manufacturers develop shorter product lifecycles and offer a greater variety of models, this provides shorter 'market windows' in which generating the sales volume is necessary to support the massive development costs of the new product. In most manufacturing sectors the current system is still mainly forecast, based on production and push-based selling, using discounts and incentives is leading to lower profits, thus more volume is needed to maintain the equilibrium. To face these challenges, companies and supply networks have to think about new production systems and manufacturing concepts which enable a fast response to the customer's needs and a flexible handling of capacities. Furthermore companies are moving or have moved from centralized operations to decentralized operations in order to take advantage of the available resources and in many cases, simply to be closer to their markets. Therefore, manufacturing supply chains undergo a major transition. Currently the supply systems are for the most part based on 'stock push', whereby the majority of products is sourced from existing finished goods inventory in the marketplace.

Build-to-Order (BTO) strategies offer a new direction for manufacturers who suffer in this climate of spiraling costs and punctured profits. But these strategies have to be extended to encompass the changed global environment of the markets. Consequently, Build-To-Order strategies have to be investigated, designed and developed for network environments. This encompasses the ramp-up, production, and phase out phase of the product life cycle.

The European manufacturing industry in Europe faces fierce competition in all its major markets and is dealing with a customer who is more demanding. To face these challenges, companies and supply networks have to think about new production systems and manufacturing concepts which enable fast responses to customers' needs and a flexible handling of capacities. Consequently there is a need for Build-to-Order (BTO) strategies for manufacturing networks.

The main research targets are the creation of build-to-order manufacturing network processes and methods based on the application of enabling ICT infrastructures. Such network-wide BTO strategies require a close collaboration within business processes for capacity planning, order management, and production and transport especially if BTO parts delivered by first and second tier, suppliers are manufactured in BTO manner as well.

The concrete results of performing research and technological activities in this area represent new methods and business processes for network-wide BTO as well as the application of enabling ICT tools.

2.3.2. Real-time logistic networks

Global and real-time network management

The overall vision of the global real time network management can be seen in the ability to have a real-time visibility onto all of the network’s segments, acting locally on disturbances or changes in the demands, integrating the planning processes of all network companies efficiently and flexible, and enabling the adaptability of the network from the operational level up to a structural level of product and network design. This includes the definition of new business models, contractual arrangements, collaboration incentives and integrated sales networks. Business models will consider networks consisting of SMEs and large companies as well. Successful collaborative models coming from Europe, but national and regional experiences will be considered too.

For this purpose new solutions will fully integrate different technologies (e.g., sensors, radio frequency identification devices, localization devices, remote monitoring and control equipments) for planning and controlling material and information flows across critical processes in networks. The deployment of these solutions will consider the users’ needs and requirements related to data and information accessibility and security.

The need to cooperate with globally dispersed partners has made the management of production networks a very demanding task. Global manufacturing networks call for the ability to have a real-time visibility onto all of the network segments in order to act locally on disturbances or changes in the demands, and integrate the planning processes of all network companies efficiently. A global real-time network management requires further integration of sensors into the production and logistic equipment, collecting data about environment conditions and storing this information for the further decision processes on the local level. The design and application of advanced equipment, capable of detecting other devices, being able to communicate and thus enabling self-organizing sensor networks for the solution of local operational decisions, will increase the scope of adaptability of the global production and logistics networks. Based on the achieved transparency of the network status, a continuous monitoring of the network performance is possible, opening the way to detect unplanned, delayed or missing events within the network very early and analyse whether the effects of these events are critical for the network operation.

The envisioned outputs represent integrated solutions for the management of global production and logistics networks. These solutions must be demonstrated and evaluated in industrial settings.

Supply chain integration and real-time decision-making in non-hierarchical manufacturing networks

The aim of the networked production is to cut logistics costs, to reduce high inventories of current assets and simultaneously to shorten the lead times of material and information as well as to improve the service levels in a customer-orientated way. These aims can only be reached by means of common efforts, which result in benefits for any company involved, when realized. In the already existing manufacturing world of highly distributed value-adding activities, which will further increase in the upcoming years, these targets can only be achieved by means of the close collaboration of the companies in the network.

Against this background it is obvious that a central planning and control of a network is only realisable if one dominant company is existent in the network, which is, however, rather uncommon. In fact, in most cases, the companies try to keep their acting and decision autonomy, which is essential for them for achieving their company targets. This inevitably results in a decentralized planning and control of manufacturing networks – although a central coordination of a network could probably be possible, regarding technology. Therefore production in the future will predominantly occur in non-hierarchical company networks. The integration and production/operation management of such networks is characterised by a non-centralised decision making. Depending on the customer and the product, the rules and procedures for this decision making may change.

Capacity analysis and planning is a key activity in the provision of adequate customer service levels and the management of the company's operational performance. Traditional capacity analysis and planning systems have become inadequate in the face of several emerging manufacturing paradigms. One such paradigm is the production in collaborative enterprise networks, consisting of subsets of autonomous production units within supply chains working in a collaborative and coordinated way. In these distributed networks, capacity analysis and planning becomes a complex task, especially because it is performed in a heterogeneous environment where the performance of individual manufacturing sites and of the network as a whole should be simultaneously considered.

This collaboration can only work if the network companies working along the value chain are integrated through synchronized processes and harmonized IT systems. This vertical integration on the one hand means that the processes for the planning and control of production and logistics have to be closer interlinked between the companies, enabling the exchange of order, inventory, demand, and capacity information, and synchronizing the processes initiated by this information exchange, resulting in innovative collaborative production and logistics processes. On the other hand the necessary ICT systems supporting the processes also have to be integrated so that the information exchange and the process synchronization is enabled throughout the network. These integration needs call for tools making it possible to model, evaluate and realize the process integration and to shorten the time necessary for the IT systems integration.

Non-hierarchical company networks aim at enhancing the competitiveness of European manufacturing sectors by increasing the capacity of industrial SMEs to operate globally in an agile manner, in order to adapt to the rapid evolutions of existing and future markets. The supply chain integration and production/operation management of such networks is characterised by a non-centralised decision making. Depending on the customer and the product, the rules and procedures for this decision making may change. Furthermore, companies can be part of several production networks at the same time, thus making the planning, management and optimisation a very complex task. The main development issues and targets are collaborative planning, management and optimisation of production resources including production planning and capacity management in non-hierarchical company networks as well as distributed planning/scheduling models and supporting tools. Also methods and tools for material flow management across the overall network and the product life cycle, integrated production monitoring, offering order status information for the customer and the network, equipment monitoring and maintenance, integrated maintenance including real-time monitoring (design, implementation, operation) enabling new and protected services for the production equipment as well as planning and control of reverse logistics / recycling are targeted. The new methods and the supporting tools must work in a decentralised manner enabling the participating enterprises to work in several production networks at the same time. The securing of information and knowledge should also be given a special emphasis, as it is a key to the success of such networks.

Real-time network visibility by mobile components in production networks

A necessary prerequisite for optimizing and managing production networks continuously is the realization of a real-time network visibility. With this visibility companies within the network have instantaneous access to the current network status in order to see where activities are not carried out according to plan, thus endangering production processes requiring the in-time materials supply and consequently breach delivery promises given to customers. This can be achieved through the application of Radio-frequency identification (RFID) technology. RFID tags allow the storage of important information like product identification, order information, delivery targets on a chip which can be read contact free. Furthermore the tags allow also that further information is written on them, thus making a real-time picture of the network status close to the product and moving through the network is possible. By attaching RFID-tags to the parts, products or transportation containers, reading and writing information on the tags and a full-scale visibility of the network can be realized, together with the possibility to excel the control of the network. This traceability can only be realized if all network participants, manufacturing and service companies, are integrated into an overall process approach, delivering the right information on time to the other network companies. In addition to established technologies for the localisation of products like GPS or GSM between participants in the network, enable the development of radical new approaches for the monitoring and failure management in production networks.

A further research target can be found in the necessary integration of the RFID systems into the different backend IT systems as enterprise resource planning, production, transportation and warehouse management. Only with this integration the network visibility together with its advantages for industry can be achieved.

Finally a scaleable filtering, compression and visualization of the captured network status, adapted to the different needs and levels of the network companies, has to be realized in order to make the utilization of the gained network status information as efficient as possible.

Networked production requires the development of new processes for network-wide monitoring and exception management through the application of new identification, communication and positioning technologies which can be mounted onto the products and parts of them routing through the production and logistics network. The manufacturing networks will employ location services to meet specific business needs such as preventing loss or thievery of valuable mobile assets, automating workflows, managing inventory and tracking equipments, supplies or people. Another important research target is to develop methods and supporting tools for the filtering of the available information so that human problem solvers are immediately guided towards those objects – parts, production equipment, and transportation devices – that require their immediate attention. Research will focus on the application of smart mobile components and networks integrating multiple wireless communication technologies (GSM, GPRS, WLAN, RFID, Bluetooth, Zigbee) and sensors as well as integrating them into intelligent manufacturing structures.

Deliverables shall include processes, methods and the application of supporting tools for a mobile business system suitable for production networks. A demonstration and validation in production and logistics network is required.

2.3.3. Knowledge-based and adaptive networked manufacturing

Knowledge-based order management in networked manufacturing

One research aspect, seen in a very large time scale, is the idea of making the orders the primary driver for adaptability, while this adaptability crosses the different levels of networked production as mentioned before. The aspect of knowledge-based product and network configurations should set the frame for the necessary adaptability of the network. While configuring the products in a knowledge-based way, incorporating the knowledge of the network's structures, processes and adaptability capabilities, the orders should be defined together with the customer so that the product configuration, delivery performance and manufacturing costs are matched. The management of the orders should incorporate the real-time management of the network, integrating the local decision processes towards the network's wide routing of the order. Finally the ability to decide on structural changes or parameter alterations should be brought down to the local execution nodes and processes so that together with the continuous network performance evaluation self-adaptable networks will be created.

The trend towards an international division of labour together with reduced product life-cycles and the increasing importance of customized products will significantly change the engineering order management within production networks. The respective engineering departments of the network's enterprise have to collaborate closer and faster in order to meet the increase requirements, especially in respect to time-to-market and product customization. This requires that the composition of the manufacturing and distributing network must be defined dynamically for each order. This formation of the network partners must match the order requirements with the capabilities and competencies of the manufacturing enterprises. This collaboration of different engineering disciplines requires interoperable methods supported by appropriate tools. Thereon clear organizational structures and processes of the collaborative engineering and order management must be developed by defining activities, responsibilities as well as rights and duties of the ones involved.

Factories and logistics networks on demand

One important improvement through which European manufacturing companies can gain a competitive advantage is the short term adaptability to highly dynamic changing customer demands. This covers all segments of the manufacturing network, from the product design, along the supply and distribution up to the manufacturing system supplier networks. Products have to be (re-)designed, produced and delivered to specific customer wishes as fast as possible, higher product volumes demanded in specific markets should be produced and delivered without raising the costs and the whole network should also adapt to downswings in demands very quickly in order not to focus on products still giving a substantial profit margin. By realizing this adaptability, not only the network planning and control processes have to be fast and efficient, but also the single manufacturing and logistic technology has to be adaptable to customized products and product design changes, and should allow scalable manufacturing processes according to the demanded volume.

Essential improvements on the operation and control level should also be realized. Here agent control technology seems to be a promising candidate for the technological basis realizing this operational autonomy. It is necessary to develop an integrative engineering approach for the design and application of these autonomous, agile devices such as storage equipment or machinery, creating the agent-based local intelligence together with the technological advances, needed for the realization of this engineering approach. A further enhancement of the adaptability can be seen in the direct communication and coordination between the materials, parts and products created in manufacturing and the manufacturing and logistical equipment itself. Employing advanced ICT such as RFID enables to attach operations and control logics to the physical material flow.

In the near future traditional hierarchical and tight supply-chains will have to be much more re-configurable, agile, collaborative and responsive, moving towards a self-forming supply-chain and inevitably posing new and demanding challenges on its management. Research targets consist of the development of adaptive manufacturing methods for production and logistics networks. Such methods should apply modern ICT technologies and approaches for intelligent, autonomously operating machines and products. It is necessary to develop an integrative engineering approach for the application and design of these autonomous, agile devices such as storage equipment or machinery in order to realise a high degree of agility within production and logistics networks.

2.3.4. Networked manufacturing services

Global platform of networked services management

In the future, traditional hierarchical and tight supply-chains will have to be much more re-configurable, agile, collaborative and responsive, moving towards a self-forming supply-chain and inevitably posing new and demanding challenges on its management. To support this envisaged trend it is necessary to proceed with the development of a conceptual framework for a self-forming business networking environment based on the idea of an innovative Plug-and-Do-Business Paradigm. Thus, it will be very important to explore different directions, namely: Support for short-lived ad-hoc virtual formations of collaborating partners and the issue of an enterprise to discover potential business partners upon demand and advertise itself in standard ways and the support of a highly dynamic involvement of an enterprise in different business activities, serving different roles at the same time.

For producers of machinery and equipment, this means that the selling argument of the future is not any longer just the technical level of the product but rather its contribution for solving a problem of the user. This ability to solve problems of the user manifests itself in additional "value-added services" that assist the user with planning and dimensioning, rapid installation, smooth operation and uncomplicated system alterations. In short: value-added services covering the entire life cycle of the product.

In order to achieve the flexibility and the resulting adaptability of a network, each company in the network has to define and offer services for the design, planning and control of the network segment, on which it is responsible for, based on their capabilities and competencies. Bringing these services into a service-oriented architecture for manufacturing and logistics planning and control applied wide networks, generating the necessary flexibility towards adapting to fast changing market demands by restructuring the product or the network, changing the network operations or using potentials existing in the current network status. Furthermore the realisation of such a service-oriented architecture supports the further decentralisation of activities in non-hierarchical networks, as the encapsulated services can be defined and executed by each company independently.

Products are slowly loosing their dominate role concerning the market’s success of production companies. Instead the market is demanding for ‘all-inclusive’ solutions incorporating the product itself as well as product-related services such as transport, installation, training, diagnostics, maintenance, and recycling. Only very large companies can offer all these services on a global level. The vast majority of manufacturers have to collaborate with local enterprises when offering their services to new markets. The establishment and the operation of such new collaborations require new methods and supporting tools for service offering, service discovery and service management. Research projects should cover and support the entire range of processes within networks for creating value added services and the interoperability of services.

Networked product/service engineering

The Networked product/service engineering research topic focuses on the segment of product engineering networks, because in this segment a lot of potentials are not yet realized. In today’s situation more and more companies in a network with specific competencies are necessary to come up with the design of a new product or service. Furthermore the design process has to be accelerated to shorten time-to-market and extended to integrate the customer demands more closely. Collaborative design will embrace new methodological supports and tools for understanding, tracing, and predicting usage modalities of customers throughout life-cycles of products, thus enabling effective products design tailored on customer needs. New internet distributed KB CAD systems will be designed and developed. To come to such networked product and service design processes and tools for the collaborative product/service design between customers, partners and suppliers, one has to take into account the possibility of distributing the design work across the global network. To integrate and collaboratively develop the different competencies of the network companies an integration of the knowledge resources across networks by specific processes and means has to be targeted.

Innovative customer-driven product/service design in global environments

Intelligent customer driven innovation focuses on the integration of customer influence in the design and development process and the related demands of the manufacturing and logistic processes. Moreover, multi-site and multi-nation product development is becoming more and more an international business. Companies will design products, including the production systems and even factories themselves, for customers all over the world. They will also develop and manufacture these products with partners and suppliers from all over the continent. Intelligent customer-driven innovative product-service design in a global environment is set for new challenges, such as culture specific customer preferences, location specific production technology and logistics, round the clock 24-hour collaborative development, different cultures, attitudes and procedures for participating companies. The expected results can take the form of : validated tools for cost-effective and rapid creation, management and use of complex knowledge-based product-services that combine the customer-driven approach with enablers for competitiveness at internationally networked locations; tools facilitating collaborative design in temporary partnerships; and new business and management processes in virtual company networks around the world.

2.4. Digital, knowledge-based engineering

Manufacturing Engineering is a holistic approach, which includes the engineering of the factory structure, the development of the organization, the product design engineering, the process engineering and the development of the required tools and application systems. At all levels, e.g. manufacturing network, segment or system, machine or equipment, subsystems and processes, the factory and its manufacturing processes can be defined in their "current" and/or "future" states, under the so-called "digital" and respectively "virtual" representations. This relates to the employed models, methods and digital tools or simulation applications and systems used to represent the static or the dynamic states. As the knowledge represents the main source innovation and implementation of the digital and virtual factories and products, the whole area concerning the research and applicative field mentioned above is structured under the cluster of enabling technologies and tools named "Digital and knowledge-based engineering".

According to the major objective of the European industrial sector, e.g. to play a leading role at global level, the manufacturing enterprises called factories, have to be approached as a new and complex type of product. They have to have the following main features: factories are long life products, which have to be adapted permanently to the needs and requirements of markets and economic efficiency. Nearly all influencing factors are continuously changing and sometimes have the character of turbulence. Factories operate in networks and are parts of logistic networks with chains in: design and engineering of the products, supply chains from customer orders to customers' delivery, supply chains for consumable materials and waste, supply chains for factory machines, equipments and tools. The factories and products are digital and virtual by embedding in both these states the corresponding required knowledge. The innovative and enabling technologies and tools identified as crucial for this cluster are grouped according: "Sustainable digital factories and products: design, modelling and prototyping", "Virtual factory simulation and operation", Real-time (Smart) Factory", and "Process modelling, simulation and management" and graphically represented under the **"Manu*future* Trans-sectoral Roadmap:** Digital, Knowledge-based Engineering" (Figure 5). These technologies are planned to be deployed in time scale and priority as follows:

- **On short term with high priority** the collaboration of "Digital Manufacturing Engineering" with the "Digital Product Engineering" through rapid prototyping of Virtual Factory synchronised with the 3D/CAD integration of engineering tools and digital prototyping of virtual products.
- **On medium term with high priority as well,** the factory data management under the so-called Life Cycle Data Management for Digital and Virtual Factory and Products conducts towards the development of the Virtual factory framework aiming at integrating heterogeneous and autonomous technologies and tools for planning, design, manufacture and implement the above two entities in digital and virtual states. The Real-time Factory represents one of the desired goal, by

integrating and synchronising the Digital factory with real-time data towards the adaptation to reality.

- On **long terms** the envisioned "Multi-scale process modelling, simulation and management" aims at implement the holistic approach of manufacturing engineering at all its scales, from network to manufacturing processes and states, from digital, virtual to real-time.

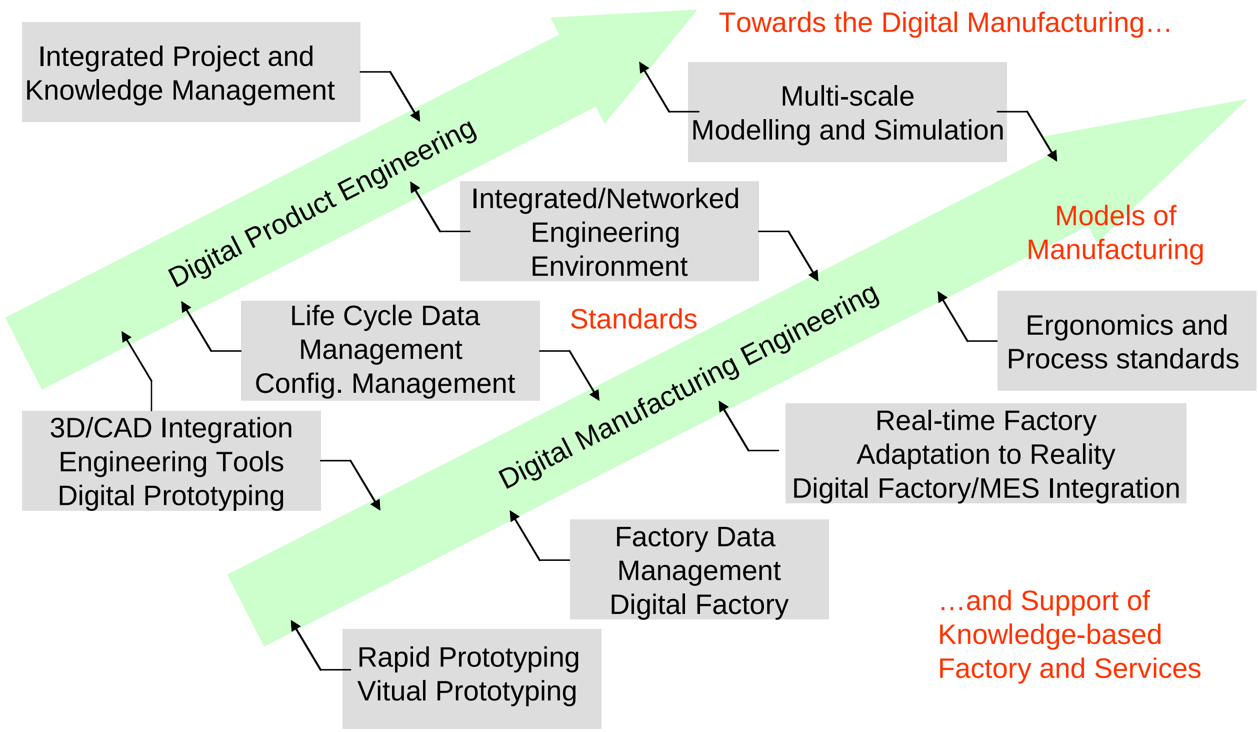

Figure 5. Manu*future* Trans-sectoral Roadmap: **Digital, Knowledge-based Engineering**

2.4.1. Sustainable digital factories and products: design, modelling and prototyping

Digital manufacturing for rapid design and virtual prototyping of factories on demand

Consumer needs and expectations of the future will require a continuously and rapidly evolving production framework: thus production systems, from small to large scales and integrated factories, shall be conceived and set up in more and more shorter times. This will require a conception and development of new methodologies and innovative tools, which enable and support the rapid design and prototyping of the entire production system. The creation of a holistic, up-gradable, scalable Virtual Factory can foster high cost savings in the implementation of new manufacturing facilities, thanks to the effective representation of buildings, resources –process- and products. Decision makers and designers can benefit from the closer integration of product, process and plant developments through advanced modelling and simulation.

- Development of a Virtual Factory Framework, focusing on a development of a reference (standard) factory data model, generic architecture for collaborative virtual factories and products through integration of heterogeneous models, methodologies, technologies and corresponding tools of digital and virtual factories;
- Employment of Virtual/Augmented and Mixed reality technologies and tools for enhancing the factory experience and the immersion and presence of humans in the environment of virtual factories ;
- Development of technologies and tools for factory, product, process modelling, simulation and virtual prototyping;
- Support for the integrated process-product engineering and implementation of production processes simulator architectures for the automation systems development and configuration;
- Integration of Digital Manufacturing technologies (industrial process simulation) with VR/AR;

The envisioned main results of these research activities represent: a complete detailed framework for the Virtual Factory and tools for the quick, reliable and optimized creation of knowledge-based manufacturing systems and factories, enabling collaborative, interdisciplinary and multicultural design/analysis and optimisation of processes to be executed effectively and efficiently in global virtual company networks. The required tools should consist of software, using intelligent databases and data analysis and presentation methods, complemented by models, processes and guidelines enabling their usage. Their capability needs to be proven through successful employments in European manufacturing companies, resulting in significant measurable improvements of business success indicators like time-to-market, customer satisfaction, market share and revenue as well as in improved soft factors like working climate, quality of life, environmental protection and innovativeness.

Sustainable Life Cycle Management of factories and products

The modern view on manufacturing engineering resides in incorporating the Life Cycle paradigm into the factory as a whole, its corresponding products, manufacturing processes and technologies. The idea of a "Product Life Cycle" is essential for the path to sustainability by expanding the focus from the production site to the whole factory and product life cycle. The main goal of Factory and Product Life Cycle thinking is to reduce the resource use and to improve the technical and social performance, in various stages of a factory and a product's life. Life Cycle Management is the application of Life Cycle thinking and models to modern manufacturing engineering practice, with the aim to manage the total and comprehensive life cycle of the factory and its products and manufacturing processes and services towards more sustainable consumption and production. Life Cycle Management is about the systematic integration of the product's sustainability into the manufacturing strategy, planning, product design and development of decision making and communication and of collaborating applications. By implementing the Life Cycle Management's capability, considerable benefits, such as a faster time to market, lower costs, reduction of rework and rejection dates and more component and technology reuses are achieved. This approach provides the image of a three-dimensional life cycle space for factories, products, and manufacturing processes. Each of these entities has its own life cycle, consisting of specific phases. Figure 5 presents the factory and product life cycles in their relevant life phases.

Each factory follows a life cycle from its initial concept in the mind of an entrepreneur to the ecological dismantling, through a series of stages or phases. Despite the identified and recognized phases: design and planning, construction, operation and maintenance, refurbishment or obsolence and end-of-life phase or dismantling, this work focuses on the first phase, design and planning the factory. In this phase, in great interdependence with the life cycle of products and used technologies, the factory processes and its production facilities are planned.

Figure 1 traces the factory's life along investment planning, engineering, process planning, construction & ramp-up, production, service and maintenance, and finally, dismantling or refurbishment. Two states of the factory and its manufacturing processes have been distinguished [18, 19]: "digital" and "virtual", making a clear difference between the models, methods, technologies and tools, which are used in advanced Manufacturing Engineering (aME). The digital factory represents the static image of a factory, modelled and re-presented by using digital manufacturing and modelling technologies. The projection of the factory into the future, through simulation and 3D/Virtual and Mixed Reality technologies, represents the virtual factory. Applying the authors' concepts regarding the digital and virtual factory, the factory life phases can be structured as follows. From investment planning to construction and ramp-up, the factory is digital. In these phases, it exists in its virtual form as well, being permanently optimized through simulation. Then the digital and virtual factory is constructed and ramps up. All remaining phases trace the real factory.

Simultaneously, the products, which will be manufactured in the factory, are passing through the main phases of their life cycle, planning, development, design, rapid prototyping, production, usage & service and recycling. By transferring the authors' concepts, concerning the digital and virtual factory, to the products, products are digital and virtual between the planning and rapid prototyping phases. The real product lives from production to recycling.

The overlapping of the factory operation & maintenance and the manufacturing of products in the so-called production phase, represents the crucial and at the same time critical point, called "Crossing-Life Cycles Point". Here, virtual products and factories are becoming real. The real product is built into the real factory. Then the manufacturing processes are implemented by using the most suitable technologies. At this point, all the already performed engineering activities and efforts are to be proved and verified. In this phase, the real factory has to be highly transformable in order to quickly respond to the changes occurring in the product world: frequent product launches, increased product complexity as a consequence of using advanced and emerging technologies, e.g. the fast development of micro- and nano-electronics, increased micro-computerization, and new material developments.

The Crossing-Life Cycles Point shows the results of the preceding phases concerning the manufacturing of products under optimum conditions (time, quality, costs). The point not only highlights the efficiency and effectiveness of the used models, methods, technologies and tools for planning and designing products, processes and factories in the digital and virtual world, but also the appropriateness of using them. The main advantage resulting from this approach is the transformability and changeability of the factory's structures throughout their whole life, according to the manufactured products, the corresponding manufacturing processes, and the technologies used under economical conditions. Thus, in the operation phase the factory is already prepared to react to a change, regarding a new release of a traditional product or a new product, a newly implemented state-of-the-art manufacturing process or the use of an innovative technology. These foreseen and possible changes have already been taken into consideration in the planning phase. Then, the factory is able to respond adequately and to adapt itself to these changes and turbulences in order to remain competitive. The information gathered in the production phase represents a valuable input for continuous re-planning and adapting.

High value added product design and virtual prototyping

A market's success of new products or services is largely determined by decisions taken during the design phase. An interdisciplinary and intercultural design team needs the ability to anticipate the future preferences of the customer in order to be able to develop attractive products. Successful development projects focus on the integration of customer influences in the design and development process and the related demands for manufacturing processes and thus enable intelligent customer-driven innovations. The need for a deeper integration of customer preferences from the timing, quality and product capabilities perspective, creates entirely new challenges both in the execution and the management of development projects. These challenges are of a threefold nature:

- Commercial challenges are ranging from distributed supply chains and networked business models to intelligent new selling and payment methods
- Social aspects include for example the integration of multi-site and multi-national/ multi-cultural development teams as well as culture specific customer preferences
- Technical issues are to be found in the realization of radical new product features and intelligent production systems, as well as in responding to strengthen environmental and socio-economical questions.

For the team members of development or management areas it is, due to the ever rising complexity of their tasks, increasingly difficult to keep up with the pace that is required in order for the European industry not to lose its already weakened position in global manufacturing. Their ability to cope with the above mentioned challenges needs to be strengthened through common European efforts, aiming at enabling European companies' product development teams to respond quickly, efficiently and effectively. For this, they need to be put into possession of tools that are tailored and fine-tuned for the specific European characteristics of product development, considering the European approach to industrial design. These tools need to enhance and enable the usage of globally recognized European capabilities and must therefore be consisting of software tools as well as of radical new methodologies, business processes and best practice guidelines.

The main issues and targets for the development of these tools are:

- Enabling the development of intelligent products and services with multiple and adaptable capabilities through knowledge based design for the integration of multiple functional-adaptive and self-optimizing systems
- Collaborative and multidisciplinary product design in virtual global company networks, using optimized standards, data exchange formats and product description features
- Virtual mock-up, including enhanced virtual production design (including transfer to ramp-up and operation through diagnosis, simulation, data analysis) and prototyping with improved human-machine interaction
- Life cycle value management, for example implementing customer value optimization through life cost modelling or user centred business models and using reliable prediction methods
- Rapid customer driven product/service development, enabling customer-designer-manufacturing interaction and mass customization
- The central issue is the realization of new methods for reliably predicting costs and greatly lowering time to market while highly improving product and service quality/ features and customer-orientation. By doing so, the social aspects of innovation and the challenges of the management of cultural aspects in cross-company international networks, need to be respected.
- Advanced (research integrating) design methodologies and tools to reduce time to market of research.

All these issues and challenges have to be overcome through the development of tools for the quick, reliable and optimized creation of knowledge-based products and services, enabling collaborative, interdisciplinary and multicultural design processes to be executed effectively and efficiently in global virtual company networks. The required tools should consist of software, using intelligent databases and data analysis and presentation methods, complemented by models, processes and guidelines enabling their usage. Their capability needs to be proven through successful employment in European manufacturing companies, resulting in significant measurable improvements of business success indicators like time-to-market, customer satisfaction, market share and revenue as well as in improved soft factors like working climate, quality of life, environmental protection and innovativeness.

Interdisciplinary design of high performance, reliable and adaptive manufacturing equipment

Interdisciplinary design aims at supporting the mechatronics design approach towards rapid and cost efficient and effective design and implementation and operation of next-generation production systems. In order to achieve this objective, new ways of interdisciplinary system modelling for the design phase have to be developed and then exploited.

The initial design phase, mainly focused on: insight, abstraction, cross-fertilization, domain-independence (multi-disciplinarity) aspects, has to be supported by new approaches as: structured, innovative, fast and synergistic conceptualization and diagnostics ('learn from previous mistakes'). On the second design stage, following fields represent high relevance: domain-specific (dynamics and control, (differential) geometry, network and graph theory, statistics and measurement, tribology, construction, etc. Tools supporting them are already available, remaining in many cases scattered, fragmented and isolated.

The aim represents the development of a design environment which integrates the existing tools and combines them with a proper common library environment that enables quick retrieval, reuse and tracking of the corresponding design methodologies and tools. Even more essentially, a methodology which supports the modelling and design decisions has to be developed. The methods should provide sufficient insight of what the design tools are actually doing and point out throughout the whole design process the need for additional expert support. One of the main benefits of this environment represents not only the support of the design process, but also contributes to the continuing education and training of the users.

Such a support should also keep the designer away from drifting away from the original goal (functional requirements, adaptability, life-cycle cost, etc). Furthermore, it should take the user out of his common context and terminology and thus facilitate the communication with team members to stimulate synergy and cross-fertilization.

The integration approach is holistic, in terms of enabling flexible optimisation of multiple criteria, including default attention for sustainability in the sense of reduction of material, energy consumption, waste and noise production, addressing all aspects of both production equipment and product, both at the technical and management level.

The main research focuses in this area are the following:

(1) Development of new methods for optimisation by co-design/ establishing the right conceptual system design format (Function modelling…)

(2)Development of a design environment by integrating domain-specific tools, focusing on the following main research directions: integration of and creating the synergy between existing tools; simulation of holistic production systems and of machines/equipments; development of Design Advisory Systems, used to manage complex models and the modelling process itself - decision support of transferring functional specs into specific domains (hardware /software); domain-independent general structures combined with domain-dependent libraries and toolboxes ; standardization and synchronization of the information which has to be exchanged between tools; distributed simulation / co-simulation

The challenge related to the design and development of the desired environment resides in the complexity of integration of heterogeneous methodologies and tools, which maintain their own business models, procedures and data locally and in the requirement of dynamical data exchange. State-of-the-art ICT has to be employed in a platform of development.

Related issues to the challenges presented above are: structuring and generalizing the (knowledge) content of existing tools; data management of complex mechatronic objects; combination of engineering (design) tools and planning / marketing / bookkeeping tools; interfacing between humans & simulation ; Business models for modelling by industry (Open format for modelling components…)

Innovative design of special equipment and tools

The sector of tools, moulds, dies and fixtures for manufacturing is a key technology sector of European manufacturing. The definition of the requirement of these elements is hardly under pressure in the ramp-up phases: critical time, responsibility for precision and capability, last minute changes, high costs. To support this critical business it is necessary to develop and implement innovative solutions as the following:

- Technical flexibility made by modular design, flexible automation and soft-tooling (adaptation of the software)
- Design systems (3D) with an integration of analytic methods (mechanic, termal, electric, electronic)
- Integration of the management of objects (factory data management, simulation, virtual engineering) into the digital factory
- Distributed engineering systems
- Knowledge based information supply
- E-Tool Management and remote services
- Integration of RFID and smart factory systems: ubiquitous computing, sentient computing, location systems

Engineering of ICT-based products

Manufacturing Systems are mechatronic Systems. The engineering of customised manufacturing systems includes the engineering of mechanics, electrics and electronics. The reliability of systems depends on the complexity of integration. Engineering needs the integration of systems for the design and analysis of integrated data models and the systematised engineering of software. The integrated engineering of complex technical solutions is a strong recommendation in industrial companies for:

- Modular design
- Reproducibility and adaptability of software components
- Standardisation of components

- Efficient generation: function oriented
- Test equipment and simulation

The main research in this area has to be directed towards the development of engineering systems for customer specific software and for manufacturing (machines, tools, transport, handling, flexible automation), aiming at managing the complexity and increasing the adaptability and reliability.

Tolerance systems for micro- and nano-scaled products

For the usual dimension, Industrial tolerance systems are standardised down to µm. In the dimensions of micro- and nanometer they have lacks because of extremely influencing factors of capable measurement (Roughness- Form, Position) and influencing factors of the environment (Temperature, contamination by particles etc.). The tolerance systems have to be scaled down to support the reproducibility of parts and components in combination with measurement procedures and technologies. Problems of calibration, management of measurement and of high precision technologies have to be solved by industrialisation. Tolerance systems have to be integrated in the design and quality management, especially under the aspects of micro- and nano-manufacturing, aiming at increasing the reliability of micro- and nano-manufacturing as a base for future standards and the design of reproducible parts and components.

2.4.2. Virtual Factory simulation and operation

New classes of models for the simulation of complex manufacturing and assembly systems

The strategic planning of complex manufacturing and assembly systems is greatly in need of modeling tools that can be used to quickly and clearly interpret and evaluate ideas to reorganize and expand such systems.

One mandatory attribute of the model class, which should be developed, is a capability to map change dynamics of order, product and resource quantities for a defined time horizon. Existing static models for mapping manufacturing and assembly systems fail to meet these requirements. The two well known classes of dynamic models – system dynamics models and microscopic simulation models – also fall short since system dynamics models are too abstract and microscopic simulation models too intricate for tasks of strategic planning.

Input data of mesoscopic models include a planner's conception of the anticipated development of individual sub-processes, specified in quantity-time diagrams (QTD). Only total quantities of relevant objects (orders, products and resources) are mapped. Individual simulation objects are not. In this context, the term mesoscopic refers to the transition in modelling and simulation from movements of individual objects to spatially distributed movements of entire object groups that are mapped, based on specific attributes. Even the primary results of a simulation have to be furnished as a QTD, which can be used as the basis to freely calculate definable parameters for evaluation.

The main research has to focus on the development of fundamentally new classes of models, which support the aggregated representation of processes in complex manufacturing and assembly systems. The core of such models has to be mathematically formulated, because this makes the necessary transformations of QTD possible. The model classes, which are to be developed, will be the basis for developing new possibilities in order to map and analyze processes, which planners will be able to employ to complete their strategic tasks for complex manufacturing and assembly systems with significantly more speed and precision.

Comprehensive and holistic approaches of multi-scale modelling and simulation of manufacturing systems

Modelling and simulation of complex networks of manufacturing systems is regarded as one of the central challenges of the research in manufacturing technologies. Adaptable simulation networks of cooperating and semi-autonomous software systems will lead to a fast market launch for new products as well as to shortened set-up times of production systems. The particular challenge of modelling and simulating manufacturing systems consists not only of determining the interactions of the different parameters and influencing factors but also of representing them in real-time simulation models. In the context of different usages, the term "real time” is here understood as a fast reaction to arising events as well as the time-deterministic calculation of plant behaviours for control-coupled simulations. The multi-scale simulation of manufacturing systems aims at connecting different computation and data models, based on simulation approaches, through a continuous information flow, higher order equation systems and universal interfaces. The goal of this connection is bridging discrete and numerical simulations and areas of application in the manufacturing domain. Under the notion “multi-scale”, not only the spatial and temporal scales within separate manufacturing processes are understood, but also the different scales of all running processes in the whole manufacturing enterprise, called factory, as well as the different scales in the model itself. Therefore, for the purposes of the virtual representation of the factory as a whole, at different levels of abstraction, several heterogeneous modelling approaches have to be coupled with each other.

In order to comprehensively approach modelling and simulation at all scales of manufacturing systems, from network to manufacturing processes, the following challenge has to be overcome: the integration between the heterogeneous simulation models. This heterogeneity consists of the migration of simulation models from numeric simulations for the process and material modelling towards the discrete simulation for the purposes of logistics simulation. The complexity arises when approaching the modelling of the horizontal scales of the factory as a whole, beginning with the technical manufacturing processes, through equipments, robots, production systems, segments and networks of production systems. As a conclusion, the following scales and aspects have to be regarded:

- all levels of factory structures, according to a bottom-up approach: from manufacturing processes, up to machines, manufacturing systems, production sites and finally manufacturing networks;
- several areas and concepts related to: mathematics, physics, chemistry, engineering, economic science;

- several simulation methods: molecular dynamics, finite elements, event-oriented simulations;
- spatial expansion: atomically, microscopically, mesoscopically, macroscopically;
- temporal expansion: nanoseconds, seconds, hours, days, weeks, years.

The application areas of multi-scale simulations for modern manufacturing systems lie particularly in: a) factory and logistics planning, b) work and process planning, c) construction of the operational funds, d) programming, control, e) processing and e) quality management.

The concrete product emerged of the heterogeneous simulation models representing the prototype of the Digital, Virtual and Real-time Factory.

Modelling of parallel, serial and hybrid kinematics

In recent years machine tool builders are forced to develop machine tools which enable the highly-effective and accurate manufacturing of a wide range of different products with different manufacturing attributes, e.g. parts which have to be milled and turned in one clamping. Beside these different technical specifications, machine tool builders are forced to develop optimised machine tools, which are quickly successful on markets with high cost pressures.

Under these circumstances it is extremely difficult for small and medium-sized enterprises (SMEs) to choose the right machine concept, to define the integration of hybrid processes and to optimise the kinematic structure and the structural behaviour in the early concept stages. In addition to the complex decision of the machine's setup, SMEs are often not in a position to use various complex software tools to evaluate different concepts.

Within this project different easy usable methods and simulation tools for the design process of serial, parallel and hybrid kinematics of machine tools will be developed, taking into account the expected range of products and manufacturing processes. The complex mechatronic system machine tool should be represented by suitable sub models, which enable companies to compare different concepts and find the best possible setup of the machine tool under the mentioned boundary conditions.

Virtual Reality-based simulations for machine operations and Life Cycle impacts

In the planning, development and utilization of machineries and plants, digital methods need to be consistently employed throughout the entire life cycle to generate improvements, shorten planning times and enhance product quality and reliability. It is becoming ever more urgent for enterprises to integrate advanced VR technologies in their existing infrastructures and to reorganize existing processes.

Virtual functional models of specific machine configurations as the starting point, virtual products, machine and plant models are produced, which, additionally incorporate usability concepts and educational methods, already enable evaluating and improving products and processes in manufacturing and operating enterprises before their real commissioning. Functions and processes can be safely tested and procedures can be trained.

The research efforts have to initially focus on the development and integration of VR applications in the entire life cycle. These applications include planning, development and simulation tools, new methods and procedures for occupational health and safety; oversight and support of certification processes, development of process models and knowledge storage systems with supporting technical-didactic methods and training personnel in different processes on complex products, machinery and plants.

New methods and tools will be combined by using distributed simulation, methods for simulating and analyzing shape varying and moving 3-D body surfaces, mixed reality technologies for the control, operation and maintenance of complex assets, augmented reality applications for process supports and quality assurances. The expected results are VR based tools, methods and prototype applications for machines, production systems and plants and production logistics networks.

Distributed telepresence in haptic-visual-auditory collaborative manufacturing environments

The rapid advances in computer and network technologies induced the challenge of distributed and collaborative design environments. This is based on the more increasing importance of the remote collaboration for manipulating 3D models in the design domain, due to the competitive and complex product development processes. HCI community envisioned that telepresence represents on of the main enabling technologies, having a relevant impact on the remote collaboration in manufacturing engineering. Telepresence means technical tools enabling a human operator to be present in another, removed or not accessible remote environment with his subjective feeling. Supporting verbal and non-verbal communication is seen as an important issue for facilitating the remote collaboration and a main requirement for the implementation of distributed 3D collaborative design environments.

The research in the telepresence field aims at overcoming several challenging barriers between the operator and the teleoperator, for ex. a barrier can be the distance, but also the scaling (small-scale telepresence - e.g. minimum invasive surgery, micro-assembly - or also large-scale telepresence). Additional to the visual and acoustic sensory immersion, in particular haptic immersions are required, mainly tactile (pressure, temperature, roughness, vibrations...) and kinesthetic (proprioception, inertia effects, the force of gravity) channels are used, in order to improve the immersion in the virtuality.

The overall objective of this area represents the design and implementation of a so-called haptic-visual-auditory collaborative manufacturing environment, seen as collaborative common work space, in which distributed telepresence collaborations, with the modalities mentioned, are supported (Tele-collaboration). Networked and geographically distributed operators in a common manufacturing environment have to solve a complex manufacturing task and they are supported in their perception and immersion in the virtual environment by auditory, visual and haptic immersions.

The research program can be oriented towards 2 areas:

- Development of the knowledge base, which is required for the design of the haptic-visual-auditory collaborative manufacturing environment, consisting of new models, methodologies and enabling technologies and applications. It concerns methodical bases for communication, for the different visualisation and immersion modalities

- Development of different employment scenarios where the haptic-visual-auditory collaborative manufacturing environment can be used.

The integration of envisioned haptic-visual-auditory systems and tools improves the overall communication and collaboration between the involved operators in the manufacturing processes.

Pattern recognition in manufacturing

The application areas of pattern recognitions like image analysis, character recognition, speech analysis, man and machine diagnostics, person identification and industrial inspection are converging in the manufacturing industries in the last years. Studying the operation and design of systems that recognize patterns in data, and inclosing subtopics like discriminant analysis, feature extraction, error estimation, cluster analysis (together sometimes called statistical pattern recognition), grammatical inference and parsing (sometimes called syntactical pattern recognition), the pattern recognition area supports more and more manufacturing enterprises, mainly for cost reduction purposes. The cost of manufacturing in general, and in particular the costs associated with assembling complex devices, would benefit tremendously from this kind of technology.

The overall objective represents the development of new and innovative pattern recognition methodologies and tools for the purposes of manufacturing engineering. The research efforts can be directed to several areas and validated in several specific application fields:

- Development of pattern recognition methods and tools for the 3D design activities. An envisioned application is to suddenly recognize the orientation of a part in a bin. By using the pattern recognition, the operation becomes easy, and orders of magnitude cheaper than any AI solution, if the corners of the part announce themselves (requiring a couple of localizers on each part).

Development of a pattern recognition-based integrated approach to design compact manufacturing facilities by using facility layout planning techniques to drive design and selection of multi-function machining centres. This is supported by the integration of pattern recognition systems and tools into the collaborative manufacturing environment by having as a proposed application field the integration of facility layout and flexible automation, as two approaches for reduction of material handling costs and product travel distances. These two have been always implemented independently of each other.

2.4.3. Real-time (Smart) Factory Management

Capturing and synchronising heterogeneous production data with the Digital Factory

The real-time factory offers an intelligent, real-time operational management of factory processes and resources. It tightly integrates the real factory with the digital and virtual factory by continuously communicating, connecting and evaluating the factory's operational data. Planning and evaluation activities belong to the virtual factory. They are based on simulation and visualization, process management, and information management. The real-time factory additionally introduces interconnected, self-adapting, cognitive devices and systems for the real-time operational management of the factory. This new way of factory planning employs a set of various local and distributed planning activities (e.g. production facilities, logistics, organizational planning) for a digital factory and makes predictions for a virtual factory which are based on the realization of the original plans. The technique of collaborative and distributed planning addresses the generation of plans and of monitoring instructions at different spatial and temporal events. The real-time factory is based on sensors that collaborate in complex networks, continuously acquiring the actual state of the factory, e.g. machine states, flow of material, product quality, and human resources. The process of integration of data, provided by the sensors systems with the data stored in the digital factory and data obtained as output of simulation and optimization of the virtual factory, has to cope with the challenge of capturing real-time data and then synchronisation.

The research efforts have to mainly focus on the coupling of the digital and the virtual factory with the real-time factory through the development of the so-called sensitive digital and virtual factory, capable of managing real-time data, captured from several heterogeneous and autonomous data sources and applications, as follows:

- Employing the ubiquitous computing techniques and self-organizing sensor networks, for data collection, aggregation, and processing in an intelligent way. This data has to be integrated and managed in a factory repository, forming the basis of context-aware systems in the real-time factory.
- Handling the uncertainties occurring in dynamic and distributed environments with stochastic methods (e.g. Bayes-nets, Markov Decision Processes - MDP, Partial Observable - MDP), supported by collaborating multi-agent technology. This supports the operation in highly dynamic environments since production plans can be repaired online or even be newly generated by context-aware sensor data interpretations and communication protocols. Due to the economic relevance those processes must be accompanied by adequate evaluation, controlling and planning models.

Manufacturing Execution Environment for the Smart Factory

Factories and manufacturing resources are permanently changing. Paradigms of the past ignored this by using the following ways:

- Scheduling of operations in Production Planning and Control (PPC) from month down to days and shifts,
- Manufacturing execution scheduling and supervision including feed back down to hours and minutes
- Real time control in the machines down to µsec.

Modern IT technologies make it possible to manage the factories in Real time and distribute the information of situations to all actors of the production system. For this it is necessary to integrate Data Collection, Data Mining and Sensors for Monitoring of Resources in overall real time architecture and present the situation permanently in the digital environment for planning, management and support of peripheral actions. By the way – this is called the "Smart factory".

Elements of the Smart Factory are:

- Wireless technology in factories
- Integration of Diagnostic Systems
- Real-time control and data collection for learning procedures
- Location systems for mobile objects
- Integration of Factory Data Management (FDM)
- Intelligent Federation system for information supply on demand
- Visualisation of the state of the art

The main objective of this research action is the development of a Factory Management System, based on new communication technologies and open system architectures. A federation platform for the integration of information supply has to be open for the integration of a wide spectrum of automated systems and has to support the execution by Visualisation (Factory cockpit) in the chains of engineering, order management and resource management. The main goal represents the development of a platform for Manufacturing Execution, which is integrated in the digital factory environment of manufacturing engineering, process planning and continuous optimisation (learning elements).

2.4.4. Process modelling, simulation and management

Manufacturing process modelling and simulation

All manufacturing processes are instable because of the high number of dynamic influencing factors and the technical problems to define all phenomena and their relation (interferences and overlaying) or to measure the real conditions and parameters in processes. High variances and the potentials of inventions are usually evaluated through physical experiments. Today, high performance computings and a high number of computerised methodologies, to realise process simulation in the areas of mechanical, coating, joining processes and non conventional processes, can be used. Processes are influenced by the thermal, mechanical and dynamic behaviour of machines and robots. And they are elements in process chains from the raw material up to the finished product. Simulation can even be used for analysing solutions, which are designed in CAD and CAM. Simulation reduces the cost and time of physical experiments and tests.

The content of this action is to focus on the research of applicable modelling and simulation technologies in the fields of processes with mechanical, energetic, fluidic and chemical phenomena for modelling and simulation of parts manufacturing. The simulation systems should have links to CAD-Models and integration of basic analytic methodologies for engineering finite elements, mechanics and fluid mechanics, molecular dynamics or others. They have to be integrated in the Engineering chains of manufacturing. The models have to be evaluated by experiments.

Knowledge-based process planning for hybrid systems

Hybrid systems are characterised through a mixed and changeable degree of automated and human work. Human work is essential for changing operations like in a series production with high numbers of variants and customised orders. Process planning, supporting the preparing and optimising of manufacturing operations, has to execute the work under strong time pressure and with high accuracy. Defects in process data and process parameters, programmes for automated operations, are creating losses and defects in the shops. They need tools for efficient planning in the chain between engineering and execution, with a link to the shop real situation.

A possible solution to the above mentioned challenges represents the embedding of knowledge in the process planning by means of elementary standards of work (global process standards), experience based and cognitive learning, data, knowledge and best practice based integration in real-time manufacturing execution systems and real-time resource management. The implementation of vision systems for processes in distributed (networked) manufacturing and for capability of resources have a main relevance for this topic.

In recent years the developments of vision systems have concentrated on solutions that detect defects earlier in the process or prevent them from being created at all. As an example, so called Vision Labs have been developed, designed to automatically sample sets of containers from the production line and perform a series of highly accurate tests. These measurements are monitored with a special software tool for control variations, where actions can be taken to prevent the problem drifting to an out-of-specification state. In this way, quality can be maintained or improved, efficiencies increased, and costs minimized.

Several solutions and tools should support the objectives' achieving: knowledge support of the so-called Intranet-Federation platform, cockpit application for planning and execution in partly autonomous socio-technical environments of manufacturing.

Process planning in a customized production

Regarding the increasing demands concerning flexibility and cost reduction in car body manufacturing, flexible forming systems which can be used for the realization of complete car body parts, offer the chance to achieve considerable economic effects. These systems can be used for the realization of different parts of the same part family (e.g. doors, bonnets, …) or for the manufacturing of completely parts of different part families. Using these systems, it is possible to form the main part geometry as well as special designs or functions defining features.

The main component of such a manufacturing system can be represented by a forming device, which consists of a forming tool (in a press) or a "self-driven" forming tool, respectively. The forming tool itself can be based on several components, such as "multi-useable" modules or part-related segments (e.g. for corner areas). Beside the main forming steps, other operations can also be integrated (e.g. calibrating, punching, trimming, joining etc.).

An important precondition for the realization and use of such manufacturing systems is the development of a method in order to identify the process steps for the realization of the special part geometry. Following knowledge-based aspects have to be included:

- A scanning system of the part geometry (CAD data)
- An automatic part classification
- An automatic identification of the main geometry and special geometric features
- A determination of forming processes and required tool components

To guarantee the feasibility, automatic FE simulation and optimization loops (if required) should be also implemented.

Deliverables include (i) methods for the development, realization, configuration and reconfiguration of flexible forming systems, (ii) the automatic coupling of the process planning and forming device configuration with FE simulation and (iii) a prototype flexible forming system.

Process planning for multi-materials and functional material manufacturing

The need for light weight constructions as well as integrated functions and miniaturisation leads towards an increasing use of multi-materials and functional materials in several fields of application.

In the field of light weight constructions the high strength materials are used for low weight and high rigidness. To also achieve appropriate damping behaviour, multi-materials as combinations of metal sheets and plastic sheets, are applicable. Also functional combinations of 3D shaped parts, made of different materials, can contribute to a lowering of the weight of constructions, especially in vehicle constructions.

Also the increasing functional integration as the integration of mechanical, electrical, fluidic and other elements into one part, during an early stage of machining, is essential for short and reliable processes.

For this reason there is a need for the planning of design and machining of functional integrated parts. This will include the design of multi-materials and multi-material parts, the investigation of machining processes for the assembly of materials and shaping of multi-material parts and the assembly of shaped multi-material parts. In addition the functionalisation of mono-materials by an integration of active and elements is necessary.

2.5. Emerging Technologies

The implementation and development of the "Next-Generation European Manufacturing Systems" is enabled by a set of the so-called "Emerging Technologies". These are defined in this approach as the manufacturing and engineering technologies and tools whose science, basic principles and theory are understood and well formalised, and at least some useful and wide accepted field of applications and studies are recognized. Despite the identified and partially proved applicability, their potential is mostly unfulfilled as evidenced by a lack of significant products, and maybe possibly by the lack of market demand or need. These are of high potential remaining as the risk taken by the pioneers in implementing them to be as expected recompensed by competitive advantage, adaptability and high flexibility in order to cope the market demands and permanent changes of new products and their related services. Several emerging technologies relevant for the "Next-Generation European Manufacturing Systems" have been identified and structured according the following four main clusters: "Environmental and Energy Technologies", "Performance and Efficiency Oriented Technologies", "Advanced Material Engineering" and "Product-oriented Technologies". Distributed on the time scale and priority, these have been graphically represented into the "**Manu*future* Trans-sectoral Roadmap: Emerging Technologies" (**Figure 6**)** and having the following deployment by synchronisation, collaboration and harmonisation of integration and application in products and manufacturing systems:

- **On short term with high priority** the collaboration between the high performance traditional technologies, which have to be pushed beyond their limits, with the low energy consumption and scavenging technologies towards the implementation of the clean manufacturing processes.
- **On medium term with high priority as well,** the advanced material engineering and functional surfaces, white-bio and refineries have to be fully integrated into the process chains for the purposes of the miniaturisation of mechatronic components.
- On **long terms** the envisioned "Emergent and generative processes" aims at implement the cognition-based process control of high-precision and reliable (zero-defect) manufacturing engineering.

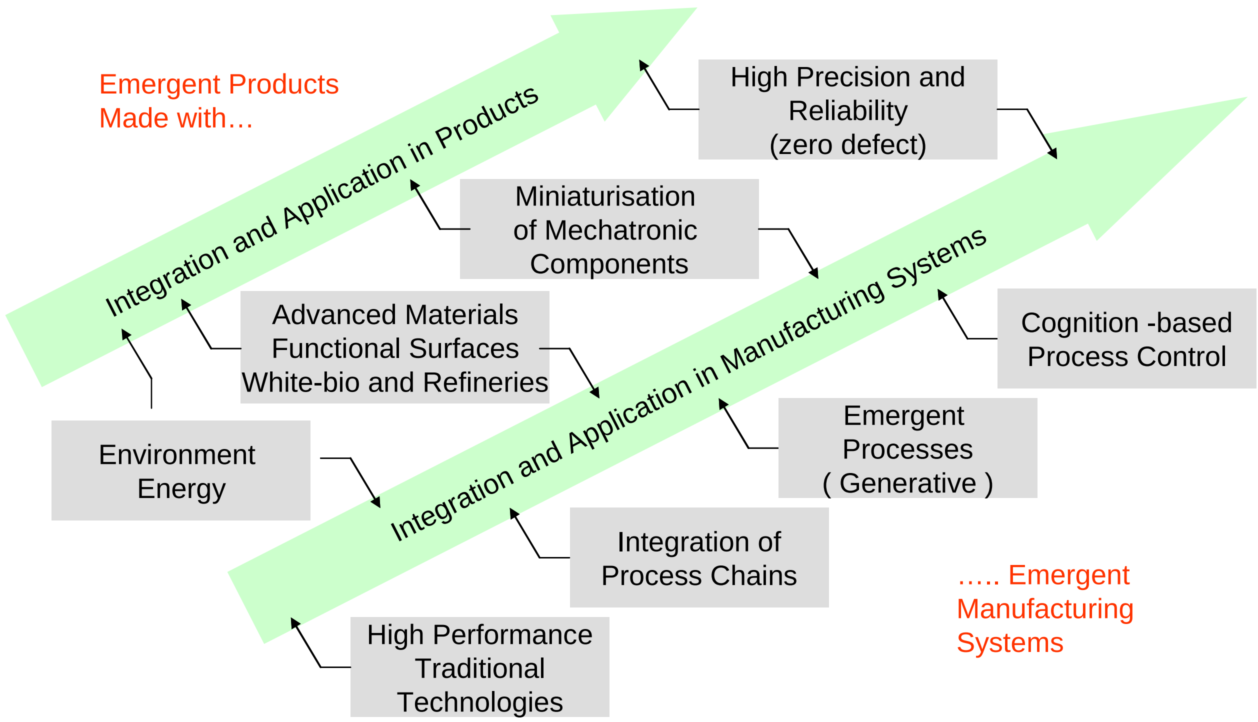

Figure 6. Manu*future* Trans-sectoral Roadmap: Emerging Technologies

2.5.1. Environmental and energy technologies

Energy Supply Life Cycle Management

Different systems of energy supply are used in manufacturing: process energy (heat), energy for driving machines and systems, energy for working environments, light, special operations and regeneration of media and material etc. Seen from the point of the cost of energy in manufacturing and impacts on the environment, a general initiative has to be started, which initiates a reduction of energy consumption in manufacturing. The scope of this action is a Total Energy Management System (TEMS), achieved through the following main research activities :

- Development of an energy management system, similar to quality management, which includes the life cycle from engineering to disposal and recycling,
- Set of methodologies for preventive energy reduction: design to decrease energy, energy assessment, evaluation of energy
- Innovations to reduce the energy consumption of machines, energy supply systems, infrastructure, logistics and buildings

This action has to include the emission of energy.

Low energy Factories

There are many technologies available, which can contribute to the objective of reduction of energy in manufacturing. The technical content of this action is the implementation of innovative technologies for energy supply and energy consumption in manufacturing by pilot low energy factories. Special technologies for this are:

- Construction and design of buildings for manufacturing with low energy losses.
- Implementation of energy systems based on renewable energy systems (including solar)
- Heat exchanger and energy recovery
- Energy monitoring and intelligent control

The scope of this action is the implementation and evaluation of energy systems for manufacturing plants to get experiences with innovation solutions including practicability and economic impacts. The action should have a background of a real investment in a new factory, especially in a technology field, which is representative for many others, and which brings together interdisciplinary teams: architects, construction engineers, manufacturing engineers, energy suppliers, specialists for the environmental side etc.

Technologies for energy efficiency, consumption and scavenging

Optimised utilisation of energy streams with a low energy level is a very promising approach to reduce energy consumption and to increase energy efficiency in production processes. The detailed knowledge and analysis of the production process is the prerequisite to open up energy saving potentials in manufacturing industries. The objective will be to overcome existing process limitations by developing new production processes which integrate innovative energy efficient technologies. Optimised utilisation of energy streams with low energy levels especially includes the application of innovative approaches and technologies for the utilisation of waste heat.

Clean manufacturing processes

In the automotive and machinery industry the structures in metal or polymers are getting smaller. Particles in these structures are reducing reliability and quality. The objective is to develop clean manufacturing processes to avoid particle contamination in products. The focus will lie on the protection of the clean environment for conventional production processes like moulding and shape cutting. The environment assures the cleanliness with airstreams, monitoring systems, filter systems, inline cleaning and other principals known from semiconductor industries.

To ensure the clean manufacturing environment advanced technologies for particle detection, cleaning technologies, sensor technologies, contamination suited product design and the cleanliness of materials have to be improved. As a concrete need, a new approach to avoid contamination in conventional industries has to be developed. A clear strategic contribution to establish a European high value added industry is expected. New, cost efficient production methods will improve the quality of products in high market value segments in industries such as automotive and machinery industries.

2.5.2. Performance and efficiency oriented technologies

High performance manufacturing technologies

Manufacturing is expected to keep on increasing it's demands in terms of quality, reliability and productivity. This tendency has been clear in the last 5-10 years, induced by the shortening of the time-to-market processes, the faster changes in the products presented in the different markets, and the increasing competence of the low cost countries.

The big manufactures (consequently, machine consumers) are producing more accurate parts in lower times, with a shorter lifetime on the market, and under more environmentally friendly parameters. These requirements are directly translated to the machine manufacturers, that are more and more being transformed into "manufacturing solutions generators", more than simply machine suppliers.

This new requirement can only be satisfied by the development of manufacturing systems, based on technologically advanced solutions, usually, integrating several high-value technologies into each solution.

The most significant aspects that should be covered by these new machines and processes will be: (1) Technologies (machines and processes), that provide more efficient and productive outputs by high Volume, high Speed and capability of Processes. (2) Technologies (machines and processes), that overcome the current frontiers in terms of accuracy, providing smooth and even super finishing conditions. (3) Technologies (machines and processes), with special mechanical and control characteristics and configurations in order to provide drastic improvements in process dynamics, increasing the productivity in the same level. (4) Technologies (machines and processes), that require less shop floor space, by means of the reduction of peripherals, optimization of machining cycles and process planning.

The main aspects that will be the subject of investigations under the scope of this topic should be: (1) Drastic improvement of the conventional manufacturing processes, by means of new technological approaches, based on new strategies, tools and machine attributes.(2) Development of alternate processes that substitute the conventional ones or combine with them, provide new productive, economic and ecological ratios. (4) Development of new machine (equipment) concepts, based on new materials (including nano and smart), new architectures and new control possibilities.

Zero defect manufacturing

Customisation and reduction of lot sizes down to "build to order" let the cost of set up, changing processes and adaptation explodes. By the way conventional methodologies for statistical process controls (SPC), methods like "six sigma" and "Process FMEA" are inefficient or not practicable because of their post- process measurement and orientation to series production. They have to be substituted by supervising and controlling the process parameters (in the capable parameters field) and by pre-processing prognosis and proactive controls. This includes the application of sensors for process diagnostics and process monitoring and visualisation. The integration of cognitive systems seems to be possible in order to realise intelligent and self-optimising machines for "zero-defect" manufacturing. The scope of this action is the realisation of manufacturing systems for capable processes (Cp 2,0 and higher) in areas of parts manufacturing with conventional technologies: cutting, forming, coating and manufacturing of electronic boards.

The research in this area aims at a development of innovative solutions for intelligent manufacturing systems, supporting of customising and build to order strategies. These will represent relevant advancements for automotive supply industries, electric and electronic components by inducing the reduction of losses by quality control and the increase of efficiency in manufacturing.

Sustainable production technologies and systems

The key factors for sustainable production technologies are: energy efficiency, efficient use of resources and materials, closing of loops, and reduction of emissions. Projects should focus on reaching these objectives. Process intensification is one way to reach these objectives. The scale-down of processes leads to improvements in process/plant efficiency, with respect to space, time, energy, raw materials, safety and the environment. Process intensification comprises technologies such as micro-reaction technology, which allows e.g. intensifying the heat and mass transport – thus saving material and energy resources. A second way to reach the objectives of sustainable production is process integration, where operations (such as equipment for heat exchange and mass exchange) are integrated into the process in order to reduce the demand for externally supplied utilities (fuel, electricity, steam, water, solvent, air). Here, development must focus on technologies that enable the integration of operations into processes, thus improving the energy efficiency and reducing the consumption of fossil resources.

One focus of biotechnology will be the development of new high-performance catalysts. Next-generation catalysts should contribute towards the achievement of zero-waste emissions and selectively use the energy in chemical reactions. They will also enable the development of new bio-mimicking catalytic transformations, new clean energy sources and chemical storage methods, utilisation of new and/or renewable raw materials and reuse of waste, and solving of global issues (greenhouse gas emissions, water and air quality).

A further contribution to sustainable production can be made by the development of new materials. Functional materials will play a major role, such as intelligent polymers, bio-compatible and bio-degradable materials with tailored properties which include e. g. thin films and surface coatings and bio-nano-composites using nano-technological and bio-mimetic material concepts.

2.5.3. Advanced materials engineering

Manufacturing of engineered materials

In the area of materials engineering, one of the main objectives is the reliable large scale production of engineered materials. The main challenge represents the strong interaction between the material properties of the different material components in engineered (composite) materials. So it is necessary to implement a detailed on-line measurement system to identify quality parameters at the several steps in the process chain. New algorithms for on-line process controls allow a delicate design of new production processes. An online-documentation of quality parameters is necessary to guarantee the trace of relevant data of product and production technologies.

The research should be focused on the development of new and innovative technologies aiming at increasing the reliability and reproducibility of the so called smart composites. A smart composite is the combination of a light weight material like fibre composites or light metal alloys with a sensor and actuator material like piezo-ceramic or shape memory alloys. So the inherent sensor effect can be used for a control of the production process and a health monitoring during the process chain.

Engineering of integrated materials

The increasing functional integration as the integration of mechanical, electrical, fluidic and other elements into one part during an early stage of machining is essential for short and reliable processes. New functionalities of mono materials by integration of active and passive elements are necessary. Process engineering and system engineering of integrated materials need innovative tools and methods for combining basic and adaptive materials in energy, information and material flow conditions. Contacts between basic and adaptive materials shall provide reliable initial pressure and resist mechanical stress in manufacturing process, training and applications without delaminating or cracking.

Today's usable adaptive materials for sensors and actuators are controlled by external electrical current, temperature, and forces. Electrical conductors, isolators and mechanical interfaces with microstructures in large dimensions have to combine in reliable production processes into basic materials. New material integrated controllers are needed, which are made of non-silicon materials and can be programmed for controlling positions or force in closed loops. Polytronics offer printable electronics on polymers but do not resist high temperature or mechanical stress. Integrated materials demand new chemical layer processing (without liquids), which do not destroy previous integrating process steps.

Mass production processes demand a higher level of automation and cost effectiveness in the whole process chains. New concepts and techniques for product integrated micro-quality management of basic and adaptive materials are needed. Concepts for environmental friendly regeneration of integrated materials are expected.

Manufacturing of advanced materials and functional surfaces

The need for light weight constructions as well as the use of high strength materials and miniaturization leads towards an increasing use of multi materials in several fields of application. The trend of miniaturization leads to 3D surface elements with micro-cavities (hole, channel) and increases the influence of micro-/nano-forces, not only between surfaces, but also between elements and the environment.

Advanced materials are characterized by a significant change in mechanical stiffness, hardness or by a combined electrical conductor and isolator or chemical activeness and resistance. As they consist of different chemical elements or slides with different behaviours (like bimetals), the material properties have "to be trained" in production conditions for a life long application. New adhesive forces between different material elements have to resist external application forces (like cutting, forming, joining) without de-lamination or waste. Tools are needed for engineering and manufacturing of determined advanced material behaviour.

Functional surfaces are characterized by a significant changed parameter as surface structure or roughness for friction forces or optical reflection, in micro-adhesive forces or metallic corrosion of coupled surfaces, for clean production and so on. A knowledge of micro-/nano-material behaviour of known macro materials is necessary to solve new nano-technologies in cost effective applications. The trend of replication technologies with micro- and nano-structures towards the highest precision manufacturing systems limits today's field of application.

Manufacturing of graded materials

To improve the performance of single parts and in general of mechanical components it is more than ever necessary to implement more and highly complex functionalities. One way to fulfil such requirements is the usage of multiple materials inside of one part and the development of new technologies to be able to realise graded material properties. The controlled integration into the product's design development and application of graded properties is representing one big step forward into complete new design and process technologies, which enable the production of until today unknown structures, part geometries and part properties. This new challenge is not only focused on new technologies to realise those properties especially the graded one, but on the whole product development process. It is necessary to develop new CAD-Software and tools to realise the design of graded materials as well as the implementation of material data inside of today's 3D modelling tools. In terms of international data exchange and the global usage of a standard format, a new and common format, where geometrical information's as well as the dedicated material properties are described, must be defined. Most of today's known and commonly used technologies are not flexible to realise controlled and predefined properties inside of one part. New technologies mainly based on the additive techniques must be developed to enable controlled build ups of different materials and graded properties inside of one single process. Further it is essential to develop new standards in measuring and specifying these new properties.

Management of hazardous substances in manufacturing

The value chain based production activities have become more complex with new technologies, materials and interdependencies. Additionally, the requirements on production processes are permanently increasing with regard to efficiency and environmental friendliness. This collaborative project should have in focus economically and environmentally efficient cleaner production methods and control mechanism which control eliminate or reduce hazardous outputs. An "integrated value chain approach", which involves avoiding, controlling, safe management and diligent use of hazardous substances including hazardous chemicals and hazardous wastes, is strongly encouraged.

The aim of the project is to analyse the whole production process taking into account the occupational health and safety, the detailed risk assessment of hazardous substances (also of the by-products) in special process sequences and cleaner alternative methods and strategies to reduce hazardous substances. Emphasis should be put on the safe management and development of ICT based control mechanisms.

Innovative white-bio technologies and bio-refineries

Industrial or white bio-technology is the application for the processing and production of chemicals, materials and energy by the use of enzymes and micro-organisms to make products in sectors such as chemistry, food and feed, paper and pulp, textiles and energy. White bio-technology could provide new chances to the chemical industry by allowing easy access to building blocks (e.g. succinic acid) and materials that before were only accessible via complex routes or not at all. White bio-technology may establish an effective way to use renewable resources, e.g. in bio-refineries. An integrated and diversified bio-refinery is an overall concept of a processing plant where biomass feedstocks are extracted and converted into a spectrum of valuable products. Bio-refineries combine and integrate necessary technologies from the biomass supply and conversion technologies through the core bio-processing (white bio-technology) and downstream processing steps towards the final application of the use for society, therefore covering the whole industrial biotechnology value chain. Different technologies to convert biomass raw materials into industrial intermediates and consumer products should be developed.

The main objective is to develop white bio-technology and bio-refineries to reach a technological level on which these technologies will become as efficient and competitive as conventional technologies. This requires a lot of R&D activities such as production of chemicals and materials, which would otherwise not be accessible by conventional means, or production of existing products in a more efficient and sustainable way, increasing eco-efficient use of renewable resources as raw materials for the industry, biomass derived energy. These are based on biotechnology, and can cover several areas as: an increasing amount of our energy consumption, development and/or selection of raw material for specific applications, development of new procedures of enzymatic or chemical modification of biomass and transformation to monomers, development of new technologies for polymerisation, fibre pre-treatment and polymer processing, development of cost-effective, environmentally-friendly biodegradable biomaterials and bio-composite materials and products made from them. The expected research activities should integrate a broad range of research competences comprising of biotechnology, chemistry, chemical engineering and agricultural sciences.

2.5.4. Product-oriented technologies

Integrated technology management in design-intensive product environments

The European manufacturing industry is shifting its focus towards design-intensive knowledge-based products with integrated services via an ever-increasing involvement of leading-edge technologies. This shift affects all industries, but the most revolutionary rethinking is fuelled by the fierce competition in mass production segments that are close to the consumer and rely on fast-changing technological environments. European economy can only react by forming intermeshed trans-sectoral technology networks of SMEs and large global companies that are leading innovators in their areas and will enable strong technology platforms.

In this environment, technology management plays a decisive role because it can empower European high-tech companies to identify, analyse and implement those technology platforms that are vital to their success.

European technology companies have to become the leader in technology management if they want to stay leading in technologies. This will be made possible by the results of the projects under this topic. Methodologies will be developed to integrate technology management efficiently into European management procedures. A trans-European roll-out of increasing technology management activities has to be enabled by the assessment of the best practices and a strong dissemination background, which will be tailored towards the specific European needs.

Innovative methodologies for protecting intellectual property and know-how

In recent years, innovative enterprises are confronted with technology know-how thievery and product imitations at alarmingly increasing rates. Especially SMEs are facing problems in enforcing legal and legitimate claims on their intellectual property and know-how. Since intellectual property rights seem to become less and less effective, a more holistic approach on know-how-based competitive advantages in technology-driven firms is needed.

The research performed in this area aims at reducing the risk of European companies to suffer from illegal and illegitimate use of their intellectual property. This will be achieved by the development of advanced and new protection mechanisms, by an integrated assessment of their benefit and effort relations or through supporting companies in the selection of adequate solutions. Projects should focus on enabling new technologies, not on legal actions against imitations. Projects should address the current situation especially of small and medium-sized enterprises (SMEs) which is mainly characterised by low resources for the identification of imitations, legal action against them as well as persecution and lobbying.

New material functionalities induced/made by manufacturing processes

The interaction of manufacturing processes and the product's materials has a considerable influence on the properties of these materials. Sometimes such effects are used to realise desirable functions of a material, but sometimes it is just an unnoticed side effect. A better understanding of such interactions provides the knowledge needed for completely new ways to realise properties of materials or material assemblies such as sandwich structures.

The careful planning of the process-material interactions, their sequence and the control of these processes enable a far better exploitation of the material's functional potentials. Appropriate manufacturing techniques will by far enlarge the processing windows and yield materials that are not used industrially today. Additionally a carefully controlled process-material interaction can produce customer specific product variants that are not economically feasible today. It will even enable new strategies for the modularisation of products and production concepts. New functionalities will be achieved by innovative manufacturing technologies for joining and integrating materials and components that do not fit together today. Advantages for new and innovative products lie in their adaptation to customer specific use and environments.

The activities planned to be performed in this research area have to focus on:

1) Manufacturing of more individual, user adapted products at lower costs by using unexploited material.

2) New concepts of built-to-order products with decreased complexity compared to the state-of-the-art.

Advanced monitoring of complex manufacturing systems

Today the monitoring of complex systems requires complex measurement and analysis functions. Algorithms use different sorts of knowledge but often depend on a regular up-date of a database or on the contact to a central knowledge base. Learning capabilities and the use of environmental data are limited.

Analysis systems for an advanced monitoring of manufacturing systems or complex products should work decentralised to evaluate the state of the monitored systems. Knowledge is essential for such tasks, so new concepts for knowledge acquisition and use are required. Innovative systems also use decentralised and distributed knowledge, new mechanisms for integration of heterogeneous data sources or completely new ideas concerning time and location of the knowledge's generation and use.

They utilise a wide variety of locally available data to give advice to the operator, including the remaining operating time, system degradation or time to the next service or repair. Also new concepts for user interaction to communicate the condition of the monitored system are applied to make operations more intuitive.

User interfaces should reduce complexity for the operator but simultaneously maintain the full extent of the system's control.

To cover new requirements or changed system environments the functionality of the used measurement components can be changed by configuration and software adaptation; configuration of whole subsystems can be adjusted on the basis of experience and history.

2.6. ICT for Manufacturing

The cluster of enabling technologies entitled "ICT for Manufacturing" represents the collaboration and in the same times the synchronisation and harmonisation of the state-of-the-art technologies coming from both areas, respectively Information and Communication and Manufacturing Engineering Technologies. These can be approached as emerging technologies in their areas by not being fully exploited based on lack of relevant application fields. The combination and brilliant integration of them can conduce at the identification of new applications and not fulfilled potential by increasing the capabilities required for the "Next-Generation European Manufacturing Systems" as adaptability, digital and knowledge-based, flexible and networked. Several identified ICT for manufacturing enabling technologies and the expected tools are graphically grouped under the so-called "Trans-sectoral Manu*future* Roadmap: ICT for Manufacturing" (Figure 7). These technologies are planned to be implemented in the manufacturing enterprises as follows:

- **On short term with high priority** the "Configuration Systems" aiming at production/services customisation will enable to the manufacturing enterprises to meet the customers' individual requirements more effectively, by providing more customization approaches related to the design and development of the new generation of modern manufacturing systems.
- **On medium term with high priority as well,** the development of the so-called "Computing and Embedded Platforms for Digital factory" seen as a generic platform which embeds all state-of-the-art modelling, simulation, optimisation, and visualisation technologies and tools for turning the digital and virtual factory into reality. On the same time scale and priority can be mentioned the "Digital Libraries and Content for Engineering and manufacturing" and "Cognitive Control Systems: modelling technologies and architectures". The development of an integrated framework for networked "Multimodal collaboration in manufacturing environments" aims at enhance the interfaces human-machine-machine through new and innovative easy and friendly mode of interaction.
- On **long terms** the envisioned "Grid Manufacturing" aims at migrate the Grid Computing technologies and tools for coping with the challenges of networked manufacturing, respectively the lack of high-flexibility. The "Pervasive and Ubiquitous Computing" as emerging and in the same time enabling ICT will support the implementation of the adaptive, evolvable ubiquitous manufacturing systems.

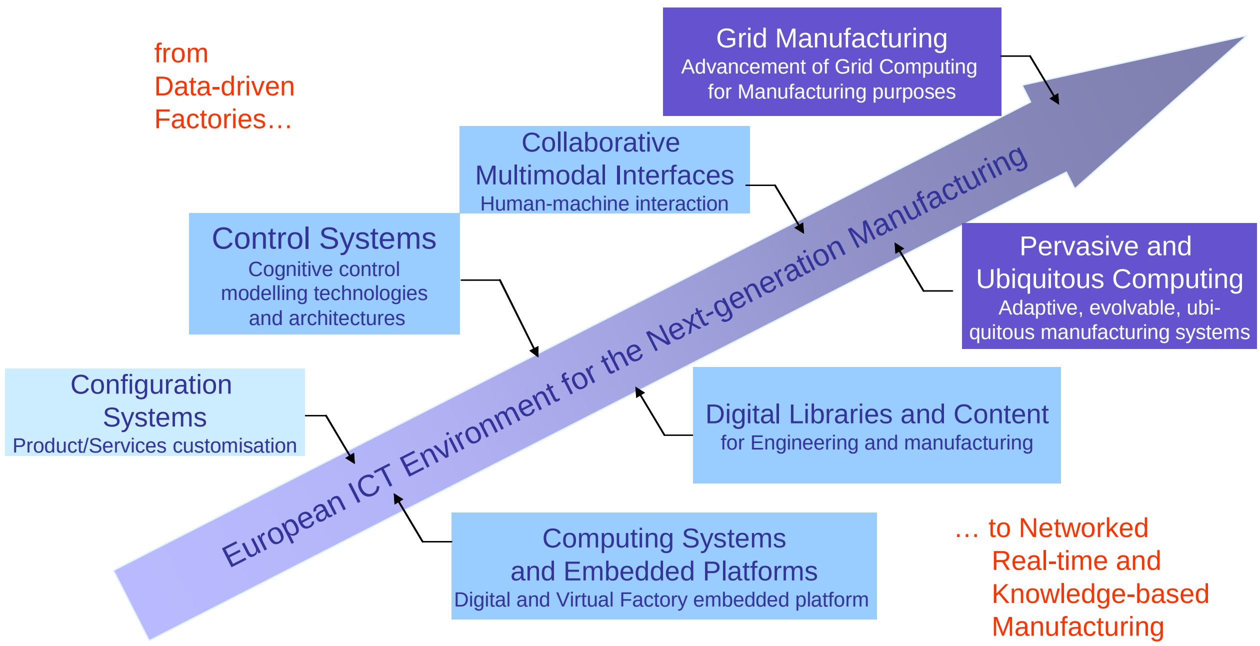

Figure 7. Trans-sectoral Manu*future* Roadmap: ICT for Manufacturing

2.6.1. Configuration systems: customisation of products and services to the market requirements

Configuration systems are key tools in supporting the enterprises to quickly bring out innovative and profitable products to the market. The current systems for product services customization allow customers to specify their requirements by selecting and configuring products and the related services. Customers' individual requirements beyond product configuration and adaptive configuration of complex items (products or services) cannot be fulfilled in these systems. However, such systems, typically designed for expert users, are too technical for the average customer. The integration among the product customization system and other application systems of the enterprise is seldomly considered. Systems enabling enterprises in order to meet the customers' individual requirements more effectively, by providing more customization approaches, represent one of the main requirements related to the design and development of the new generation of modern manufacturing systems. Through system integrations for continuous manufacturing management, the system as a whole eases enterprises to optimize their product and service development processes and supply chains according to the customers' requirements in a systematic way. Several weaknesses of the current systems have to be overcome:

- the current systems are designed for one typical user class, not approaching the fact that users differ in needs, knowledge about the product details, and expertise
- many configurators are product-oriented in their communication process, ignoring the needs of large user groups, e.g. goal oriented customers, who cannot deal with, are not interested in product details.

Design and implementation of user-adaptive configuration systems for products and services towards the enhancement of the existing customer relationship management systems (CRM) represent the main research activities that have to be performed.

The modern user-adaptive configuration systems have to cope with the above mentioned challenges through:

- enhancing the usability of already existing configuration systems by extending them with user-adaptive interfaces, supporting and guiding the user through the configuration process in a personalised way
- development of new models of representation of knowledge about products and services, having as a result the so-called customer-driven product and service generic model,
- development of new techniques to support the adaptive configuration of items, which is essential to comply when purchasing a complex product, or registering for complex services, through a user-driven management of the product and service model, the personalisation of the interaction, and user-adaptive explanation of conflicting requirements is identified in the customisation process,
- development of new modes of integrating the user interaction with configuration, through intelligent user interfaces mediating the user and the configuration system.

The integration of the envisioned user-adaptive configuration systems for products and services with the CRM systems improves the overall communication with the user and supports the satisfaction of users' individual needs at the cost of mass-production.

2.6.2. Digital libraries and contents for engineering and manufacturing

In many fields of the engineering area, such as electronic engineering or mechanical design, the new designed and developed products are mainly based and then defined of already existing components. In order to increase the efficiency and the quality of the design process, the digital libraries have to feature a high level of availability regarding stored information on the already existing components, and of exchangeability or remote access through networks. In the last years, several requirements emerged, regarding parts and components catalogues. With the development of digital mock ups in a number of industries, the need is to fully access digital representations of all the parts intended to be used in new products. A solution for this typical data modelling problem represents the PLIB (ISO) standard, which uses EXPRESS information modelling language. The development of electronic versions of paper catalogues and their distribution over the Internet, identified as typical document structuring problem, has as a possible solution by using the XML tagging technology. Since the PLIB approach is not suitable for the purposes of browsing, presenting and understanding this information, the new XML-based exchanging technologies seem to be appropriate, but not enough reliable to be used by applications that should exploit the meaning of the structured information. The conversion digital library information in catalogue format, the publishing of this information in the Internet and then the integration into the factory collaborative information environment, represent a challenge which will be faced in the next years by fitting the needs of engineering and manufacturing with the progress in the advancement of Digital Libraries ICT research field.

The research aims at defining the digital library services as a key component of factory digital infrastructures, allowing content and knowledge to be produced, stored, managed, personalized, transmitted, preserved and used reliably, efficiently, at low costs and according to widely accepted rules, standards and protocols.

Several scientific goals are envisioned:

- Ensuring the long term accessibility and usability of the content of the digital factory, respectively parts and components, which have to be available in digital form through digital libraries.
- Development of new and more effective technologies for intelligent content creation and management, and for supporting the capture of knowledge, its sharing and reuse.
- Development of new methods for supporting people and organisations to find new ways to acquire and exploit knowledge, and thereby learn.
- Design and implementation of the so called authoring environments for engineering and manufacturing, aiming at supporting the design activities, based on new forms of interactive and expressive content using and motivating the multimodal experimentation and exploration of the design space. These design environments for engineering and manufacturing will facilitate the content, sharing automatic tagging (XML DTD) of existing multimedia content of parts and components. This content will be stored by using open standards, as annotated output in scalable repositories, enhanced with integrated indexing and search capabilities.

2.6.3. Networked multimodal collaboration in manufacturing environments

For each kind of system, mainly ICT systems, a high degree of user friendliness at the interface between a human and a machine is a decisive prerequisite for being generally accepted. The new manufacturing production systems and their applications are characterized by multi-modal interfaces as well as by the pro-active behaviour of the application system. Therefore, various interfaces must be sensibly combined with each other, and the interaction with humans must be perfectly adapted to the individual situation of the human. Specific challenges including, among others, the selection of suitable interfaces for specific applications, the dynamic changes of interfaces based on changes in the state of the human such as "experiences gained" or "accident", as well as the experience-based optimization of such interfaces.

Multimodal data, including video (gestures, body motion, facial expressions, gaze), and audio (speech) constitute natural ways to build interfaces with machines. However, the combination of multiple data sources face a number of challenges, arising from their distinct nature (like asyncronicity) and their complex relations (modalities can at times be redundant, complementary or contradictory).

The following main research directions are envisioned as being relevant for multimodal interactions. In the first research area or direction, the aim is to directly command a computer, machine or equipment via static and dynamic facial and body gestures (a described hand trajectory, or a sequence of hand postures) and speech commands. The machines should become able to register human emotions (and related states), to convey emotions (and related states), to "understand" the emotional relevance of events. The second research follows the main idea to automatically analyze natural individual actions or group interactions and react accordingly in "smart" spaces like meeting rooms, or mainly in the so-called "Smart factory".

The main research objective in the area of multi-modal interaction represents the development of an integrated framework for networked multimodal collaboration in manufacturing environments. The environment aims at sensing the existing computing and manufacturing environment and adapt them to provide a prescribed quality-of–service, by involving the information transformation, where it is needed, and evolving methods for multimodal human/machine communications, implemented at client stations, in order to enhance naturalness, ease-of-use and functionality.

The implementation of the new human-machine interaction has to approach the following directions and aspects:

- Development of new statistical approaches for gesture recognition and enhancement of already existing and suitable approaches, namely Artificial Neural Networks (ANNs) and Hidden Markov Models (HMMs). The existing models, for ex. HMMs, well known methods to model temporal data do not exhibit optimal properties to discriminate between sequences of distinct classes.
- New approaches for the problem of data fusion for multimodal person localization, tracking, and action recognition. The already existing and current approaches focus on the Graphical Models and the Sequential Monte Carlo for audio-visual speaker-based tracking and action recognition. There is a need to develop new asynchronous HMMs, capable of manipulating and managing several streams of information that could contain asynchronous joint information.

2.6.4. Manufacturing control systems for adaptive, scalable and responsive factories

Modern manufacturing control systems must respond quickly to continuous changes in the next generation responsive factory. With traditional manufacturing control system programming, it is time-consuming to make changes as a result of separate databases for the programmable logic controller (PLC), Human–Machine Interface (HMI), and supervisory control and data acquisition applications or modules. New engineering approaches that ensure efficient, robust, predictable, safe and secure behaviour for multi-scale, distributed, scalable and responsive manufacturing and factories are required, as well. The re-configurability of software for current machine control systems is very limited, although the concept of component-based software integration has already been adopted in controller software development. Specifically, the following limitations and then the challenges in current control software development practices hinder the re-configurability of manufacturing: 1) Application software is partitioned and implemented with proprietary information, 2) Control behaviours of the software are either built inside the implementation and hence, not customizable, or not modularized and associated with the corresponding software components, 3) Software implementation is specific to platform configuration.

The development of new models of control systems which has to provide control and diagnostic codes, enabling the network architecture, data mapping and control and diagnostic system to be designed and integrated in a unified and single tool, represent the main research objective in this area.

The scientific activities and research steps consist of creating a customized process control and quality data interface system to network stand-alone pieces of manufacturing equipment, such as PLCs, robots, process machinery, and test stations, at all levels of the next generation responsive factory, respectively from the network of factories to manufacturing processes.

2.6.5. Computing systems and embedded platforms for advanced manufacturing engineering

The envisioned "next generation disruptive factory", a complex long life product, which has to be adapted permanently to the needs and requirements of markets and economic efficiency has a holistic and multi-scale approach, e.g. manufacturing network, manufacturing system/factory, segment or system, machine or equipment, subsystems and processes. It is "digital" in its "current" state and "virtual" in "future" states.

Digital manufacturing uses a wide range of engineering and planning tools and applications to integrate efficient and effective new information and communication 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. Digital manufacturing employs the distributed data management, tools for process engineering, tools for presentation and graphic interfaces, participative, collaborative and networked engineering and multi-modal interfaces. Digital manufacturing has as main output of the representation of the factory as it is today, e.g. the static image or the so-called "digital factory and manufacturing".

Starting with this digital representation of the factory and manufacturing and employing the virtual manufacturing technologies, simulation tools and specific applications and systems, the factory and its manufacturing processes are represented in their dynamics. This is the reflection of the "actual" state of the future, the so-called "virtual factory and manufacturing". All the above mentioned activities have to be supported along the factory life cycle phases and along all scales by the newest convergent technologies, and the corresponding models, methods, tools and systems. A new engineering approach is required, having as a main foundation the conventional and new manufacturing technologies, and as pillars, the manufacturing and information and communication technologies, which converge enabling each other in the pursuit of this common goal: to give reality to the envisioned digital and virtual factory.

The overall objective of this area represents the design and development of the so-called "Reference architecture for advanced Manufacturing Engineering". This is seen as a generic platform which embeds all state-of-the-art modelling, simulation, optimisation, and visualisation technologies and tools for turning the digital and virtual factory into reality. Together with other reference designs/architectures for embedded platforms, it will allow industrial users to engineer new applications in advanced manufacturing engineering with minimal efforts.

The main envisioned research activity aims at:

- Development of an innovative concept for a reference design/architecture. It should be as generic as possible, cutting across factory application domains, e.g. layout planning or ergonomics, and it should be accompanied by appropriate tools and component libraries. The initial priorities are conceptualisation, analysis, design, demonstration and evaluation of the prototype platforms. The architectures will concentrate on composability, networking, robustness/security, diagnosis/ maintainability, and resource management, evolvability and self-organisation. Main challenge: the heterogeneity of the digital manufacturing technologies and tools which have to be integrated.

This activity has to be accomplished with the innovations achieved in the ICT area of novel architectures for multi-core computing systems, mainly new architectures and the corresponding system-level software and programming environments, advancing from single to multi-core scalable and customisable on-chip systems, incorporating multiple, networked, symmetric or heterogeneous, fixed or reconfigurable processing elements.

The aimed at and planned activities will:

- Support and reinforce the current paradigm shift towards multi-core systems and embedded applications. Master these new computing architectures to allow European companies to achieve world-leading positions in computing solutions and products.
- Enable supplier companies in digital manufacturing technologies and tools to increase their market share through the availability of inexpensive generic embedded platforms with high European added value.
- Enable a broader number of users to integrate powerful computing solutions in their products quickly and at a low cost, thereby strengthening their competitive position.
- Fostering European excellence in computing architectures, system software and platforms for manufacturing engineering. Developing European competences in the use of high-end computing to enable the development of manufacturing engineering.

2.6.6. Pervasive and ubiquitous computing for disruptive manufacturing

A new challenge in manufacturing engineering represents the migration of ubiquitous computing into the manufacturing world. The manufacturing engineering community and enterprises need this emerging new technology, ubiquitous computing, in order to develop an adaptive and evolvable manufacturing environment which is present anytime, anywhere, and which can access desired information by real-time. This will support the globalization of business environments which globalize the production and logistics issues across multiple factories over geometrically remote sites, as well. This rapidly changing global business environment requires each manufacturing enterprises to remotely monitor and control from real time status of processes, materials, production procedures and workers for an optimum management.

This ubiquitous environment for manufacturing engineering needs to economically provide diverse communication functionalities to interface with existing (e.g. Process I/Os, serial communications & Fieldbus) and new (e.g., Industrial wireless Ethernet, RFID, USN (Bluetooth & Wi-Fi) and PLC (Power Line Communication), data processing and decision making functions. It is also essential that the new environment needs to use tether-free internet technology. This technology will enable information integration of all applications being used in manufacturing systems and the best use of the information for optimum decision makings.

The research activities aim at supporting the manufacturing enterprises with solutions to collect and use production information from globally distributed factory by real time.

The scientific goals and planned research steps are mainly represented by the development of a ubiquitous environment for advanced manufacturing engineering that integrates processes, manufacturing resources as materials, production procedures and equipments, machines and people (workers) within a single machine-to-machine (M2M) physical platform under a centralized management to establish the ubiquitous manufacturing;

2.6.7. Grid Manufacturing: advancement of Grid Computing for manufacturing purposes

Networked manufacturing systems are expected to have much more flexibility to respond to dramatic changes in the world market. But a real responsiveness might come from dynamic and unlimited resource accessibility rather than from a rigid company boundary. The grid manufacturing is regarded as the next generation advanced solution for the bottleneck of networked manufacturing. With the appearance of grid computing, whose core is dynamic and has a cooperative resource share, grid manufacturing will be the further goal of networked manufacturing. Grid manufacturing realizes the share and integration of manufacturing system resources and supports the collaborative operation and management. It is based on grid and associated techniques to supply enterprises with reliable, standard, easy accessible and cheap manufacturing resources and services, thus realising the cooperation of the whole process including supply chain, design, manufacturing and sale, and decrease the costs, shorten the manufacturing period, raise the quantity and finally improve core competences. Current challenges for the network of manufacturing enterprises: innovation, speed and flexibility. Required characteristics of networks of manufacturing enterprises are: collaboration, decentralisation and inter-organisational integration. In order to turn this new concept into reality, few definitions have to be mentioned, as follows:

A) "grid manufacturing = a new industrial paradigm, aiming at enabling the collaborative sharing of resources and competences in manufacturing engineering"

B) "grid manufacturing = the use of networked and distributed manufacturing resources in order to:

- support the collaborative planning, operation and management of manufacturing,
- respond to the emerging challenges: innovation, speed and flexibility"

C) "grid manufacturing = a common collaboration platform for networked manufacturing"

D) "grid manufacturing = integration of grid technology with manufacturing technology for the purposes of networked manufacturing"

The overall objective of the research performed in this area represents the development of a concept for grid manufacturing paradigms and of the corresponding roadmap, having as an expected overall output the first prototypical implementation of a Virtual Grid Manufacturing.

The envisioned scientific goals and research steps are as follows:

- identifying the needs and the development of new business models and rules, required for inter-enterprise collaboration, rules of trust,
- identifying the needs for the development of standards to enable the manufacturing enterprise to exchange its products, services, to develop the interfaces with others, related to IP, ICT, financial, material flow level and other aspects,
- development of methods and tools, required to assist the manufacturing enterprise: to be connected to the grid, to provide products, manufacturing operations and services to the grid, to operate in the grid, mainly to access the operations and services offered by the grid,
- design, development and prototyping, the first broker of grid manufacturing operations and services under the name **Manu-Google**, as a similitude with google.

As main outputs of the above mentioned activities, following concrete expected deliverables have to be mentioned:

- Package of recommendations concerning the required standards, enabling/facilitating the participation of manufacturing enterprises in the Grid,
- Package of recommendations concerning the required tools, enabling the Grid operations,
- Results of studies in several main aspects of the Grid,
- Potential architecture of the Grid,
- Practical simulations and demonstrations,
- Roadmap for Grid Manufacturing.

2.7. Exploitation of the convergence of technologies

The exploitation of the convergence of technologies cluster aims at developing the next generation of high value-added products and new engineering concepts exploiting the opportunities, integration and convergence of, for example, nano-, bio-, info- and cognitive technologies for the stimulation of new industries and to respond to the emerging product needs of more well established industrial sectors. The research focus is on the application of basic research results for the development of new science based products and methods for their design and manufacturing in order to create potentially disruptive products and production systems (Disruptive Factories). The production system and its components are anticipated to be products in their own right. Several technologies coming from the above mentioned areas, nano-, bio-, info- and cognitive, have been in this stage identified as relevant for the implementation of the envisioned "Next-Generation of European manufacturing Systems". These are shortly presented in the following.

2.7.1. Next-generation HVA Products

Science based high added value (HVA) products are a key result to be achieved for moving the European manufacturing sector towards a new competitive advantage on the global scale. Such an RTD activity needs a strong exploitation of world-leading developments in enabling technologies such as new materials, nano-, bio-, info- and cognitive technologies.

Next generation HVA products for the final consumer have to be 100% personalised, comfortable, safe, healthy, and eco-sustainable.

Therefore the following major RTD sub-topics have to be addressed:

- introducing innovative sensors, actuators and embedded cognitive technologies for active products, supplying functionalities and services for comfort, health and safeness of the consumer;
- introducing bio, micro- and nano-components, as well as intelligent and multifunctional materials, for self-adaptive and eco-sustainable products.

Main development issues and targets, and deliverables are:

- methods and tools for forecasting consumer attitudes and needs based on social and cultural aspects to conceive disruptive new products-services, anticipating the market dynamics;
- knowledge based collaborative environments for the design of next generation products, integrating new materials, nano-, bio-, info- and cognitive technologies;
- new manufacturing processes for next generation consumer oriented science-based products.

RTD activities have to be developed with reference to relevant manufacturing sectors as benchmarks with reference to:

- traditional industry (e.g. textile, wood and leather products);
- mass production (e.g. automotive and white sector);
- specialised suppliers (e.g. aerospace, machine tools);

in order to shift such manufacturing sectors towards more science based HVA solutions.

2.7.2. Education and training in "Learning Factories"

Technical and organisational innovations change the structure of manufacturing industries. Main drivers are new technologies for micro- and nano-scaled products, engineered materials and new processes characterised by fast adaptation, networking and digital factories. The content of this action is the fast transfer of basic knowledge from research to application by education in learning factories. The learning factories have to be equipped with an integrated system for manufacturing engineering with 3D CAD, Analysis and planning tools for manufacturing processes, with high end Product Data Management, VR- Systems (Digital Factory) and a physical laboratory with changeable manufacturing and assembly systems. The labs should even be equipped with new solutions for information supply like ubiquitous computing, wireless technology and navigation systems, implemented in an ERP-, Order-Management and Manufacturing Execution System. Simulation of logistics, kinematics and processes are elements of the learning factory. For Education and Training it is necessary to link the shop level systems with the digital environment. The Learning Factories offer basics for engineers and technicians in praxis with the following topics:

- Basic knowledge in changeable production systems,
- Optimisation of Manufacturing in real and digital environments,
- Learning fast adaptation of factories,
- Usage of high end ICT in manufacturing,
- Management of change, from conventional to high performance technologies,
- Process Planning and Process Management.

The learning factories are regional oriented with relations to the structure and technology portfolio of the dominant sectors of manufacturing. The courses qualify the participants for advanced engineering and management. They should get a certification for the results.

2.7.3. Disruptive Factory: "Bio-nano" convergence

Many consider that the convergence of the bio- and nano-worlds will be a rich source of new products particularly for human health. Products emerging from the science base are likely to form the basis of new industries. Such multidisciplinary industries require effective new product introduction processes and tools, and new manufacturing processes and production systems that are both effective and match global regulatory requirements. Many will require new businesses and models and delivery methods. The main development issues and targets are:

- Tools for the commercialisation of products emerging from the science base at the convergence of bio-nano.
- Business models, new product introduction processes and technologies for the delivery of bio-nano products.
- Processing of current and emerging naturally derived and synthetic medical device, therapeutic and industrial biomaterials.
- Step change methods/disruptive processing of chemical pharmaceuticals of increasing

complexity.
- Scalable processing of bio-pharmaceutical and genetic, cell, tissue and regenerative and nano-medicine based therapies including third generation tissue scaffolds.
- Sensor, instrumentation, measurement, characterisation and control techniques and systems for the above mentioned, including bio-chips and laboratory on a chip technology.

The expected outputs are: new generations of products and manufacturing processes, new business models and methods for delivering these products, and instrumentation and characterisation systems for these emerging products.

2.7.4. Disruptive Factory: "Bio-cogno-ICT" convergence

The modern scalable, adapatable, responsive manufacturing enterprise, the so called factory, has to be supported along its life cycle phases by the newest convergent technologies, mainly by bio-, cogno- and ICT. So, it is "cognitive" at all its scales (network, manufacturing system…), by embedding elements of technical, social and distributed cognition. It has to be "consciously clean" by an employment in critical phases of the environmental technologies. The enabling ICT technologies, like autonomous computing, ambient intelligence, or web-services, are still far from meeting this challenge as the only ones of the manufacturing industries. A new engineering approach is required, having as a main foundation the conventional and new manufacturing technologies, and as pillars, the nano-, bio-, cogno- and information and communication technologies, which converge enabling each other in the pursuit of this common goal: to make the envisioned "next generation, conscientious clean disruptive factory" real. This new engineering approach bases on concepts and methods from the interdisciplinary field of cognitive science, mainly represented by artificial intelligence, mechanical and electrical engineering, biology, cybernetics, psychology, linguistic, neuroscience, social sciences and philosophy. The employment of convergent technologies disrupts the traditional way of approaching the factory, in its economic sense, by enhancing it with the "disruptive" feature.

The *main objective* is to harmonise cogno-, bio- and ICT, under the orchestration of manufacturing technologies for developing innovative concepts, models and various implementations of the main issues of technical, social and distributed cognition in different socio-technical environments, mainly focusing on the manufacturing systems or factories. New concepts and paradigms for "cognitive technical spaces", adaptability, safety engineering, usability, scalability, robustness and technology acceptance etc. are proposed to support sustainable development of the European manufacturing sector. The planned research activities lead to *overall design processes and generic models* that are used in all application areas.

The research activities are conducted to develop concepts, models and methodologies/tools for design and manufacturing networks of cognitive manufacturing machines, such as prototypical implementations of robust and adaptive cognitive manufacturing systems for the following application areas: design of cognitive assistant systems, products such as cognitive cars and cognitive traffic control, cognitive robots, machine tools and production control, cognitive systems for domestic and organisational environments.

The main research areas which serve as a fundamental basis for achieving these concrete goals, the design and construction of several instantiations of cognitive technical systems are:

- Technical, Social and Distribution Cognition,
- Modelling, Simulation and Prototyping of Cognitive Systems,
- Human and Machine Learning in Cognitive Systems,
- Communicating, Perceiving and Acting in Networks of Technical Systems,
- Cognitive Systems, Safety, Reliability, Security and Comfort Engineering.

Deliverables will take the form of prototypical implementations of the "Disruptive Factory" in industrial settings, in order to prove the migration of the new paradigm in the real manufacturing industry. The pilot prototypes would represent a valuable incentive for the private sector of investment.

3. Manu*future* Research Areas. Mappings and Deployments

3.1. Mapping of Manu*future* Research Topics to European Manufacturing Clusters

The Manu*future* topics presented in the above Chapter are characterised by their specific relevance for the European industrial sectors. In the vision of Manu*future*, the 25 sectors are structured according two main groups, further on called European Manufacturing Clusters. The first cluster, entitled Manufacturing of Investment Products represents the demand of RTD issued from all industries structured in 6 sub-clusters, as in the left side of the Figure 8 is presented. The new and innovative solutions resulted as output of the RTD activities performed in all European research institutions and organisations have to be implemented in the second cluster, called Manufacturing of Products, consisting of 6 groups of industries, formed as in the same Figure 8 on its right side is showed. All Manu*future* research topics give reality, through their development and after then implementation, to the envisioned European Production System represented by the new industrial paradigm “Factories as Products, which are adaptive, digital, knowledge-based and networked around the whole Europe”.

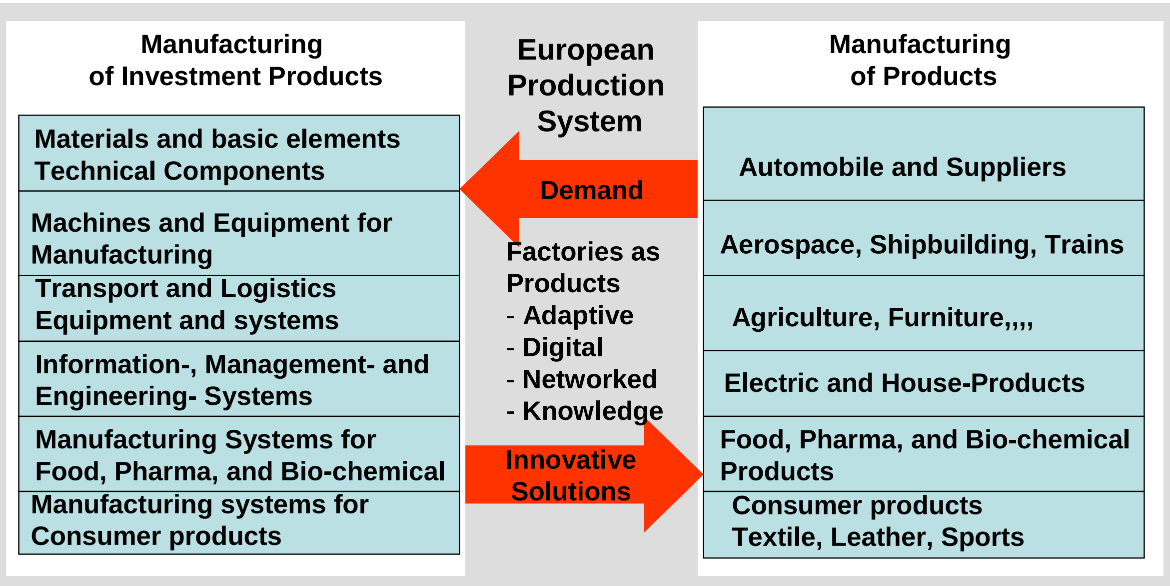

Figure 8. Mapping Manu*future* Research Topics and European Manufacturing Clusters

In the following figures, respectively Figure 9 and Figure 10 the relevance of the topics are highlighted according three levels of relevance as follows: green represents the high relevance, yellow a medium one and white a normal relevance.

Relevance of the Manufuture Research Topics for the European Manufacturing Clusters	Materials and basic elements Technical Components	Machines and Equipment for Manufacturing	Transport and Logistics Equipment and systems	Information-, Management- and Engineering- Systems	Manufacturing Systems for Food, Phama, and Bio-chemical	Manufacturing systems for Consumer products	Automobile and Suppliers	Aerospace, Shipbuilding, Trains	Agriculture, Furniture,,,,	Electric and House-Products	Food, Pharma, and Bio-chemical Products	Consumer products: Textile, Leather, Sports
1 New Business Models												
1.1. European answers for Production System												
1.2. European management system												
1.3. Innovative management models, methodologies and tools												
1.4 Service and consumer-oriented business models												
2. Adaptive Manufacturing												
2.1. Adaptive Factories												
2.2 Adaptive production systems, machines and processes												
2.3. Intelligence for enhanced processes												
2.4. Adaptive tools and components												
3. Networking in Manufacturing												
3.1. Innovative strategies for networked manufacturing												
3.2. Real-time logistic networks												
3.3. Knowledge-based and adaptive networked manufacturing												
3.4. Networked manufacturing services												

Figure 9. Relevance of the Manu*future* Research Topics for the European manufacturing Clusters (I)

Relevance of the Manufuture Research Topics for the European Manufacturing Clusters	Materials and basic elements Technical Components	Machines and Equipment for Manufacturing	Transport and Logistics Equipment and systems	Information-, Management- and Engineering- Systems	Manufacturing Systems for Food, Phama, and Bio-chemical	Manufacturing systems for Consumer products	Automobile and Suppliers	Aerospace, Shipbuilding, Trains	Agriculture, Furniture,,,,	Electric and House-Products	Food, Pharma, and Bio-chemical Products	Consumer products: Textile, Leather, Sports
4 Digital, Knowledge-Based Engineering												
4.1 Sustainable digital factories and products: design, modelling and prototyping												
4.2 Virtual Factory simulation and operation												
4.3 Real-time (Smart) Factory Management												
4.4 Process modelling, simulation and management												
5 Emerging Technologies												
5.1 Environmental and energy technologies												
5.2 Performance and efficiency oriented technologies												
5.3 Advanced materials engineering												
5.4 Product-oriented technologies												
6 ICT for Manufacturing												
6.1 Configuration systems: customisation of products and services to the market requirements												
6.2 Digital libraries and contents for engineering and manufacturing												
6.3 Networked multimodal collaboration in manufacturing environments												
6.4 Manufacturing control systems for adaptive, scalable and responsive factories												
6.5 Computing systems and embedded platforms for advanced manufacturing engineering												
6.6 Pervasive and ubiquitous computing for disruptive manufacturing												
6.7 Grid Manufacturing: advancement of Grid Computing for manufacturing purposes												
7 Exploitation of Convergence of Technologies												
7.1 Next-generation HVA Products												
7.2 Education and training in "Learning Factories"												

Figure 10. Relevance of the Manu*future* Research Topics for the European manufacturing Clusters (II)

3.2. Time Deployment and Prioritisation of the Manu*future* Research Topics

The Manu*future* Research Topics have been investigated regarding their deployment on a scale time, respectively 7 years, by giving those priorities and relevance for the identified targets of each research area as established in the Manu*future* Research Agenda – SRA (e.g. New Business Models, Adaptive Manufacturing, etc.)

The Figure 11, Figure 12, Figure 13 presents the deployment in time and the corresponding prioritisation of the New Business Models research area. The area targets are as follows: New Taylor, Economically sustainable manufacturing, Zero defect manufacturing and Holistic manufacturing. The prioritisation is highlighted, as in all cases, by combining and harmonising the corresponding colours of each target.

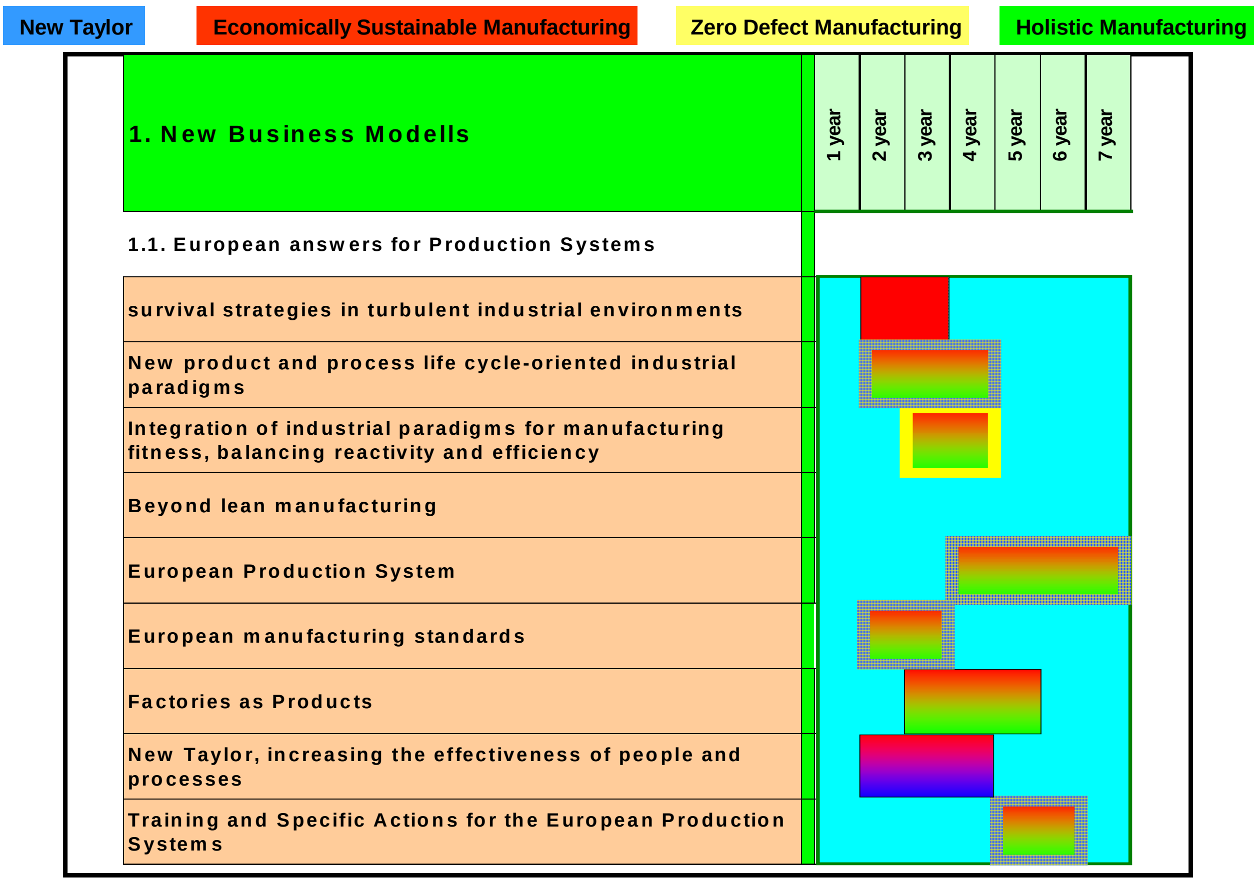

Figure 11. Time Deployment and Prioritisation of the New Business Models Research Topics (I)

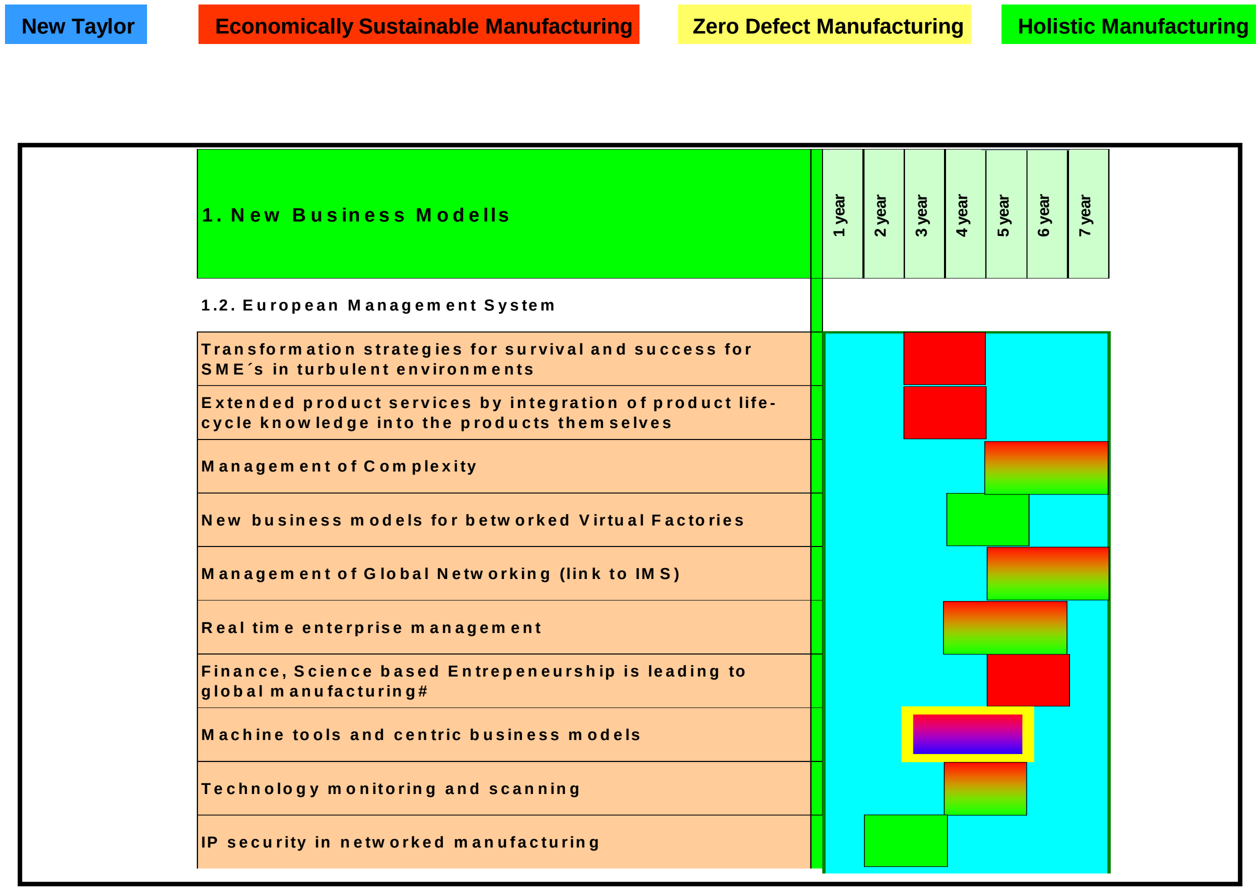

Figure 12. Time Deployment and Prioritisation of the New Business Models Research Topics (II)

New Taylor | Economically Sustainable Manufacturing | Zero Defect Manufacturing | Holistic Manufacturing

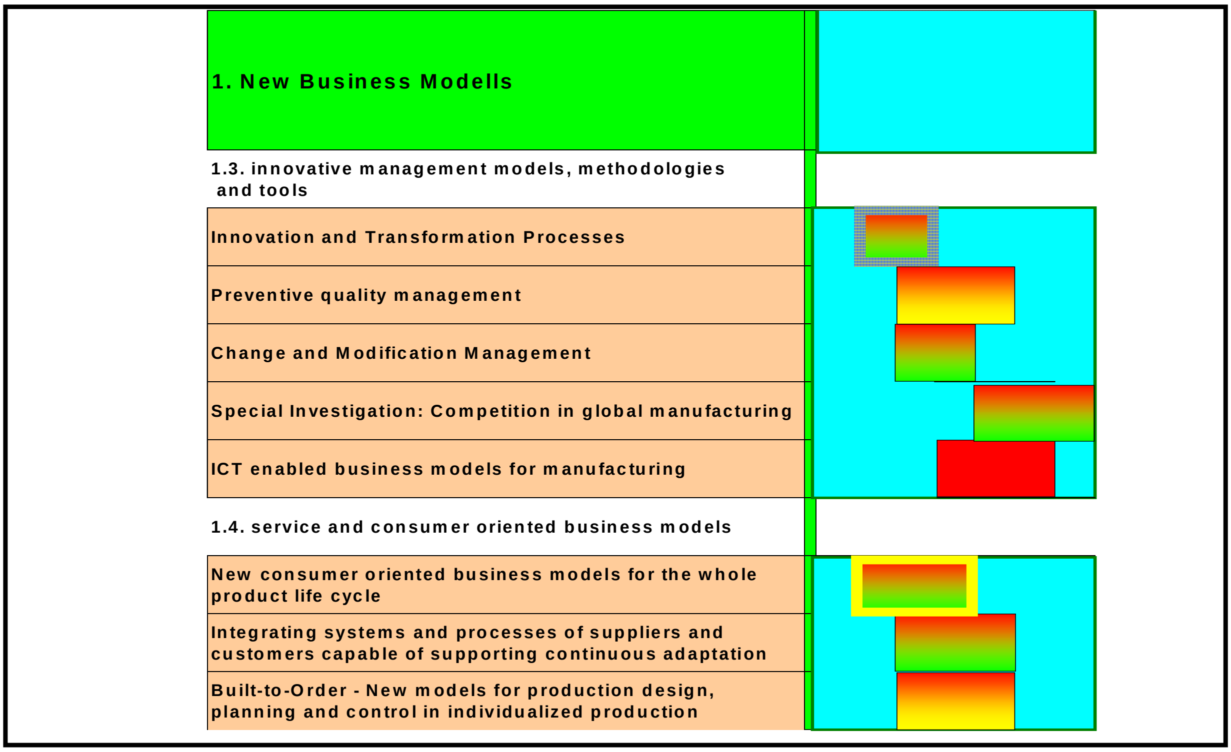

Figure 13. Time Deployment and Prioritisation of the New Business Models Research Topics (III)

The research area Adaptive Manufacturing deploys its topics and shows their prioritisation in the Figure 14 and Figure 15, according the same rule as in the case of New Business Models area. The area targets are mentioned in the figures, as well.

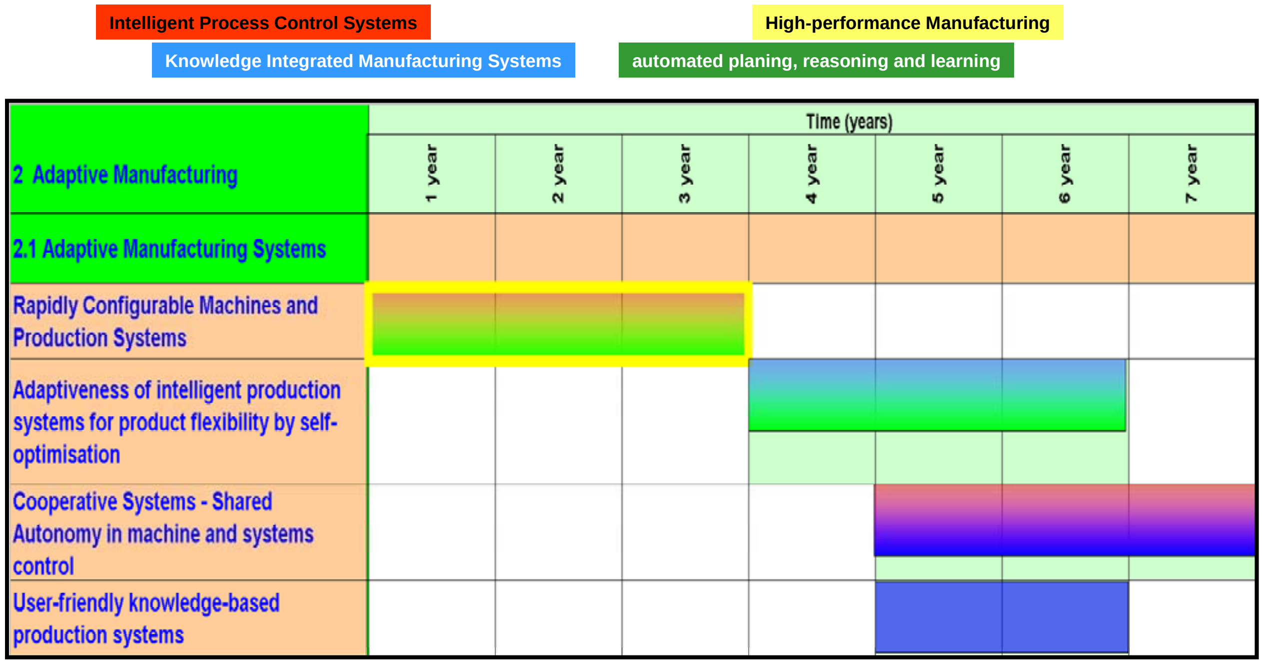

Figure 14. Time Deployment and Prioritisation of the Adaptive Manufacturing Research Topics (I)

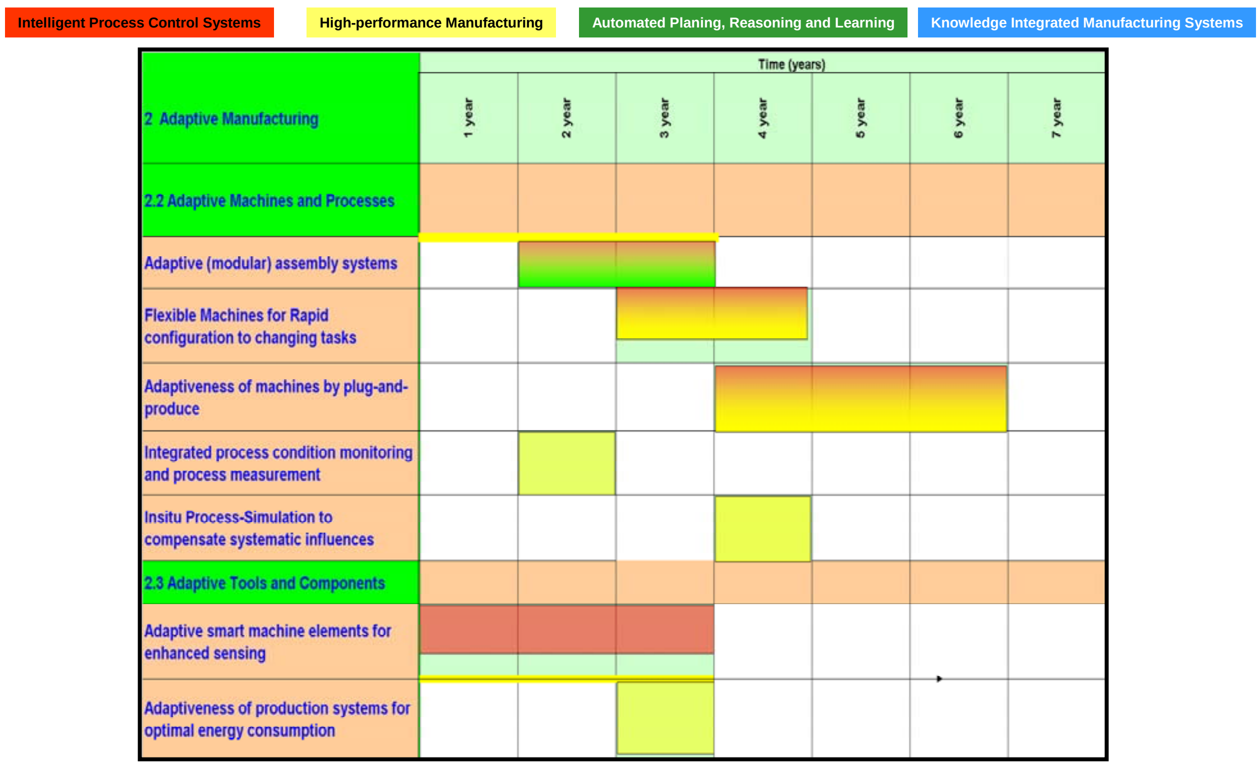

Figure 15. Time Deployment and Prioritisation of the Adaptive Manufacturing Research Topics (II)

The research area Networking in Manufacturing is represented in the Figure 16 and Figure 17. The rule of time distribution and application and the prioritisation follow the same rules as above presented.

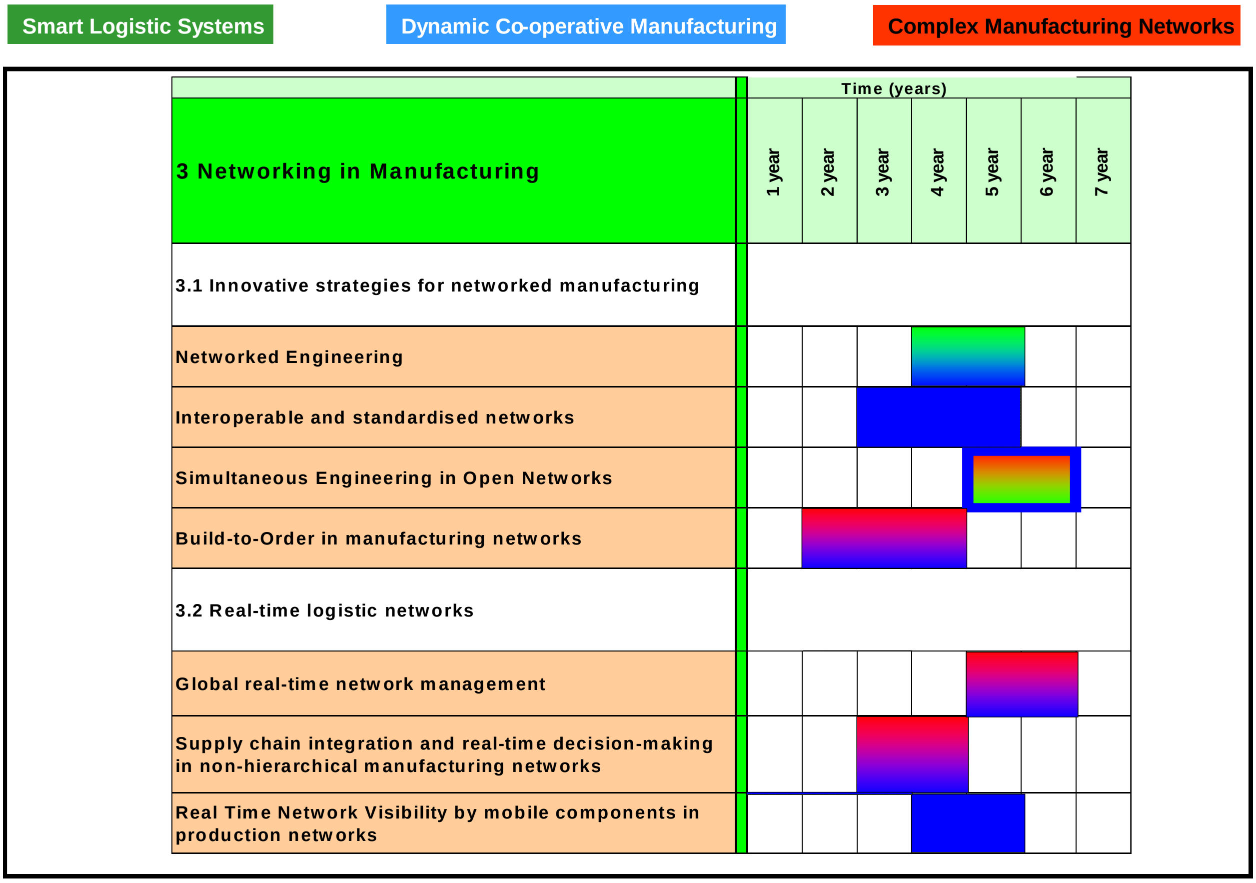

Figure 16. Time Deployment and Prioritisation of the Networking Manufacturing Research Topics (I)

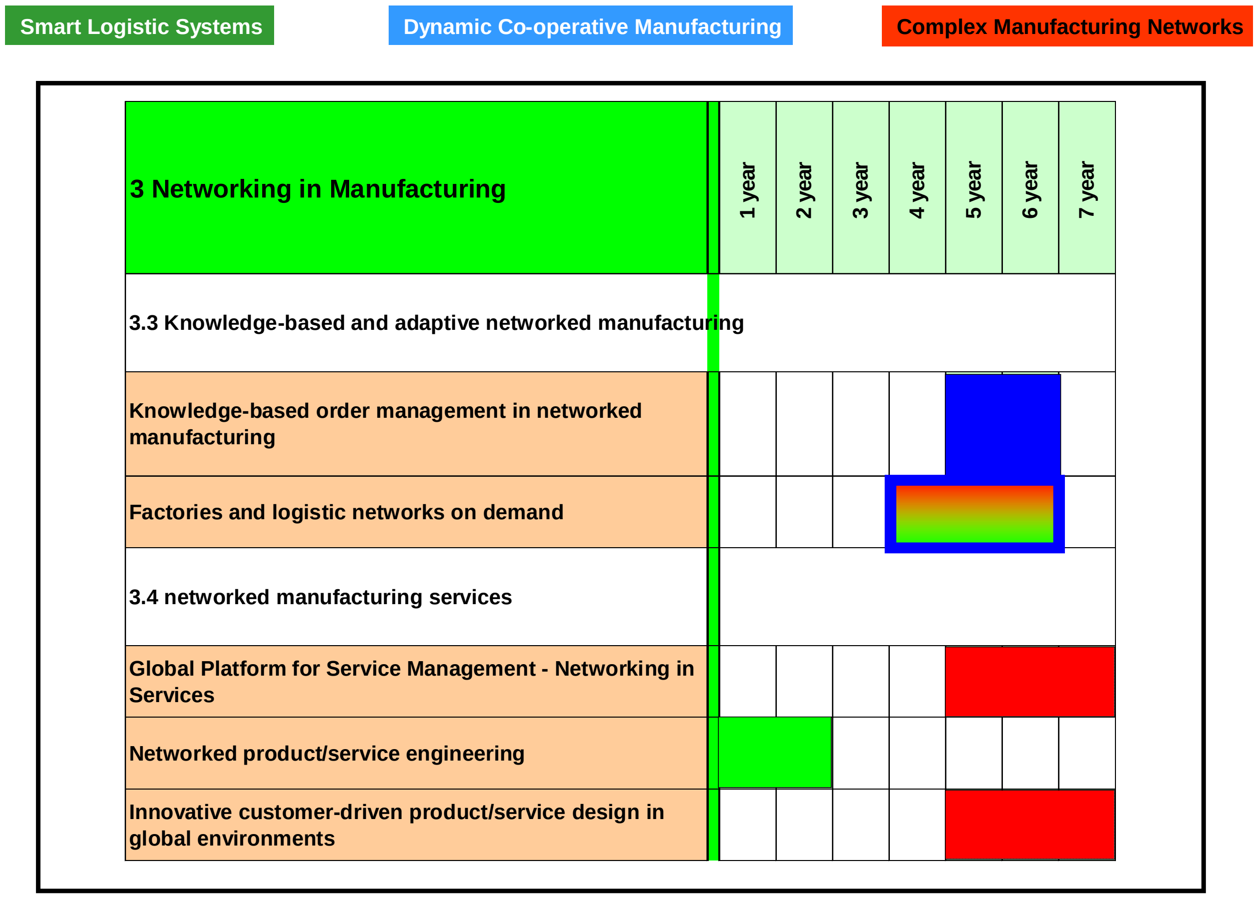

Figure 17. Time Deployment and Prioritisation of the Networking Manufacturing Research Topics (II)

The research topics of the area Digital and Knowledge-based Manufacturing are planned to be implemented on the time scale according their own priorities related to the identified targets as drafted in the Figure 18, Figure 19 and Figure 20.

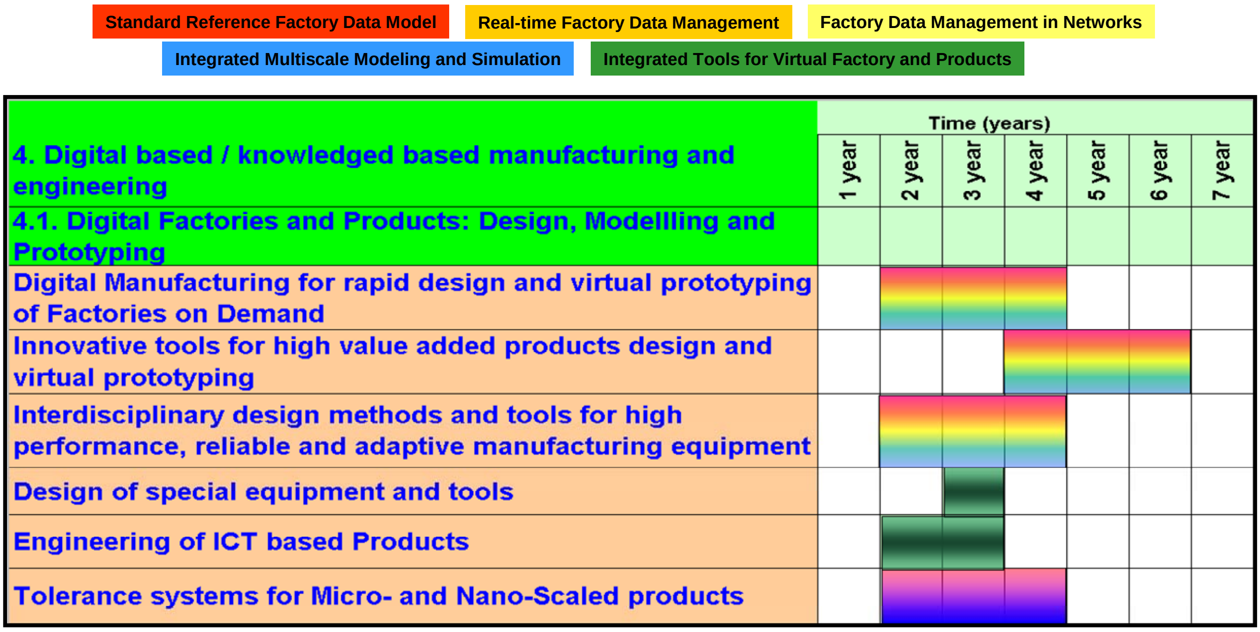

Figure 18. Time Deployment and Prioritisation of the Digital and Knowledge Research Topics (I)

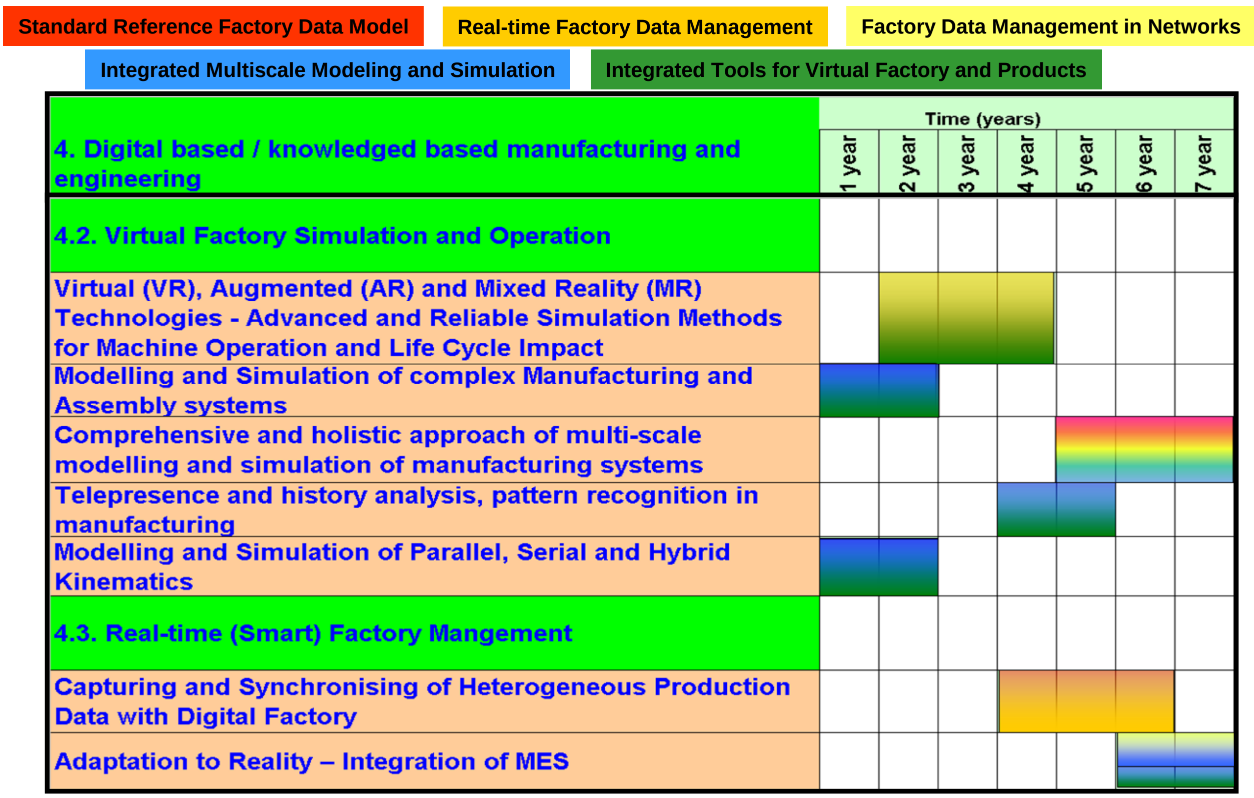

Figure 19. Time Deployment and Prioritisation of the Digital and Knowledge Research Topics (II)

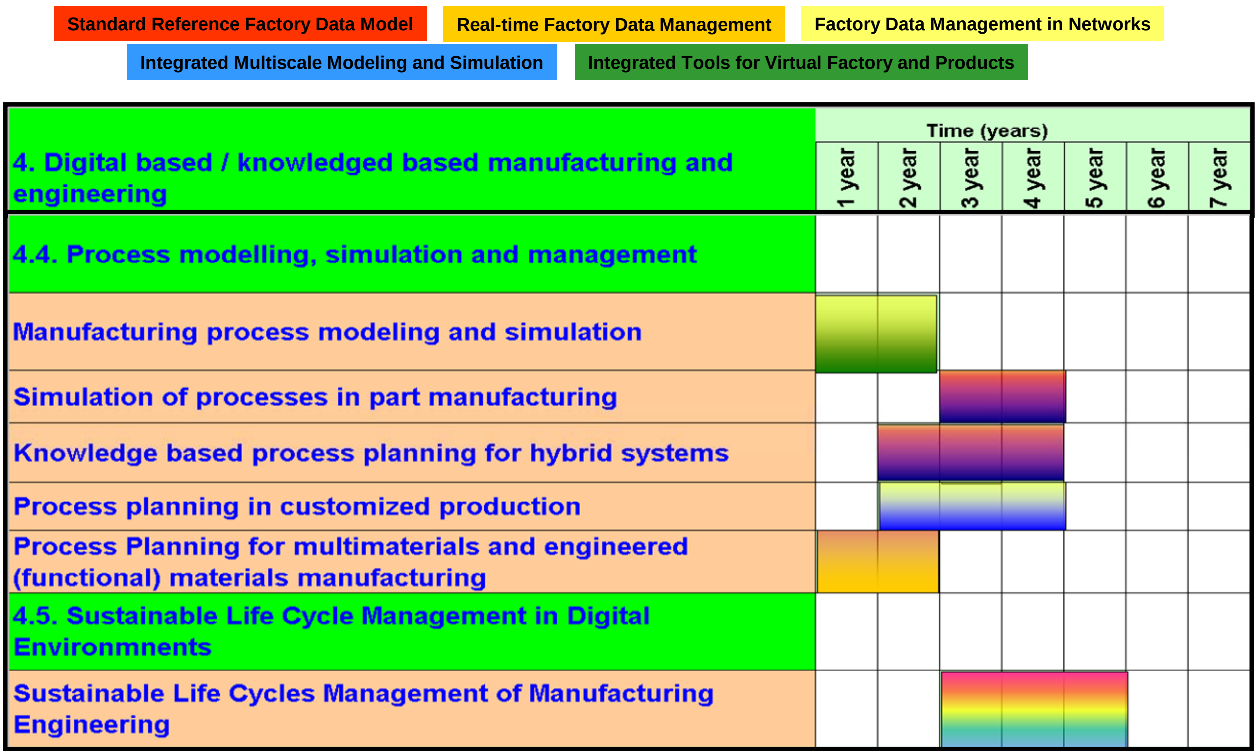

Figure 20. Time Deployment and Prioritisation of the Digital and Knowledge Research Topics (III)

The Emerging Technologies Research Area is presented in the Figure 21, Figure 22 and Figure 23, according the time horizon and prioritisation according the relevant targets.

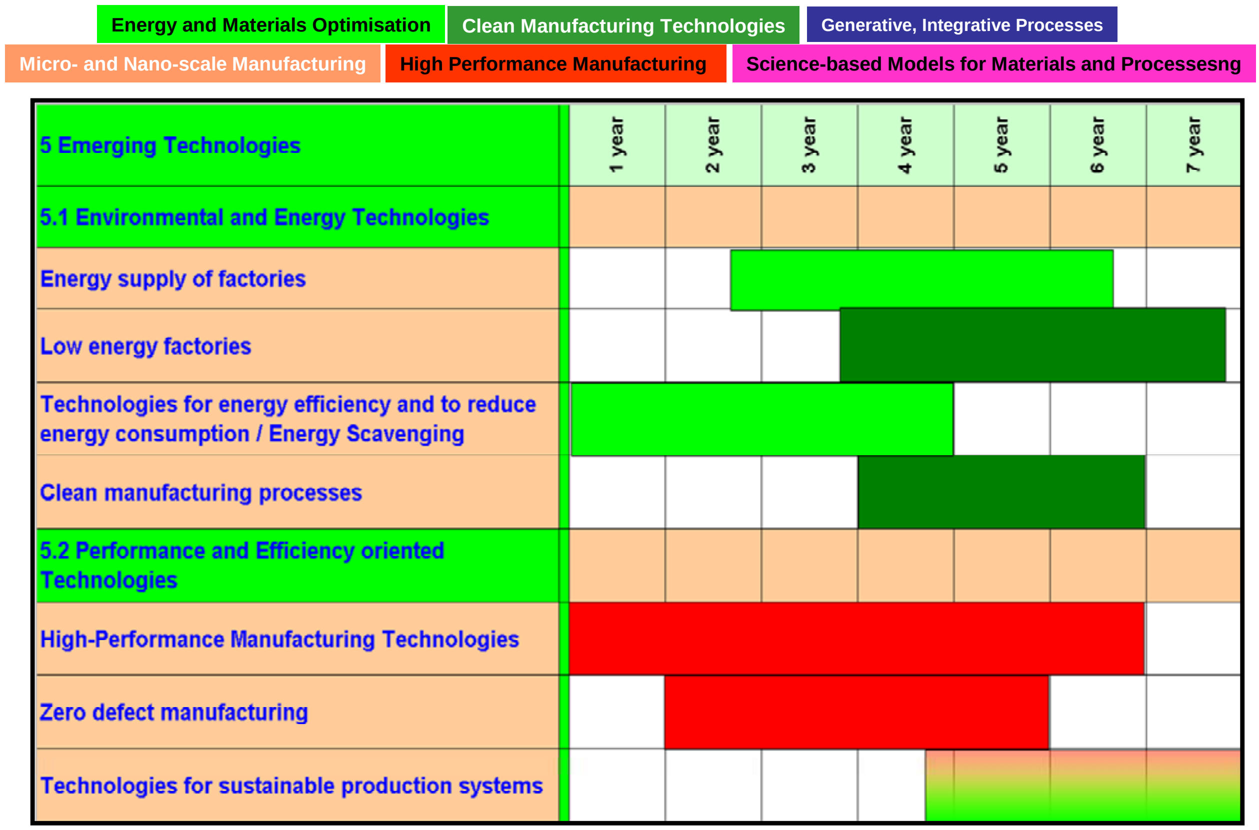

Figure 21. Time Deployment and Prioritisation of the Emerging Technologies Research Topics (I)

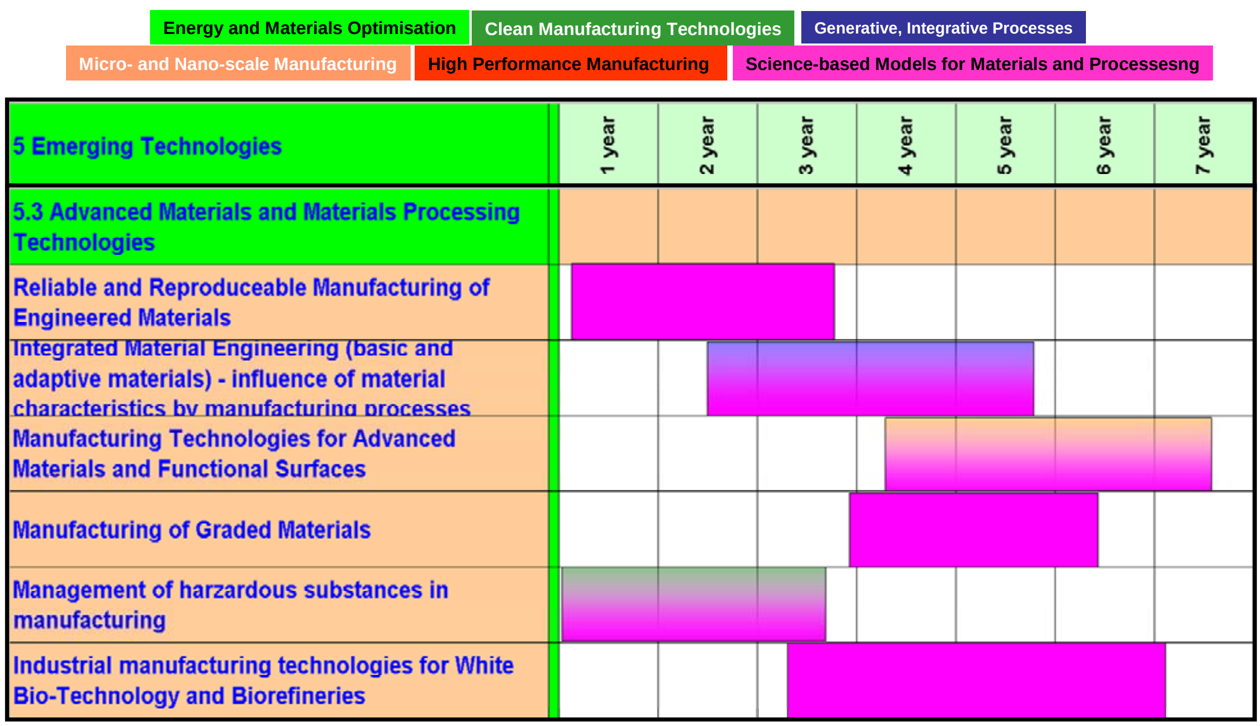

Figure 22. Time Deployment and Prioritisation of the Emerging Technologies Research Topics (II)

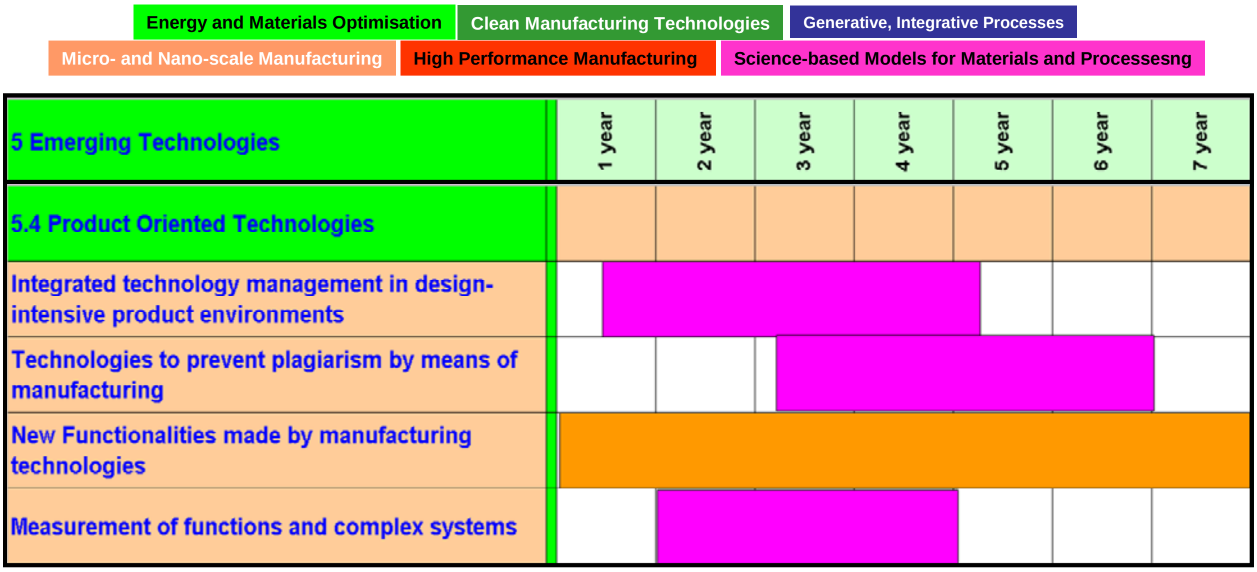

Figure 23. Time Deployment and Prioritisation of the Emerging Technologies Research Topics (III)

3.3. ANALYSIS OF IMPACT INTENSITY BETWEEN TRANS-SECTORAL TECHNOLOGIES AND SECTORS

The analysis of the relevance of the pillar roadmap: trans-sectoral push & pull technologies by sectoral demand is reported in the Annex.

The purpose of cross-referencing RTD Areas and industrial sectors is to assess the impact level of trans-sectoral technologies on sectors.

The starting points are, on one side, the domain of RTD Areas and, on the other side, the collection of sectoral roadmaps.

1. The first step is to examine each sectoral ***roadmap*** and point out its ***targets***.
2. Second, these targets are more deeply analysed to better catch its ***technological content*** and its ***time horizon*** and then connected to one or more ***RTD Areas*** for the same ***time horizon***.
3. From steps 1 and 2 a sectoral cross-reference is built between ***targets*** and ***RTD Areas*** by ***year***.
4. From such table, results are then aggregated through the ***targets***, leading to a simpler cross-reference between ***sector*** and ***RTD Areas*** by ***year***, while taking into account the weight of the elementary cross-referencing.
5. Finally, a global cross-reference is built of RTD Areas, Sectors, years and relationship status.

4. RECOMMENDATIONS FOR IMPLEMENTATION OF KNOWLEDGE-BASED FACTORY AS A PRODUCT

According to the Manu*future* Strategic Research Agenda principles – framed in Italics - after the extensive and joint roadmapping work, the Leadership SSA Consortium main indications are reported in blue:

The Multi-level action

Attaining the objectives of the Lisbon and Barcelona Councils will only be possible by involving the largest possible number of stakeholders. In this context, the benefit of cooperation between Manufuture 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 Manufuture concepts and results, together with assessing a common "core" of business or areas of interest.

At European level

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

- Sectoral European Technology Platforms such as in road transport, construction, aerospace, textile, food, etc.

- Trans-sectoral ETPs such as in industrial safety, micro-nano-technologies, rapid manufacturing, etc.

- Enabling technologies ETPs such as in embedded systems

First recommendation is that these Roadmaps define an all-inclusive strategic research agenda taking into account Europe's overall manufacturing needs from sectoral, trans-sectoral and enabling technologies viewpoints.

These Roadmaps may represent the trans-sectoral "deliverables" – cited by the Manu*future* SRA – able to "*represent the common starting point for the activities of the other TP's at National/Regional level to address specific vertical needs*".

At National/Regional level

National Technology Platforms related to the Manufuture European Technology Platforms …..At the end, a coordinated effort at all levels is working with the aim of defining the manufacturing research priorities and committing to make it happen. Aligning the development goals and priorities of all 25 Member States is therefore crucial in building a common interest in close co-operation between production companies and R&D organisations as a foundation for expansion into global markets.

The second recommendation is that these Roadmaps require to involve National and local initiatives, particularly in the new Member States.

At SME level

Another stakeholder group of outstanding importance is the innovative SMEs and other independent enterprises, which figure largely in the structure of all manufacturing sectors.

SME's are main players in several sectors, capable to develop, produce and sell innovative products and services to more and more demanding consumers. In others, they are linked in diverse networks with OEMs in the value chains

The third recommendation is that SMEs participation ensures integration activities engaging them in a long term partnerships across Europe. They need access to research organizations and make use of research results and human resources. These roadmaps imply to reinforce the reliability of the manufacturing critical infrastructure for quick transfer of research results to marketable products.

Favourable climate

A consensus of support for the Manufuture vision will naturally enable the creation of a European Manufacturing Innovation and Research Area (EMIRA) as an integral part of the European Research Area

The fourth recommendation is that Roadmapping needs continuous foresight and roadmapping as a rolling process involving the major communities of European researchers. This means to reinforce and support the anticipatory work together with the monitoring of industrial technologies deployment and diffusion for the benefit of the integration in the sectors industries.

New paradigm needed

The current industrial paradigm is no longer adequate to meet these needs. …..However, certain industries are physically tied to the European region.

The fifth recommendation is that R&D in manufacturing must also support along the Roadmaps trajectories the continuous productivity and efficiency gains in order to maintain the competitiveness of the European industries.

A roadmap for industrial transformation
Appropriate knowledge-based solutions can be derived using the industrial transformation reference model shown in Figure 2, and research areas and targets be prioritised on the basis of criteria such as the expected value addition. …the approaches used and the results obtained can be transferred to sectoral domains, according to their specific needs.

The sixth recommendation is that a concerted multi-level early take-up of the Roadmaps' KEY Horizontal RTD elements of this 'new environment' - throughout EU industry - will be the Response to sustainable competition in worldwide markets.

5. CONCLUSIONS

The needs and demands of European manufacturing industry, confronted with today’s challenges of increasing competitiveness, globalisation, continuous change and transition of industries, can be fulfilled best with the following strategic priorities:

1. Survival & Re-positioning by innovative Production Systems
2. Technological Leadership & Re-inventing Business (New Business Models)
3. Global Market Expansion
4. Leadership in New Emergent Sectors

To develop the required approaches in support of the European Manufacturing Industry’s transition towards higher levels of international competitiveness and sustainability, the SSA LEADERSHIP has jointly defined and developed:

- a roadmapping approach and framework to develop roadmapping actions and related activities for European manufacturing
- sectoral roadmaps for the 25 most relevant European industrial sectors and their related manufacturing technologies
- the Manu*future* workprogramme “New Production” offering 105 innovative trans-sectoral manufacturing research topics and technologies based on 350 fact sheets
- an orientation towards tomorrow’s positioning of European manufacturing in support of the European Technology Platforms
- strategic recommendations how to implement Manu*future* in Europe

Some of the most important priorities from the developed Manu*future* workprogramme “New Production” with industrial trans-sectoral perspective are:

- New Industrial paradigms for management of manufacturing
- Management to survive in critical situations: low technologies
- New Taylor: The role of workers and new methodologies
- “Factories are Products”: System technologies for Manufacturing
- Innovation and Transformation Process: “The learning factory”
- Customer oriented business models
- Requirements for standards and IP security
- Adaptive – intelligent assembly of complex and customised products
- Smart machine elements: “Smart Factories”
- Build-to-order: customisation
- Interoperable Production Networking: regional synergies
- Digital factories: Factory Data Management
- Engineering of ICT in manufacturing systems: Engineering of automation

- Tolerancing of micro-systems (standards)
- Multi-scale Modelling and Simulation of Manufacturing Systems and Processes
- Process Planning of multi-functional materials and engineered materials
- Energy efficient production
- High-performance technologies
- Management of hazardous substances

Important recommendations from the Leadership SSA Consortium to facilitate the implementation of the manufacturing workprogramme towards Manu*future* - as outlined in full detail in the previous chapter - are:

- The Manu*future* roadmaps represent a common starting point for the activities of all other TP's at National/regional level to address specific vertical needs.
- The implementation of roadmaps requires National and local initiatives involvement, particularly in the new Member States.
- SMEs need direct access to research results and human resources of research organizations in order to assure quick transfer of research results to marketable products and innovative processes across all sectors.
- Roadmapping needs continuous foresight and monitoring of industrial technologies deployment as an ongoing process involving the major communities of European research.
- R&D in manufacturing must support along the roadmaps trajectories the continuous productivity and efficiency gains in order to maintain the competitiveness of the European industries.
- Sustainable competition of European industries in worldwide markets will only be achieved by concerted multi-level actions implementing the 'KEY Horizontal RTD Elements' – as identified by the Manu*future* roadmaps.

The presented results of the SSA Leadership workpackage WP2, *Roadmap Development*, will be taken over and further detailed by the sub-sequent Leadership workpackages WP4, *Implementation*, and work package WP5, *Dissemination*.

In this context, the further discussion and dissemination of the developed Workprogramme "New Production" together with invited representatives of the European Technology Platforms is planned to be held still this summer during a Roadmapper' s Conference organised by the Leadership Consortium.

Furthermore, it is intended to publish major parts of the developed Manu*future* workprogramme "New Production" in consensus with the Commission and the Leadership partners in form of a booklet publication.

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- LBORO – Loughborough University
- CETIM - Centre Technique des Industries Mécanique
- INESC-Porto – Instituto de Engenharia de Sistemas e Computadores do Porto
- CECIMO - European Committee for Co-operation of the Machine Tool Industries
- CAMT - Wroclaw University of Technology
- Fundación FATRONIK
- VDMA - Verband Deutscher Maschinen- und Anlagenbau e.V.
- AGORIA

✓ Partners' Roadmappers from the above organizations:

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Carlo Brondi	CNR ITIA
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Daniele Dalmiglio	CNR ITIA
Cecilia Lalle	CNR ITIA
Giacomo Liotta	CNR ITIA
Augusta Maria Paci	CNR ITIA
Francesco Paolucci	CNR ITIA
Marco Sacco	CNR ITIA
Francesca Tiberi	CNR ITIA
Ricardo Bueno	Fatronik Fundacion
Engelbert Westkämper	FhG IPA
Carmen Constantinescu	FhG IPA
Stefanie Germer	FhG IFF
Jacqueline Görke	FhG IFF
Daniel Reh	FhG IFF
Barbara Schenk	FhG IFF
Ulrich Schmucker	FhG IFF

Antje Tiefenbach	FhG IFF
Bernd Hellingrath	FhG IML
Sven Krause	FhG IML
Markus Witthaut	FhG IML
Pater	FhG IML
Michael Eisele	FhG IPA
Michael Hoepf	FhG IPA
Harald Holeczek	FhG IPA
Christoph Schaeffer	FhG IPA
Wolfgang Schäfer	FhG IPA
Siegfried Stender	FhG IPA
Philip Elsner	FhG IPK
Pavel Gocev	FhG IPK
Markus Rabe	FhG IPK
U. Rothenburg	FhG IPK
Kristian Arntz	FhG IPT
Jörg Frank	FhG IPT
Christoph Neemann	FhG IPT
Sebastian Nollau	FhG IPT
Lars Georgi	FhG IWU
H.-J. Koriath	FhG IWU
Ralf Lang	FhG IWU
Frank Treppe	FhG IWU
Sylke Palitzsch	FhG UMSICHT
Hartmut Pflaum	FhG UMSICHT
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Ricardo Madureira	INESC-Porto
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Paul Hourd	Loughborough University
Kathryn Walsh	Loughborough University
David Williams	Loughborough University
Claudia Rainfurth	VDMA

✓ Among all industries, we interviewed the following ones either individually or in the course of workshops:

ADIRA
APRILIA-PIAGGIO spa
ARCELOR Innovation
Audi AG
AUDI Werkzeugbau
BASF AG
Bayer Technology Services
Buchan Concrete Pods
CAF - Construcción y auxiliar de ferrocarriles SA
CALIBERG
CAMOZZI spa

Caterpillar Inc.
Ceramtec
CLEPA
COGEMOULE
COMAU spa
Corus
DaimlerChrysler
Danfoss
Danonrail
DECHEMA e.V.
Deckel Maho Gildemeister Service
Degussa AG
DELMIA
Dematic
DFG Deutsche Forschungsgemeinschaft
Drent Goebel Darmstadt (SME)
DUARTE
Fachvereinigung Organische Chemie im VCI
Feinkäserei Hochland GmbH
Fiat
FIDIA spa
FILANTO spa
FINMECCANICA spa
Fleissner GmbH&Co.
FORNARI spa
GE Healthcare
GEMS GEMSTAR S.r.l.
Gillette Gruppe Deutschland GmbH & Co.oHG
GSK
Heidelberg Cement
Heidelberger Druckmaschinen AG
Hilti Corp.
Hipp GmbH & Co. Vertrieb GmbH
HOFMANN Werkzeugbau
IBEROMOLDES
Imerys
Indumetal
Innse-Berardi Spa
Intercytex
IRUMOLD
ITALIAN CONVERTER spa
JCB
JOBS spa
Karl Mayer GmbH
Koenig & Bauer AG
KOVINOPLASTIKA LOZ
K-Panels
Krones AG
Lafarge
Leitz GmbH & Co. KG
Lindauer Dornier GmbH
LN MOLDES
MAN Roland Druckmaschinen AG
MANDELLI spa
MARES
Marzoli
Mayer & Cie GmbH & Co.KG
MCM spa
MECANOPLASTICA

Meggle GmbH
MOLDOPLASTICO
MORBIDELLI spa
Nobel Biocare
Océ Printing Systems GmbH
ORTIM
Outokumpu Oyi
Parametric Technology Comp. PTC
Phoenix Feinbau GmbH & Co. KG
PRIMA INDUSTRIE spa
Printed systems GmbH (SME)
PSI Manufacturing
PTS Paper Technology Specialists
Raps GmbH & Co.KG
Rieter
Riva Group
ROBOPAC
ROMAGNANI
Sächsisches Digitaldruck Zentrum GmbH (SME)
Saint-Gobain
Sanofi Aventis
SAP
Saurer GmbH&Co.KG
SCHNEIDER-FORM
Schott
SCM spa
SERMO
Siemens Dematic
SIMOLDES
SOMEMA
Stoll GmbH & Co. KG
Stora Enso
Talgo
TAP
TECTURA/ Microsoft Business Solution
Tetra Pak Processing GmbH
ThyssenKrupp AG
ThyssenKrupp Automotive
ThyssenKrupp Stahl AG
TORRIANESE PANNELLI srl
Trützschler GmbH&Co.KG
UGS TECNOMATICS
UPM Kymmene
Vanderlande
Villeroy & Boch
Voestalpine Stahl GmbH
Voith Paper
VSM AG
Weihenstephan Research Technology Center
Westfalia Separator FoodTec GmbH
WH Smith & Sons
WMF Württembergische Metallwarenfabrik AG
Yorkon
Zott GmbH&Co.KG
ZSK Stickmaschinen GmbH