Road 4 FAME

Deliverable 2.3

Report on Socio-economic Developments

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PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
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[1] **R**=Report, **P**=Prototype, **D**=Demonstrator, **O**=Other

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1 Executive Summary

Context and content of this document

This *report of socioeconomic developments* presents an overview of *trends* which can be considered to be relevant to the manufacturing domain, and which may act as *drivers* in the sense that they drive developments in the manufacturing domain and have an influence on the *needs* in the manufacturing domain.

Relevance of this document

The trends and drivers presented in this document provide the foundation for establishing the *pull perspective* in Road4FAME. Knowledge of these trends and drivers is important because they have a direct influence on the *needs* of manufacturing businesses in Europe, with which the Road4FAME roadmap must be aligned.

Approach

The overview of trends and drivers was established from screening relevant strategy documents (see Annex I). Trends and drivers are presented in three groups: i) General megatrends identified in strategy documents which do not have a specific manufacturing focus, ii) manufacturing-relevant megatrends identified in strategy documents which have a manufacturing focus, and iii) manufacturing trends which are taking place *within* the manufacturing domain or which have an *immediate effect* on the manufacturing domain. All trends have been prioritised according to their appearance throughout these documents, and their order within this document has been derived respectively.

For each trend or driver, considerations on implications for IT architectures and servicesare presented.

Overview of content

The table on the following pages gives an overview of the trends and drivers with relevance to the manufacturing domain (i + ii). The relevance of IT architectures and services to address them has been indicated as follows:

- Grey: no relevance
- Yellow: Relevant, but not important or challenging
- Green: Important and challenging

Trend/Driver	Impact	Relevance of IT Architectures	Relevance of IT Services	Time-scale[3]
Manufacturing-relevant megatrends				
Demographic change	Ageing workforce	Support mobility	Assisting services etc.	SoA-L
Globalisation	Distribution of manufacturing sites	Architectures & Interfaces to support SC configuration & integration	Support for design & management of production networks	SoA-M
Innovation and new technologies	Acceleration of new technology adoption, new business opportunities	-	-	S
Knowledge as enabler	Manage workforce knowledge, knowledge-driven product development and production optimisation	Architecture to support access to and distribution of knowledge	Services for knowledge management and exploitation	SoA-M
Slow innovation & underinvestment in R&D	Long time-to-market	-	-	SoA
Language barriers & cultural differences	Communication issues in (global) manufacturing networks	Architectures supporting communication services	Services for seamless communication	SoA-M
Rise of environmental consciousness	Resource efficient manufacturing	Architectures for access to resource consumption data and related information exchange	Services for resource management, traceability and certification of products and production, etc.	SoA-M

[3] SoA = State of the Art, the trend is in effect today
S = Short term, the trend is expected to emerge soon
M = The trend is expected to emerge within a medium-term time period
L = The trend is expected to emerge within a long-term time period
V = Vision, the trend is expected to emerge in the far future

Manufacturing trends (related to market and business models)				
Demand for individualisation and high quality standards	Cost-efficient production of individualised products	Flexible and reconfigurable production systems; Interfaces for customer involvement	Services to support customisation, transfer of product specifications to manufacturing, and related production control	S-L
Optimisation and decision making	Increase competitiveness, faster reactions / optimisation responding to changing environment conditions	Enable information gathering and control in (distributed) production systems	Services for real-time data mining, pattern recognition, decision making, forecasting, etc.	S-M
Shortage of skilled staff	Appropriate education of workers and management of workforce knowledge	-	Services for knowledge management, education support, etc.	SoA-S
Increasing demand for products & services	Increasing market volumes for products and services	Enable access to market-specific knowledge, consider market-specific production network set-ups	Support collection and analysis of customer expectations, emerging trends, etc.	SoA
Increasing complexity of products, processes, supply networks	Modularisation of products and production, Complexity management and usability	Architectures to enable easy configuration and management of complex systems	Supportive services for complexity management, self-X, etc.	SoA
Enhancement of products by embedded IT and integrated services	Products supporting production processes, Extended lifecycle information, Added value for customers	Integration of products to factory IT environment and after-sales data acquisition	Services provided by products, Supportive services for manufacturing	SoA-L
Shorter product lifecycles	Frequently changing manufacturing environments, Improved product lifecycle management processes, Implementation of service-based business models	Flexible and reconfigurable production systems, Seamless integration of PLM tools and manufacturing	Services and methods for faster innovation and total product and production lifecycle management	SoA-S
Maintain competitiveness for high-wage countries	Optimisation of efficiency, quality standards, product innovation, etc.	Depending on concrete measures	Depending on concrete measures	SoA-L

Local adaptation / manufacturing close to markets	Geographically distributed manufacturing networks	Enable simplified information exchange in manufacturing networks	Services for value stream / production network design and management	SoA-S
Companies increasingly focus on their core business	Outsourcing	Enable information exchange and business process integration among production network participants	Supportive services for production network management	SoA-S
Urban production	Appropriate infrastructures (transport, environment conditions)	-	-	S-M
Increasing importance of work-life balance	Assistance systems, learning tools, Mobile working	Enable mobility for workers	Services for intelligent assistance which enable workers to focus on creative and value-adding tasks, reduction of routine and stress-sensitive tasks	M-L
Lack of technology acceptance	Resistance to change due to lacking education and demonstration	Must address the concerns (easy to understand, ensure security, robustness, etc.)	Must address the concerns (easy to understand, ensure security, robustness, etc.)	SoA
Additive manufacturing / 3D-printing	Fast, customer-specific, and distributed manufacturing	-	Services for easy design, order dispatching, transfer of design information to production facilities	M
Emergence of smaller, more dynamic enterprises	Increase innovativeness, faster reaction to market trends and changing customer demands	Enable collaboration among innovative companies to fasten and better exploit innovation potentials	Enable collaboration among innovative companies to fasten and better exploit innovation potentials	SoA-M
Added value potential through new services	New (B2B or B2C) services and business models enabled by intelligent products, e.g. cars, manufacturing equipment	Enable related information access and exchange	Tools for product-service design, alignment of production and service networks, …	M-L

Extension of perspective to production site / company associations	Planning and executing manufacturing throughout company borders	IT-Integration of production networks with regard to information, security, etc.	Services to provide data according to individual access rights, application needs, etc.; support for global decision making and optimisation	M
Virtualisation and digitisation	Better understanding of product and production behaviour and performance	Enable efficient and low cost usage of related tools and their integration	Services for communication, product and production design, etc. using virtual techniques	S-M
Manufacturing trends (related to specific measures in manufacturing)				
Resource productivity and efficiency	More efficient resource usage, avoidance of waste, improved recycling (and re-manufacturing) solutions	Enable information gathering and system control decisions focusing on resource product and efficiency as well as complete life cycle of products and production	Services for real-time data acquisition, forecasting and decision making with focus on resource productivity and efficiency	S-M
Increasing flexibility of production facilities	Ability to react to faster changing markets with regard to lead times, products, etc.	Support reconfigurability, reduction of lead times, fast ramp-up, real-time data exchange, etc.	Services for finding optimal configurations and their simplified implementation	SoA-L
Maximise efficiency and quality	Maintain / increase competitiveness of manufacturing companies	Enable information gathering and system control decisions to maximise efficiency and quality	Services for real-time data acquisition, forecasting and decision making with focus on efficiency and quality	SoA
Increasing hybrid cross-over solutions / use of ICT technologies	Interconnection of ICT disciplines and multiple application areas in order to enable new / improved features of IT systems	Enable seamless integration of infrastructures, processes, etc.	Process alignment, optimisation, scheduling, etc.	SoA-M
Flexibility in supply chain participation	Fast establishment / reconfiguration of production networks	Appropriate interfaces for fast and easy supply chain integration	Supportive services for SC planning, reconfiguration, simulation, optimisation, etc.	S

Evolution and emergent behaviour of production networks	Improved reaction to unexpected events, continuous adaptation to changing requirements	Interfaces for fast and easy production network reconfiguration	Associated supportive services, e.g. to recognise unexpected behaviour of systems and their environment and suggest appropriate reactions	S
Reduction of lead times	Reduction of inventories, increase customer satisfaction	Enable seamless real-time information exchange	Support and optimise scheduling, production, testing, etc.	SoA-S
Reduction of start-up, scale-up and maintenance times, effort for equipment integration	Faster recuperation of capital investments, faster introduction of new process innovations, faster adaptation of production to changing needs (e.g. products), etc.	Standardised interfaces for engineering processes and factory components	Supportive services for fast ramp-up (e.g. virtual commissioning), maintenance, etc.	SoA
Reduction of inventories	Reduction of unproductively employed capital without jeopardising the production flow	Access to relevant information (demand forecasts, inventories, etc.)	Services to keep track of inventories, forecast demands, dispatch materials, etc.	SoA
Total product tracking	Fulfil regulations, exploitation of the full potential of planning and optimisation mechanisms, support management of product recycling, etc.	Seamless integration of products to be tracked with factory environments	Services for data gathering and analysis, etc.	SoA-M

Main challenges for architectures

From this list of trends and drivers, and the impact of architectures and services on them, the most relevant solutions for architectures and services to address the trends and drivers have been extracted. All of them are addressing functional requirements. Non-functional features like security, robustness, reliability, etc. are regarded as pre-condition for industrial acceptance of the solutions identified.

1. **Standardised, intelligent interfaces & Access to information**

   To enable easy establishment and reconfiguration of production environments, interoperability has to be ensured by means of standardised, intelligent interfaces which can be applied on the following levels:

   - For intelligent components (products, carriers, etc.) to the factory environment they are moving in
   - On equipment level to enable fast adaption to changing manufacturing processes
   - On factory level to enable fast supply chain integration
   - Among design, planning, and operational systems

   Access to information is needed to gather information e.g. about resource consumption, process and product parameters, tracking / logistics, relevant knowledge, etc. from distributed devices, IT-systems to be integrated, etc. In addition to the related interfaces (syntax and semantics), appropriate security and privacy mechanisms have to be considered.

2. **Distributed Control**

   Architectures are required which enable to control geographically distributed systems which requires secure and reliable communication.

3. **Mobility**

   Architectures are required which enable and support mobility of intelligent components (products, carriers, production equipment, etc.) as well as workers.

Main challenges for services

1. **Data acquisition and analysis for decision making and optimisation purposes**

   Services are required to gather data, and analyse it in order to derive decisions / system optimisation options from them. Possible applications are the reduction of inventories or lead times, optimisation of resource consumption, etc.

2. **Supportive services for production network management and design**

   In order to efficiently manage production networks, services and tools are needed which support the design and management, of those networks, e.g. by optimising partner selection, production site distribution, logistics, etc.

3. **Services for knowledge management**

   Services providing knowledge management are necessary to support education, gather customer expectations, emerging trends, best practices, etc.

4. **PLM-related services, product-service design, etc.**

   Services are required to support product life cycle management, product and product-service design, customisation, etc.

5. **Services supporting complexity management**

   Services for complexity management are necessary to deal with the increasing complexity caused by increasing variety and complexity of products, increasing amounts of information available, etc.

6. **Further services like maintenance support, resource management, tracking, certification**

2 Context and objectives

This section describes the role and relevance of this document and the underlying work in the overall roadmapping process in Road4FAME.

Role of this document in the overall roadmapping process

The roadmapping process in Road4FAME is depicted in figure 1 and comprises three main phases:

- Phase 1: Establishment of push perspective and pull perspective, as a preparation for the core roadmapping process
- Phase 2: Core roadmapping process to join push and pull perspective and iteratively develop the roadmap
- Phase 3: Finalization of roadmap and development of recommendations

The work documented in this deliverable is one important building block in phase 1, highlighted in figure 1. It contributes to establishing the *pull perspective* which describes the *required* innovation by the manufacturing domain.

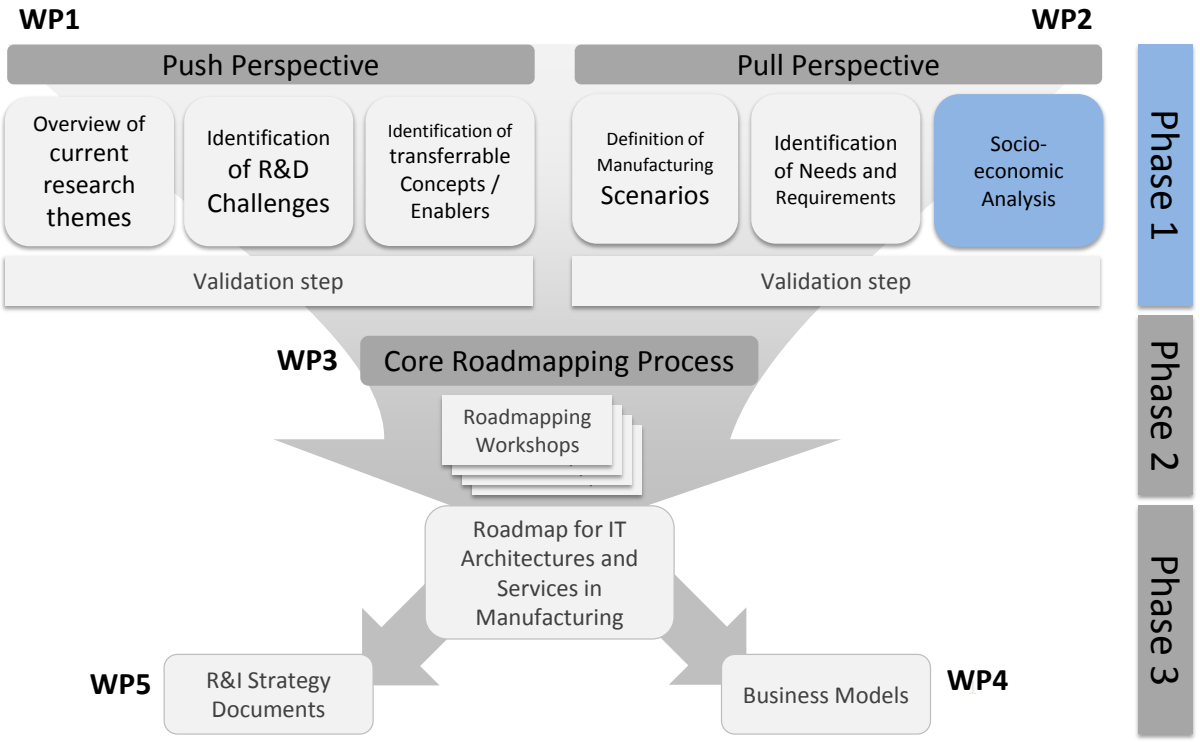

Figure 1: Road4FAME roadmapping process

Content of this document

This *report of socioeconomic developments* presents an overview of *trends* which can be considered to be relevant to the manufacturing domain, and may act as *drivers* in the sense that they drive developments in the manufacturing domain and have an influence on the *needs* in the manufacturing domain.

The overview of trends and drivers was established from screening relevant strategy documents (see Annex I for an overview of the strategy documents considered). In this document, trends and drivers are presented in three groups:

- General megatrends: These are megatrends which were identified in strategy documents which do not have a specific manufacturing focus (see section 4).
- Manufacturing-relevant megatrends: These are megatrends which were identified in strategy documents which have a manufacturing focus. Being megatrends, they are not specific nor exclusive to the manufacturing domain but they are likely to *affect* the manufacturing domain, if only in an *indirect* way (see section 5.1)
- Manufacturing trends: As opposed to the megatrends, these are trends which are taking place *within* the manufacturing domain or which have an *immediate effect* on the manufacturing domain (see sections 5.2 and 5.3). Thus, they are much more specific to the manufacturing domain than the megatrends.

Since Road4FAME develops a roadmap for IT architectures and services in manufacturing, the consortium analysed these trends with regard to their relevance for this objective. The relevance of each trend for ICT in manufacturing is explained where applicable in order to be able to consider each trend with the appropriate importance during the roadmapping process.

Relevance of this document

The trends and drivers presented in this document provide the foundation for establishing the pull perspective in Road4FAME. Knowledge of these trends and drivers is important because they have a direct influence on the *needs* of manufacturing businesses in Europe, to which the Road4FAME roadmap must be aligned.

This ensures that the recommendations derived from the roadmap are also in alignment with the needs of manufacturing companies in Europe. In turn, this ensures that any action following these recommendations – e.g. European research activities – will deliver just the results that manufacturing companies in Europe need to respond successfully to the identified trends and the challenges which these trends entail.

3 Approach and scope

As has been described in the previous section, the objective was to establish an overview of *trends* which can be considered to be relevant to the manufacturing domain, and may act as *drivers* in the sense that they drive developments in the manufacturing domain and have an influence on the *needs* in the manufacturing domain.

Followed approach

Two kinds of strategy documents were searched for relevant socio-economic developments:

a) Documents describing megatrends and

b) Documents describing manufacturing trends

The criteria for the selection of relevant strategy documents were differentiated for the two kinds of documents. For the megatrends extraction, strategy documents were selected which:

- can be considered a reputable source (i.e. are created by consultancy organisations, industry associations, or research institutes with respective expertise).
- describe high-level societal and economic developments or trends ("megatrends"), potentially also describing a future vision.

For the extraction of manufacturing trends, strategy documents were selected based on the following criteria:

- Reputable source (i.e. created by consultancy organisations, industry associations, research institutes or CSAs[4] funded by the European Commission which have sound expertise in fields related to ICT for manufacturing)
- Continuous relevance (i.e. addressing challenges which are currently still not overcome)
- Provision of an overview on socio-economic developments from an industrial (manufacturing and ICT) perspective with special focus on how technology, especially ICT, but also other manufacturing-related topics, could help to address them.

Analysis of relevant strategy documents

The analysis of relevant strategy documents has been executed jointly by the whole consortium. This enabled to consider a sound number of documents which were created not only on European and international level, but also documents available on national level, e.g. for Germany, Portugal, and Finland.

Since the analysis work of the documents was divided up among the consortium members, a common structure for documentation of the results has been used to ensure that the individual results are easily comparable. This structure was represented within a table structure covering the following aspects:

[4] Coordination and Support Actions

- Reference to strategy document (as exact as possible, e.g. including page numbers etc.)
- Title of the trend
- Explanation of the trend, e.g. what are the specific challenges to overcome
- Timeline, i.e. the timeframe for when this trend is expected to apply
- Relevance of the trend for ICT in production (relevance for services, relevance for architectures and explanation to what extend it applies)

Validation and prioritization of findings

The findings were prioritised according to their occurrence throughout the analysed strategy documents. This is thought to give an overview on the applicability of certain trends for the various domains, regions, etc. from which documents were involved to the analysis and also serves as a first validation step since topics appearing in almost all documents are considered to be quite relevant whereas topics only mentioned once may be a very specific case which is not applicable anywhere else.

As a second validation step, a review of the prioritised results, their explanations and relevance for ICT in production, was done by manufacturing experts in the consortium in order to have a sound basis for the involvement of project externals.

4 General Megatrends

In order to gather societal, economic, and manufacturing megatrends, several sources provided by different institutions have been analysed. In the process of doing so, it has been recognised that there is no one, universal document available which could serve as singular reference, since organisations and associations creating the strategic megatrends documents always have certain interests and backgrounds which influence the specific perspectives and priorities described in such documents.

For this reason, several documents have been considered during the search (see Annex I).

When analysing these documents, major, i.e. high priority, topics were identified to appear in almost all documents. According to this, **socio-economic megatrends** are in the following listed in the order equivalent to their occurrence in the searched megatrend documents.

1. Changing Demographics

This megatrend is mentioned in four out of five documents. It is also referred to as changing "demographic patterns", "ageing" or similar terms which all describe that higher life expectancy and falling birth rates are increasing the proportion of elderly people across the world, challenging the solvency of social welfare systems, including pensions and healthcare. Some regions are also facing the challenge of integrating large youth populations into saturated labour markets.

The relevance of this topic for architectures and services in manufacturing-IT is mainly related to the integration of aging workers to factories, ergonomics, etc.

2. Urbanisation

This megatrend is also mentioned in four out of five documents, in some of them described as an aspect of demographics. It refers to the fact that the population in urban areas is increasing. Almost two-thirds of the world's population will reside in cities by 2030. Urbanization is creating significant opportunities for social and economic development and more sustainable living, but is also exerting pressure on infrastructure and resources, particularly energy. As part of this trend, migration is expected to increase.

The relevance of this topic for architectures and services in manufacturing IT is mainly related to the trend of urban manufacturing, i.e. bringing factories (back) into cities and related infrastructure, flexibility, emission issues, etc.

3. Individual Empowerment / Rise of the individual / Prosperity

Mentioned in four of the considered sources, this topic is still quite relevant. Advances in global education, health and technology have helped empower individuals like never before, leading to increased demands for transparency and participation in government and public decision-making. These changes will continue, and are ushering in a new era in human history in which, by 2022, more people will be middle class than poor. Individual empowerment will accelerate owing to poverty reduction, growth of the global middle class, greater educational attainment, widespread use of new communications and manufacturing technologies, and health-care advances.

This trend of individualisation is reflected by the fact that customers increasingly demand products which stress their individuality and are a distinguishing factor in their social environment. The extent to which a supplier has the manufacturing capabilities to satisfy this demand for individualized products will increasingly determine its competitiveness. IT in manufacturing, especially suitable architectures and services, play an important role in delivering this capability.

4. Globalisation / Economic interconnectedness

Listed in three of the considered sources, this megatrend is quite relevant for future developments. The vision is that the interconnected global economy will see a continued increase in the volume of international trade and capital flow, but unless international conventions can be strengthened, progress and optimum economic benefits may not be realized.

This topic is very relevant for architectures and services in manufacturing IT since close collaboration throughout the world requires supportive measures to overcome language and cultural differences, to optimise information exchange, supply chain set-up and alignment, etc.

5. Resource stress / scarcity of resources

Three of the considered sources describe the food, water, energy, and other resources, the increasing demand for those resources as well as their limited availability. The combined pressures of population growth, economic growth and climate change will put increased stress on essential natural resources (including water, food, arable land and energy). These issues will place sustainable resource management at the centre of government agendas. Tackling problems in one commodity will be linked to supply and demand for the rest.

The relevance of this topic for architectures and services in manufacturing IT is high since related solutions could help to optimise resource usage, distribution, tracking (and thereby enable recycling), etc.

6. Technology & Innovation

Fundamental advances in important enabling technologies, including disciplines such as ICT, biotechnology and life sciences, nanotechnology, and energy are regarded as a megatrend by three of the analysed documents. In particular, information and communication technologies (ICT) have transformed society over the last 30 years. A new wave of technological advances is now creating novel opportunities, while testing governments' ability to harness their benefits and provide prudent oversight.

This trend is of fundamental relevance to manufacturing IT since these new technologies are precisely the necessary enablers for new production paradigms, control mechanisms, interaction opportunities, etc. Architectures and services will have to play their role in maximizing the benefits that these technological advancements offer to the manufacturing domain.

7. Climate Change

This topic is part of two sources considered. Rising greenhouse gas emissions (GHGs) are causing climate change and driving a complex mix of unpredictable changes to the environment while further taxing the resilience of natural and built systems. Achieving the right combination of adaptation and mitigation policies will be difficult for most governments.

The relevance of this topic for architectures and services in manufacturing IT is comparable to the aspects of resources scarcity (see item no. 5).

8. Diffusion of Power / Sharing global Responsibility

The diffusion of power has been described three times in the considered sources. It refers to the fact that there will likely not be any hegemonic power in the future. Power will shift to networks and coalitions in a multipolar world. The trend contains aspects like shift to global cooperation, growing power of NGOs, increasing philanthropy, etc.

Topics like network organising, i.e. the organisation of networks (of individuals, companies, societies, authorities, etc.) by considering the needs of individual members as well as global objectives, have to be considered here, too.

This megatrend is relevant for architectures and services in manufacturing IT as soon as it also applies for industrial settings, i.e. that there will be associations of smaller companies emerging etc.

9. Further megatrends

Additional megatrends were identified in only a single strategy document. Examples include:

- Public debt: Public debt is expected to operate as a significant constraint on fiscal and policy options through to 2030 and beyond. Governments' ability to bring debt under control and find new ways of delivering public services will affect their capacity to respond to major social, economic and environmental challenges.
- Economic power shift: Emerging economies are lifting millions out of poverty while also exerting more influence in the global economy. With a rebalancing of global power, both international institutions and national governments will need a greater focus on maintaining their transparency and inclusiveness.
- Global knowledge society: Here, several sub-trends are described: (Public) know-how bases, bridging the gender gap, and the war for talents resulting from a lack of skilled employees.
- Commercialisation, i.e. the intention and need to continuously find new business opportunities
- Acceleration of technology developments, product life cycles, individual work, etc.

For architectures and services in manufacturing IT, primarily topics like global knowledge society, individualisation, commercialisation, acceleration, and network organising play a role since they have the potential to influence / change structures, processes, and related technologies in production and associated manufacturing networks.

Beside these socio-economic megatrends, also **manufacturing megatrends** have been identified. The main trends to be mentioned here are:

1. New technologies: nanotech, robotics, and 3D printing (additive manufacturing), remote and autonomous vehicles and devices.

2. Increasing importance of labour skill: Demographic change and shortage of skilled staff force companies to focus on their employees, to improve working conditions, exploit their potential in an optimum way, etc.

3. Risk of protectionism: Potential disputes over natural resources, threats of currency manipulation, debt problems, or social upheaval in the energy-rich Middle East and other parts of the world which may disrupt global strategic collaboration which e.g. are enabled by fallen trade barriers.

5 Socio-economic developments relevant for ICT in manufacturing

This section presents all trends which can be considered to be relevant to the manufacturing domain, and may thus also influence the need for manufacturing ICT. There are two groups of trends relevant for manufacturing (for general megatrends, see section 4):

- Manufacturing-relevant megatrends: These are megatrends which were identified in strategy documents which have a manufacturing focus. Being megatrends, they are not specific nor exclusive to the manufacturing domain but they are likely to *affect* the manufacturing domain, if only in an *indirect* way (see section 5.1)
- Manufacturing trends: As opposed to the megatrends, these are trends which are taking place *within* the manufacturing domain or which have an *immediate effect* on the manufacturing domain (see sections 5.2 and 5.3). Thus, they are much more specific to the manufacturing domain than the megatrends.

Within each group, trends are listed in the order they have been prioritised based on their occurrence throughout the strategy documents. For each trends, an estimate is given regarding the time of emergence (Table 2 lists the used abbreviations). Emergence does not mean that the solutions to overcome the explained challenges are already there at that time, but that awareness related to this topic will be existing and first developments will have been made.

Abbreviation	Explanation
SoA	State-of-the-Art, the trend is already there
S	Short-term, the trend is expected to emerge soon (within the next few years)
M	The trend is expected to emerge within a medium-term time period
L	The trend is expected to emerge within a long-term time period
V	Vision, the trend is expected to emerge in the far future

Table 2: Timeline abbreviations for detailed topic descriptions

5.1 Manufacturing-relevant megatrends

The trends described within this subchapter mainly overlap with the identified megatrends, though they were trends extracted from manufacturing and IT specific strategy documents (roadmaps and research agendas) while the megatrends have been extracted from generic megatrend documents. For this reason, the prioritisation of topics listed may differ.

5.1.1 Demographic change

Explanation / Challenges: Considering increasing diversity of staff regarding age, mobility, gender, cultural background, etc., a reorganisation of learning and work is necessary to accommodate this variety. This also concerns the manufacturing domain where work places have to be adapted

appropriately, e.g. by adding intelligent assistance systems to enable workers to focus on creative and value-adding tasks, and to achieve a reduction of routine and stress-intensive tasks. Furthermore, action must be taken to facilitate transfer of knowledge from the aged workforce to the younger workers, and to assist their daily work with user-friendly ICT tools. Concepts like "human-centred manufacturing" state that future plants should be more accommodating towards the needs of the European workforce and consider them an integral stakeholder. In the same way as 'assisted living' for aged citizens, 'assisted working' should aid an ageing workforce to leverage skills and knowledge effectively for creation of innovative products.

Urbanisation will continue: City infrastructures will face new challenges as 59% of the world population will live in cities in 2030 – this figure will be as high as 81% in developed countries vs. 55% in the developing world.

Timeline: SoA-L

Relevance for ICT in manufacturing:

a) Architectures: Intelligent systems and their interaction, etc.

b) Services: Assisting services, TEL services to support training, etc.

Reference to strategy documents: Industrie 4.0 p.20, Artemis p.23, UK landscape for future manufacturing p. 16, ActionPlanT p.15, 18, EFFRA p. 20-21

5.1.2 Globalisation

Explanation / Challenges: Globalisation means that economic exchange and collaboration is increasingly taking place on a global level. Cost efficient solutions in logistics and information sharing have made it possible to utilise all the resources so that they add value in manufacturing industries. The first two megatrends have a direct effect on the organisation of supply chains and on the locations of primary markets.

Increasingly global supply chains and increasing threats to SME from the combination of skills and finance shortage, together with global OEM procurement policies result in increasing globalisation of organisations and supply chains which requires increased support for collaboration, e.g. information sharing. However, though economic power and opportunities continue moving east and beyond, increasing transport costs encourage repatriation/on-shoring.

Key features to enable and support this are access to information and remote control of distributed plants; access to and sharing of information about market variations and new potential supplier independently from their location, etc.

Timeline: SoA-M

Relevance for ICT in manufacturing:

a) Architectures: Architectures, interfaces, etc. which enable fast establishment and management of cooperations

b) Services: Associated supportive services e.g. for design and management of global networks

Reference to strategy documents: UK landscape for future manufacturing p. 17, 21, ActionPlanT p.13, EFFRA p.20-21, FIMECC p.6

5.1.3 Innovation and new technologies

Explanation / Challenges: Emerging new industries (e.g., photonics, energy generation from renewable sources) with strategic opportunities for global leadership by businesses, particularly in multi-disciplinary areas. New business opportunities for companies are expected to emerge in both established and completely new markets. Further key words like technology diffusion, power of innovation, the age of life science, ubiquitous connectivity, etc., also play a role here.

Acceleration of new technology adoption, means that new generations are more eager to utilise technological innovations than previous ones. Those who wrap the new technology into best user experience will get not only the customers but will also control the communities utilising these technologies. More and more, technologies are shared between social connections.

Timeline: S

Relevance for ICT in manufacturing:

a) Architectures: not directly related

b) Services: not directly related

Reference to strategy documents: UK landscape for future manufacturing p. 22, EFFRA p.20-21, FIMECC SRA p.6

5.1.4 Knowledge as key-enabler

Explanation / Challenges: The importance of knowledge is increasing as products, systems and business environment become more and more complex and technology-intensive. This leads to a trend of perceiving knowledge as capital, with the goal to use and exploit information across traditional boundaries as successfully as possible. A company's ability to manage and use the knowledge of its work force will increasingly exert an influence on its competitiveness and innovation capacity.

The performance of the global knowledge society will improve over the next twenty years. The importance of online knowledge networks in the Internet has increased significantly in recent years. Multiplication of potentially available information and knowledge will go on.

Timeline: SoA-M

Relevance for ICT in manufacturing:

a) Architectures: Architectures which support knowledge gathering and generation

b) Services: Services for knowledge management and exploitation

Reference to strategy documents: FIMECC p.6, EFFRA p.20-21

5.1.5 Slow innovation and underinvestment in R&D

Explanation / Challenges: Innovation still takes considerable time to be put into practice – from laboratory prototype to full-scale production – giving competitors a chance to overtake European enterprises through speed. Compared with major trading partners such as the USA, the Commission observes that "R&D in ICT in Europe is not only a much smaller proportion of total R&D spend – 17% compared with 29% – but in absolute terms represents around 40% of US expenditure". Furthermore, as "ICT represents a significant share of total value-added in European industrial strengths such as automobile (25%), consumer appliances (41%) or health and medical (33%), the lack of investment in ICT R&D is a threat to the entire European manufacturing and service sectors". Supporting R&D and innovation remains a government priority.

Timeline: SoA

Relevance for ICT in manufacturing:

c) Architectures: not directly related

d) Services: not directly related

Reference to strategy documents: UK landscape for future manufacturing p. 30, ActionPlanT p.14, 17

5.1.6 Language barriers and cultural differences

Explanation / Challenges: Language barriers and cultural differences result in communication issues and may thus decrease efficiency or introduce quality issues in global manufacturing networks.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: Architectures for seamless communication

b) Services: Services for seamless communication, such as visual communication platforms, better HMI, better voice / gesture recognition and translation, knowledge-based systems providing region-specific market know-how, etc.

Reference to strategy documents: Road2SoS

5.1.7 Rise of environmental consciousness

Explanation / Challenges: Environmental consciousness throughout society, and herewith also the production domain, will lead to lower energy consumption and less waste. In this regard, zero/low-emission energy production and technologies which enable highly efficient energy utilisation are key. Novel materials (lighter, recyclability, etc.) will also play a role. The more we increase productivity by adding intelligence to systems, the more this intelligence should repair the economic footprint of the users of these systems.

Timeline: SoA-M

Relevance for ICT in manufacturing:

a) Architectures: Architectures which enable context-awareness for easy calculation of energy consumption, foot prints, etc. and respective optimisation

b) Services: Services for traceability and certification of products and production, foot print calculation, energy consumption monitoring and measurement, etc.

Reference to strategy documents: FIMECC p.6

5.2 Manufacturing trends related to market and business models

5.2.1 Increasing demand for personalised products and high quality

Explanation / Challenges: Purchasing decisions are being made based on brand perception of safety, quality and personalised/customisable products. Cost-efficient manufacturing of individual products, which does not only cover mass customisation concepts but also total individualisation, e.g. by means of efficient implementation of engineering-to-order concepts, is a key capability to maintain competitiveness, especially when selling high-value products. Therefore, it is necessary to enable flexible adaptation to individual product specifications, short-notice change requests, first time right production, etc. Fast information exchange and usage, reconfigurable production processes, provision of non-option based configuration tools, etc. are some technological challenges which have to be addressed in this context.

The extreme case of this product individualisation is the “customer in the loop” concept, where future enterprises will tightly integrate customers in their feedback loop for design and iterative improvements of products. A further trend related to this is the “consumerisation” of manufacturing, i.e. the transition from B2B to B2C which mainly describes the related realignment of business systems inside manufacturing organisations as well as direct contact of suppliers with customers (B2B2C). New or updated supply chain concepts (e.g. from push to pull principles) may also contribute to overcome this issue.

Timeline: S-L

Relevance for ICT in manufacturing:

a) Architectures: Architectures to easily involve customer demands and enable fast and well-defined reactions to them.

b) Services: Services to easily involve customer demands, enable fast and well-defined reactions to them, services for process re-configuration including equipment setup, etc.

Reference to strategy documents: Industrie 4.0 p.19, Artemis p.44, ActionPlanT p.13, 15, 19, EFFRA p.20-21, Manufacturing Reinvented p.5

5.2.2 Optimisation and decision making

Explanation / Challenges: Real-time decisions for faster reaction to exceptions, higher planning reliability, optimised processes throughout production networks, etc. help to increase competitiveness. Intelligent methods and tools to gather information and extract suggestions / decisions from them are the key technologies to support this. Examples are concepts related to context information / manufacturing intelligence / big data. Collaboration and connectivity will give

rise to copious amounts of context and data that will have to be analysed on-the-fly and rendered e.g. on mobile devices of decision makers at both management and plant levels. To gain a competitive advantage, manufacturing companies need the capability to perform real-time analysis over a large volume of data from processes, products and business systems.

The related need for simulation and planning comes from the need to plan more rigorously the processes and to virtualize those processes so to make them more economically efficient without the need to constantly use actual physical prototypes.

Timeline: S

Relevance for ICT in manufacturing:

a) Architectures: Architectures which enable information gathering and system control based on made decisions

b) Services: Services for real-time data mining, pattern recognition, decision making, forecasting, etc.

Reference to strategy documents: Industrie 4.0 p.20, Artemis p.44, ActionPlanT p. 16, Produtech roadmap p. 33

5.2.3 Shortage of skilled staff

Explanation / Challenges: A shortage of sufficiently skilled staff especially occurs in economically strong regions. To overcome this issue, education as well as knowledge management systems and supportive tools can be appropriate measures.

Example: Western Europe will need 46 million additional highly skilled employees. Germany alone will have a shortfall of 4.4 million workers, with about half of them (2.4 million people) required in skilled professions such as research, consulting, healthcare and education.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: not directly related

b) Services: Services for knowledge management, education support, etc.

Reference to strategy documents: Industrie 4.0 p.21, UK landscape for future manufacturing p. 16, ActionPlanT p.14, EFFRA p.20-21

5.2.4 Increasing demand for products and services

Explanation / Challenges: With population projected to grow 20% over the next 20 years to over 8 billion people by 2030, demand will be generated by over a billion additional customers. Furthermore, demand will also increase due to increasing prosperity in many nations. Both trends will lead to an increase in overall global market volume for products and services and will offer tangible opportunities.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: not directly related, but becomes relevant when approaching implementation, e.g. architectures to support collection and analysis of end user expectations, emerging trends

b) Services: not directly related, but becomes relevant when approaching concrete measures

Reference to strategy documents: ActionPlanT p. 13, UK landscape for future manufacturing p. 18, EFFRA p. 20-21

5.2.5 Increasing complexity of products, processes, and supply networks

Explanation / Challenges: The increasing complexity of products, processes, and production networks require adequate action and infrastructures to deal with it in order to maintain and optimise efficiency, especially when changes occur. In order to simplify internal business operations while staying in touch with customers, companies are enriching the established concepts of standardisation and harmonisation, attempting to simplify them. Common front-ends for user interaction (customer perspective and internal tools) also help to hide complexity from users. Also modularisation of products, production facilities, and business is a relevant concept here.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: Architectures which support easy configuration and management of complex systems. This also covers aspects like self-description, self-learning, and self-configuration.

b) Services: associated supportive services

Reference to strategy documents: ActionPlanT p. 13, Manufacturing Reinvented p.7, IERC p.19

5.2.6 Enhancement of products by embedded IT and integrated services

Explanation / Challenges: The rising 'digital economy' and its impact on 'traditional' products, processes and services as well as creation of 'new' demands by embedding ICT to products, i.e. making them intelligent and, by means of this, providing additional services, results in an added value for consumers and may bring new market potential. To achieve this, challenges are to align hardware, software, services, and their implementation and allocation. Not only will ICT-enhanced products provide added value to the customer, they may also be supportive of their own manufacturing process by intelligently interacting with manufacturing infrastructures.

Timeline: SoA-L

Relevance for ICT in manufacturing:

a) Architectures: Infrastructures and architectures, e.g. for easy product integration to factory ICT-environments which could e.g. be used for tracking and monitoring as well as control tasks.

b) Services: services provided by the products and supporting production

Reference to strategy documents: Acatech p.23, UK landscape for future manufacturing p. 25

5.2.7 Shorter product lifecycles

Explanation / Challenges: Since affluence and purchasing power are increasing the pace of change, in many industrial sectors products are replaced faster than before. This causes an increasing need for shorter time-to-market for innovative products but also for total product life-cycle management processes and might also result in the implementation of service-based business models rather than product selling.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: Architectures for seamless integration of all tools used throughout the product and production life cycle

b) Services: Methods for both faster innovation and total product and production lifecycle management

Reference to strategy documents: Road2SoS, UK landscape for future manufacturing p. 23

5.2.8 Maintain competitiveness for high-wage countries

Explanation / Challenges: Since labour costs are high in Europe, it is necessary to maintain and optimise competiveness e.g. by improvement of efficiency, optimisation of added value processes, quality standards, product innovation, outsourcing and collaboration, etc.

Timeline: SoA-L

Relevance for ICT in manufacturing:

a) Architectures: not directly related (concerns mainly business models and strategy). However, detailed sub-topics such as optimisation of efficiency or quality can be addressed.

b) Services: not directly related (concerns mainly business models and strategy). However, detailed sub-topics such as optimisation of efficiency or quality can be addressed.

Reference to strategy documents: Industrie 4.0 p.20, UK landscape for future manufacturing p. 26

5.2.9 Local adaptation / manufacturing close to markets

Explanation / Challenges: Large centralised manufacturing units have now given way to networks of smaller modular factories, which are closer to centres of demand. This trend has several causes: the regulatory or customs duty restrictions of some countries, but also the reduction of lead times or costs. These can be responded to by locating manufacturing, or at least final assembly, close to the customer market. This places tremendous pressure on logistics and supply chain optimisation, as enterprises look to achieving the benefits of lean processes in a widely dispersed setup. Visualisation and tracking technologies play an important role in this process enablement. Appropriate value stream design to allocate manufacturing in an optimal way is one of the major challenges related to this topic, too.

Timeline: S

Relevance for ICT in manufacturing:

a) Architectures: Architectures, interfaces, etc. which enable and simplify management of dispersed production networks

b) Services: Services for value stream / production network design and overall management of production networks

Reference to strategy documents: Road2SoS, Manufacturing Reinvented p.8

5.2.10 Companies are increasingly focussing on their core business

Explanation / Challenges: Under global cost pressures many companies focus on their core business and optimize their comparative advantage to remain competitive. To do so, they specialise and outsource processes that are not their core competence. The challenge is to define the core business / processes and to structure the manufacturing environment & production network accordingly.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: Outsourcing requires well-defined integration with suppliers, also with regard to IT architectures and interfaces.

b) Services: Outsourcing requires well-defined integration with suppliers, also with regard to service functionalities and usage.

Reference to strategy documents: Road2SoS, ActionPlanT p.13, 17

5.2.11 Urban production

Explanation / Challenges: Urbanisation will continue: city infrastructures will face new challenges as 59% of the world population will live in cities in 2030 – this figure will be as high as 81% in developed countries vs. 55% in the developing world. Urban production addresses this, i.e. it is the trend to re-locate manufacturing facilities to cities in order to shorten commuting times, etc. Appropriate infrastructures (transport, environment conditions) to enable urban production are needed.

Timeline: S-M

Relevance for ICT in manufacturing:

a) Architectures: not directly related

b) Services: not directly related

Reference to strategy documents: Industrie 4.0 p.5, EFFRA p. 20-21

5.2.12 Increasing importance of work-life balance

Explanation / Challenges: Assistance systems, learning tools etc. which support to maintain work-life balance could help to enable and support better alignment of work, private life, personal and professional advancement.

Timeline: M-L

Relevance for ICT in manufacturing:

a) Architectures: Assistance system architectures which enable workers to focus on creative and value-adding tasks, reduction of routine and stress-intensive tasks

b) Services: Intelligent assistance tools and services which enable workers to focus on creative and value-adding tasks, reduction of routine and stress-intensive tasks

Reference to strategy documents: Industrie 4.0 p.20

5.2.13 Lack of technology acceptance

Explanation / Challenges: In an industrial environment, a certain resistance to change and scepticism towards new technologies can be observed. As a consequence, new technological developments are not sufficiently exploited. The main reason for this are often concerns about security, robustness, etc. of systems. As soon as the maturity of systems is high enough for industrial implementation, this issue can only be overcome by appropriate education and demonstration of systems.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: not directly related, but have to address the concerns (e.g. easy to understand, enable security, robustness, etc.)

b) Services: not directly related, but have to address the concerns (e.g. also easy to understand)

Reference to strategy documents: Industrie 4.0 p.21

5.2.14 Additive manufacturing / 3D-printing

Explanation / Challenges: Additive manufacturing enables fast manufacturing of specific products by means of small and flexible production facilities. To do so, appropriate materials and printing equipment, easy design of products and transfer of design to production equipment are necessary.

Timeline: M

Relevance for ICT in manufacturing:

a) Architectures: not directly related

b) Services: services for easy design, order dispatching and transfer of design information to production facilities

Reference to strategy documents: Industrie 4.0 p.19

5.2.15 Emergence of smaller, more dynamic enterprises

Explanation / Challenges: The need to be innovative is an increasing necessity in more and more markets, putting pressure on large European enterprises, once market leaders in their own domains, but now losing out to smaller and more agile companies. To cope with growing competition, European enterprises must acknowledge the importance of innovation and put it to practice faster. In response, an emergence of smaller and more dynamic enterprises can be observed, which are able to put innovation into practice more rapidly than their bigger – and slow-moving – counterparts.

Timeline: SoA-M

Relevance for ICT in manufacturing:

a) Architectures: Enabling collaboration among those enterprises, pooling of resources and assets, joint usage of production capacities, etc.

b) Services: Enabling collaboration among those enterprises, pooling of resources and assets, joint usage of production capacities, etc.

Reference to strategy documents: ActionPlanT p.14, 15

5.2.16 Added value potential through new services

Explanation / Challenges: Provision of new (B2B or B2C) services and business models enabled by intelligent products. Examples for this could be intelligent manufacturing equipment, which has integrated maintenance capabilities. For cars, some examples are already implemented, e.g. by the integration of navigation systems. To enable this, appropriate combinations of products and services and related networks have to be established.

Timeline: M-L

Relevance for ICT in manufacturing:

a) Architectures: Infrastructures and architectures to enable related information exchange and provision etc.

b) Services: New tools for product-service design, alignment of production and service networks, etc.

Reference to strategy documents: Industrie 4.0 p.20

5.2.17 Extension of perspective to production site / company associations

Explanation / Challenges: Employing ICT technologies to consider not only one's own production site when executing planning and optimisation tasks is expected to be a future trend in the manufacturing domain. This requires methods and tools (technical) as well as common policies (economic, legal) to share information and influence decision making throughout company borders.

Timeline: M

Relevance for ICT in manufacturing:

a) Architectures: Architectures to integrate production networks appropriately

b) Services: Services which e.g. provide data according to individual access rights, application needs, etc. and support global decision making and optimisation

Reference to strategy documents: Acatech p.54

5.2.18 Virtualisation and digitisation

Explanation / Challenges: Companies are increasingly opting for virtual collaboration platforms to work with the globally dispersed supplier base. They increasingly use simulation, visualisation, and virtualisation to understand the product and production behaviour and performance under virtual conditions. This not only reduces the time required for testing, but also enables organisations to test

many more scenarios. It allows for seamless collaboration across a geographically dispersed supplier base. Overall, the favourable impact on the time-to-market for the product is very high.

Timeline: S-M

Relevance for ICT in manufacturing:

a) Architectures: Architectures which enable efficient and low cost usage of appropriate tools and their integration

b) Services: Services for communication, product and production design etc. using virtual techniques

Reference to strategy documents: Manufacturing Reinvented p.5

5.3 Manufacturing trends related to specific measures in manufacturing

5.3.1 Need for resource productivity and efficiency

Explanation / Challenges: Trends such as increasing resources scarcity and cost and growing concerns about security of supply results in the need to use resources, including water and energy, in a less wasteful way to achieve the target output. Also, there will be greater reliance on renewable resources. With impending climate change and increasing world population, a transition from a wasteful to a frugal economy will be necessary, and some first steps can already be observed.

In the manufacturing domain, this requires awareness and transformation of industrial processes towards low carbon footprints and energy efficiency. Manufacturing is responsible for significant energy use and consumption of natural resources. Enterprises with high-energy consumption, such as automotive and heavy machinery, seem to have reached a limit in energy-reduction efforts and need an ICT-facilitated paradigm change to lower energy consumption further. As a side effect of being sustainable, new jobs within Europe would also be created, such as in France where the National Research and Innovation Strategy states that around six million jobs could be created over the next ten years. The introduction of optimisation methods on tools with focus on resource consumption could help to address this challenge, too. This also includes monitoring and tracking environmental information as well as related waste and material management functionalities.

It is also worth mentioning improved recycling (and re-manufacturing) solutions which address scarcity through the re-use of valuable materials in a cost effective way.

Also new product design concepts, and the usage of next generation materials for products and production could contribute to this topic.

Timeline: S-M

Relevance for ICT in manufacturing:

a) Architectures: Architectures which enable information gathering and system control based on made decisions with focus on resource productivity and efficiency as well as complete product life cycle management.

b) Services: Services for real-time data mining, pattern recognition, decision making, forecasting, etc. with focus on resource productivity and efficiency as well as complete product life cycle management.

Reference to strategy documents: Industrie 4.0 p.20, Artemis p.43, UK landscape for future manufacturing p. 14, ActionPlanT p.15, Produtech Roadmap p. 26, 31, 33, 37, EFFRA p.20-21, 33, Manufacturing Reinvented p.7

5.3.2 Increasing flexibility of production facilities

Explanation / Challenges: In order to increase their competitiveness, factories will increasingly develop their ability to react to faster changing markets with regard to production times, products to be manufactured, etc.

To achieve this, production processes must be highly adaptable and flexible and that is accomplished with the introduction of improvements in the process specially in the use of ICT, robotics and automation but also in the improved integration of CAM/CAD/CAM - CNC, the possibility to work with shorter production cycles and to have a more efficient control of the process variables.

Timeline: SoA-L

Relevance for ICT in manufacturing:

a) Architectures: Various methods, concepts, and tools, and a combination of them to support reconfigurability of factories and reduction of lead times as well as fast ramp-up, real-time data exchange, etc. This includes the dynamic design of business processes regarding quality, quantity, product characteristics, time, risk, robustness, price, environmental friendliness, etc. Depending on the business model and strategy, this means fast adaptation according to current priority criteria.

b) Services: Appropriate services for finding optimal configurations and their simplified implementation, etc.

Reference to strategy documents: Road2SoS, Acatech p. 54, Industrie 4.0 p.20, Artemis p.44, Produtech roadmap p. 32

5.3.3 Maximise manufacturing efficiency and quality

Explanation / Challenges: This is the main economic driver in the manufacturing domain which is tied to many other trends reported in this document. Promising contributions are expected from new IT-tools, logistic concepts, product design methods, quality management methods, scheduling mechanisms, etc.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: Architectures and Services to gather current status information and use them for optimisation

b) Services: Architectures and Services to gather current status information and use them for optimisation

Reference to strategy documents: Road2SoS, Acatech p. 24&53, Produtech roadmap p.32

5.3.4 Increasing hybrid cross-over solutions / use of ICT technologies

Explanation / Challenges: Transformation opportunities are numerous when companies cross traditional boundaries. Hybrid solutions that help such crossovers are mandatory, and this calls for next generation solutions, i.e. the application of new technologies to other domains. An example is the integration of mobility, connected marketing, social media, listening services, big data-related business, embedded electronics, telecom services, etc.

The potential of ICT technologies is increasingly exploited, e.g. for delivering efficiency gains through automation and integration of diverse processes along the entire value chain. However, insufficient IT management and technical skills – particularly in SMEs – and indifferent attitudes towards new ICT and innovation hinder investments in modern ICT systems and delay organisational changes in business processes and exploitation of ICT potential.

Additionally, the interconnection of systems and the number of connected devices will increase. The resulting challenge is to design, test, run, and maintain these meta-systems / systems-of-systems. Economy and society increasingly depend on such systems. However, they tend to show vulnerabilities in terms of information security and safety dependencies. Cyber-attack represents the epitome of an asymmetric threat, with a very low cost of attack and a very high cost of protection.

Technologies which should be mentioned here include:

- Exponential proliferation of mobile devices / enterprise mobility: While mobile technologies have permeated the consumer market, enterprise applications are still relatively limited. To leverage the potential of next-generation smart phones and handhelds, manufacturing enterprises need to be looking beyond conventional desktop solutions and focus on new opportunities and businesses in the mobile world.
- Real-world connectivity / CPS / Internet of Things: Sensors, automation controllers and embedded systems are already commonplace in personal life as well as in industrial applications. However, so far few companies have been deploying more than their own Intranet of Things focused on local, isolated and closed-loop scenarios. Development of the capability to seamlessly and bi-directionally interact with real-world objects and systems on a global scale, across a variety of application domains and stakeholders in a secure way, thus realising the Internet of Things.
- Explosion of data volumes collected, exchanged, stored: Here, several questions have to be answered such as ‘how to transform the vast amount of available data into useful information/knowledge?’, the distribution of relevant data will require new mechanisms to find and fetch this data, decrease of energy intensity in computing necessary (increase GFLOPS per Watt), energy harvesting capabilities for distributed devices, …

Timeline: SoA-M

Relevance for ICT in manufacturing:

a) Architectures: e.g. for seamless integration of infrastructures, processes, etc.

b) Services: e.g. process optimisation, alignment, scheduling, etc.

Reference to strategy documents: ActionPlanT p.13, 16, T-Area-SoS SRA p. 4, 10, IERC p.11, 16, 19

5.3.5 Flexibility in supply chain participation

Explanation / Challenges: Factories (especially SMEs) should easily be able to join production networks in order to be able to quickly react on market demand changes, to extend the market. Therefore, the effort to establish / change production networks, i.e. to involve / exclude partners has to be minimised. Efficient and secure collaboration between many different stakeholders will become crucial for day-to-day operations of European manufacturers. Large companies as well as SMEs stand to gain from collaborative manufacturing, service management and customer engagement via social media and other Web 2.0 tools.

Timeline: S

Relevance for ICT in manufacturing:

a) Architectures: Supply chain reconfiguration based on intelligent interfaces for fast integration, etc.

b) Services: Supportive services for supply chain reconfiguration, simulation or optimisation, etc.

Reference to strategy documents: Road2SoS, ActionPlanT p.16

5.3.6 Evolution and emergent behaviour of production networks

Explanation / Challenges: Production networks have increasingly to deal with unexpected events and react to them in an optimal way since overall markets are becoming more agile, customer demands are changing faster, collaborations can be established and dissolved faster, etc. Furthermore, they have to continuously adapt to changing requirements which results in a long-term evolution of the production networks. Understanding how to utilise existing and new production networks to adapt faster to customer demands can be beneficial in profits and brand. Influencing and adapting to evolving conditions like government policy, tax and regulations (including those related to emissions and sustainability) also plays a role here.

Timeline: S

Relevance for ICT in manufacturing:

a) Architectures: Architectures, interfaces, etc. which enable easy reconfiguration and optimisation of production networks

b) Services: Associated supportive services

Reference to strategy documents: Road2SoS, UK landscape for future manufacturing p. 29

5.3.7 Reduction of lead times to produce and deliver a product

Explanation / Challenges: In order to reduce inventories and to increase customer satisfaction, companies seek to continuously reduce lead times (time from receiving an order till delivery). To achieve this, appropriate logistics concepts and related execution and control software are needed.

Timeline: SoA-S

Relevance for ICT in manufacturing:

a) Architectures: Enable faster methods (virtual or real) or technologies for product design, prototyping, scheduling, production execution and logistics management, testing, etc.

b) Services: Services to support and optimise scheduling, production, testing, etc.

Reference to strategy documents: Road2SoS, Acatech p. 53

5.3.8 Reduction of start-up and maintenance times, effort for integration of new equipment / tools, and fast scale up of production

Explanation / Challenges: Start-up and maintenance times decrease overall inefficiency because manufacturing assets are not used productively. For this reason, the intention is to reduce these times to a minimum and to schedule the related activities to time slots where they cause as little delay in production as possible. Methods like concurrent engineering, virtual commissioning, but also fast integration by means of standardised interfaces, etc., can contribute to addressing this challenge.

The reduction of efforts when integrating new equipment / tools to production environments is important for recuperating capital investments quickly and introducing new process innovations sufficiently fast. Also the ability to scale up quickly from prototype to product can result to increasing fast market share, better Return on Investment and maintaining competiveness for longer.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: E.g. standardised interfaces for engineering processes and factory components

b) Services: Supportive services for fast ramp-up, maintenance, etc.

Reference to strategy documents: Road2SoS

5.3.9 Reduction of inventories

Explanation / Challenges: Inventories equate to tied-up capital, which must be considered unproductively employed capital. To optimize, the concept of lean manufacturing suggests reducing inventories in order to liquidize the tied-up capital for other, value-creating, purposes. However, this cannot be done without limitations. The trend of becoming leaner must be supported by extensive information technology to ensure that the production flow is not jeopardised.

Timeline: SoA

Relevance for ICT in manufacturing:

a) Architectures: Appropriate architectures, methods and tools to keep track of inventories, forecast demands, dispatch materials, etc.

b) Services: Appropriate services, to keep track of inventories, forecast demands, dispatch materials, etc.

Reference to strategy documents: Road2SoS

5.3.10 Total product tracking

Explanation / Challenges: Product tracking becomes increasingly necessary either in the context of mass customization, to manage product recycling, fulfil regulations, or to exploit the full potential of planning and optimisation mechanisms. This can be realised by means of appropriate infrastructures (e.g. wireless), architectures and services.

Timeline: SoA-M

Relevance for ICT in manufacturing:

a) Architectures: E.g. for seamless integration of products to be tracked with current factory environment

b) Services: E.g. for data gathering and analysis

Reference to strategy documents: Acatech p.25

6 Conclusion and future work

In order to establish a sound basis for the roadmapping process of the Road4FAME project, current and anticipated trends which might have impact on ICT architectures and services in manufacturing were analysed. To do so, global megatrends and socio-economic developments in ICT and manufacturing-specific strategy documents were identified, and respective trends were extracted from them. During this analysis, trends and topics have been identified which might have impact on future architectures and services in manufacturing IT. Each of them has been described, and the relevance for ICT in manufacturing has been explained.

While doing so, it has been recognized that the trends described, as well as the related ICT solutions, are partially interrelated. For example, the increasing demand for personalized products is closely related to the increasing flexibility of production environments. For this reason, IT solutions to address these topics are quite similar. Those architecture and service solutions to address the trends and drivers identified have been identified, analysed, and prioritised.

The results documented in this deliverable, together with further findings from WP2 (pull perspective) have been used to pre-populate the roadmap, together with results from WP1 which contributed the push perspective. The roadmap will be further validated, extended, and developed during expert workshops, by means of surveys and interviews, and other tasks belonging to the roadmapping executed within WP3.

Annex I: Considered strategy documents

Strategy documents *without* manufacturing focus:

- Global Trends 2030: Alternative Worlds: A publication of the National Intelligence Council, December 2012[5]
- Copenhagen Institute for Futures Studies: 10 megatrends toward 2020[6]
- Roland Berger Strategy Consultants Trend Compendium 2030[7]
- KPMG-Research-Future State 2030 (11/05/2013)[8]
- Three Manufacturing Megatrends – Address by CAN BRUTTO, President, UPS International Delivered at the UPS Asia Technology Summit Luncheon, Honk Kong, Feb. 19, 2012

Strategy documents *with* manufacturing focus:

EFFRA roadmap

The "Factories of the Future Strategic Multi-Annual Roadmap" is the result of several consultations conducted throughout 24 months by the non-for-profit association "European Factories of the Future Research Association" (EFFRA). EFFRA is composed of over 100 members including industries (both large and SME), research and technology organisations (RTOs), universities and related European associations. The Roadmap identifies the megatrends that are driving the structural transformation of European Manufacturing towards sustainable (from the Economic, Social, Environmental points of view) competitiveness and outlines how Technologies and Enablers (which include ICT) can be successfully adopted to support this transformation.

ActionPlanT Roadmap for Manufacturing 2.0

The "ActionPlanT Roadmap for Manufacturing 2.0" was developed by the ActionPlanT project between June 2010 and May 2012. The ActionPlanT project was co-funded by the European Commission under the Private-Public Partnership (PPP) "Factories of the Future" within the Seventh Framework Programme ("FP7") with the objective to prioritize most promising topics for the next Framework Programme for Research and Innovation ("Horizon 2020", covering the period 2014-2020). The document highlights the role of Information and Communication Technologies (ICT) for the European manufacturing industry and provides an overview of research challenges to be tackled in the short, medium, and long term. ActionPlanT was coordinated by SAP AG, Germany.

The content of the ActionPlanT Roadmap is reflected in the EFFRA Multiannual Roadmap to a large extent.

[5] http://www.dni.gov/files/documents/GlobalTrends_2030.pdf

[6] http://www.cifs.dk/scripts/artikel.asp?id=1469

[7] http://www.rolandberger.com/gallery/trend-compendium/tc2030/

[8] http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/future-state-government/Pages/what-are-the-global-megatrends.aspx

German “Industrie 4.0” initiative (recommended actions document)

“Industry 4.0” is defined as the fourth industrial revolution. While the first three industrial revolutions are regarded as mechanisation, electrification, and introduction of IT technologies, the fourth revolution is described as introduction of internet and network technologies, distributed intelligence, and related topics to the industrial environment.

The German “Industry 4.0” initiative consists of a future project which is jointly defined by industry, government, research, and associations like acatech, VDMA, ZVEI, and BITKOM. Actions were recommended by the respective working team. Its goal is to drive forward the German industry and research related to manufacturing, IT, and (high-tech) industries to which a combination of these topics could bring benefit.

The involved industry associations also have established a platform in order to cluster, push, align, and continue the activities which are undertaken in this context and to support interdisciplinary collaboration.

In addition to the recommended actions provided (e.g. related to security, standardisation, education, etc.), several calls for proposals have been launched by the German Ministry for Economy and Technology such as Industry 4.0 based on cyber-physical systems, autonomics for Industry 4.0, virtual techniques, and big data.

FIMECC Strategic research agenda

FIMMEC stands for “Finnish Metals and Engineering Competence Cluster”: it is an innovation company owned by 32 organisational shareholders that are Finland-based companies, universities and research institutes. FIMECC initiates, organises, and manages research programs and other activities in the field of metals and mechanical engineering.

In 2012 it issued the “Strategic Research Agenda for Finnish metals and engineering competence cluster” that, even if proposing a Vision, research objectives and strategic research themes adapted for the specific sectors of metal product and Engineering industry; started from the identification of some mega trends (therefore independent from a specific business sector) that are influencing the global European economy and market.

A landscape for the future of high value manufacturing (HVM) in the UK

This report, published in 2012, summarises the main findings of a study of the UK manufacturing environment conducted on behalf of the Technology Strategy Board. The Technology Strategy Board is The UK's innovation agency. It was established by the Government and operates at arm's length as a business-led executive non-departmental public body. Its role is to stimulate innovation, working with business and other partners, in order to accelerate economic growth. The report is the output of a broad consultation exercise with industry, academia and government. “The study maps out the environment that will shape the UK’s HVM and innovation base over the next 15-20 years. The consultation exercise identified a number of areas where there was broad consensus on trends, drivers, challenges and opportunities for UK manufacturing. This has led to the identification of a group of first pass key ‘national competencies’ in which the UK should consider developing industrial capability so it can meet the future challenges identified in the study.” Further information can also be found on https://www.innovateuk.org/high-value-manufacturing.

PRODUTECH Roadmap (Portugal)

Preparation of a Technology Roadmap for Row of Manufacturing Technologies

Technology roadmap for the row of manufacturing technologies, forecasting implementation of production technologies developments on different time horizons focusing on specific business sectors, including: footwear, ceramics and glass, cork, tanning, wood and furniture, metal-mechanic, molds, tools and plastics, ornamental and industrial rocks, textile and clothing.

This study contains relevant information for recipients with different profiles, namely:

- Enterprises applying certain manufacturing technologies
- Enterprises belonging to involved business sectors
- Scientific and technological system entities

Acatech study: agendaCPS

This study on cyber-physical systems (CPS) has been created by acatech, the German Academy of technology sciences, i.e. its members from industry and research organisations. The creation of the document was funded by the German Ministry for Education and Research. Its objective is to strengthen the German position with regard to cyber-physical systems, related research and applications. Therefore, visions for CPS applications in four domains (mobility, healthcare, smart grid, and production) are described from which socio-economic challenges and technological recommendations are derived.

ARTEMIS strategic research agenda (2011)

The ARTEMIS (Advanced Research & Technology for EMbedded Intelligence and Systems) community consists of a technology platform, an industry association, as well as the joint undertaking and further national or regional clusters and centres of innovation excellence related to the ARTEMIS initiative. The strategic research agenda provided by this community addresses three main societal challenges: affordable healthcare and wellbeing; green, safe and supportive transportation; and smart buildings and communities of the future. For those domains, visions and research priorities are given.

Road2SoS Roadmap

Road2SoS was a 25-month support action co-funded under the European Community's 7th Framework Programme aiming at developing strategic roadmaps in the field of System-of-Systems Engineering (SoSE) and their application in the industrial context. This is an emerging concept that describes the large scale integration of many independent self-contained systems to satisfy global needs or multi-system requests. One of the domains explored for the development of the roadmaps was integrated multi-site manufacturing.

Multi-site industrial production is generally the manufacturing of products throughout two or more production sites belonging to one or more companies. ‘System of Systems’ in multi-site industrial production is regarded as a System which consist of contributing systems such as singular production sites and which have a common goal, the production of (complex) products. Nowadays, SoS in this

domain are mainly known as “Supply Chains”, “Production Networks”, “Virtual Organisations”, etc. which represent various control and management concepts for distributed manufacturing.

T-Area-SoS Strategic Research Agenda

The T-Area-SoS Strategic Research Agenda was developed by the T-Area-SoS project between September 2011 and August 2013. The T-Area-SoS project was co-funded by the European Commission under the Seventh Framework Programme (“FP7”) with the objective to explore and evolve SoS/SoSE R&D themes and priorities for FP7/H2020 and to examine their capability to address societal needs, with exemplars across a wide variety of sectors including non-traditional aspects of Energy, Transport, and Manufacturing. T-Area-SoS was coordinated by the Loughborough University, UK, comprising also transatlantic partners from the US.

Internet of Things Strategic Research Roadmap

The Internet of Things Strategic Research Roadmap was developed in 2011 by the European Research Cluster on the Internet of Things (IERC). The IERC is bringing together EU-funded projects with the aim of defining a common vision and the IoT technology and development research challenges at the European level.

The Strategic Research Roadmap is the result of a collaboration between the members of the cluster research projects. It comprises an elaboration of a common IoT definition and vision, an identification of application domains, and an identification of technologies that will drive the IoT development towards the described vision.

While the roadmap does not have an explicit manufacturing focus, the described approaches and technologies are of high relevance to the manufacturing domain.

Manufacturing Reinvented

The White Paper “Manufacturing Reinvented - How Technology is changing the Future of Manufacturing” was written by a team from TATA Consultancy Services, a provider of IT- and outsourcing services and business solutions for globally acting enterprises. It suggests, among others, 7 megatrends influencing the manufacturing world and how business models should be changed according to this .