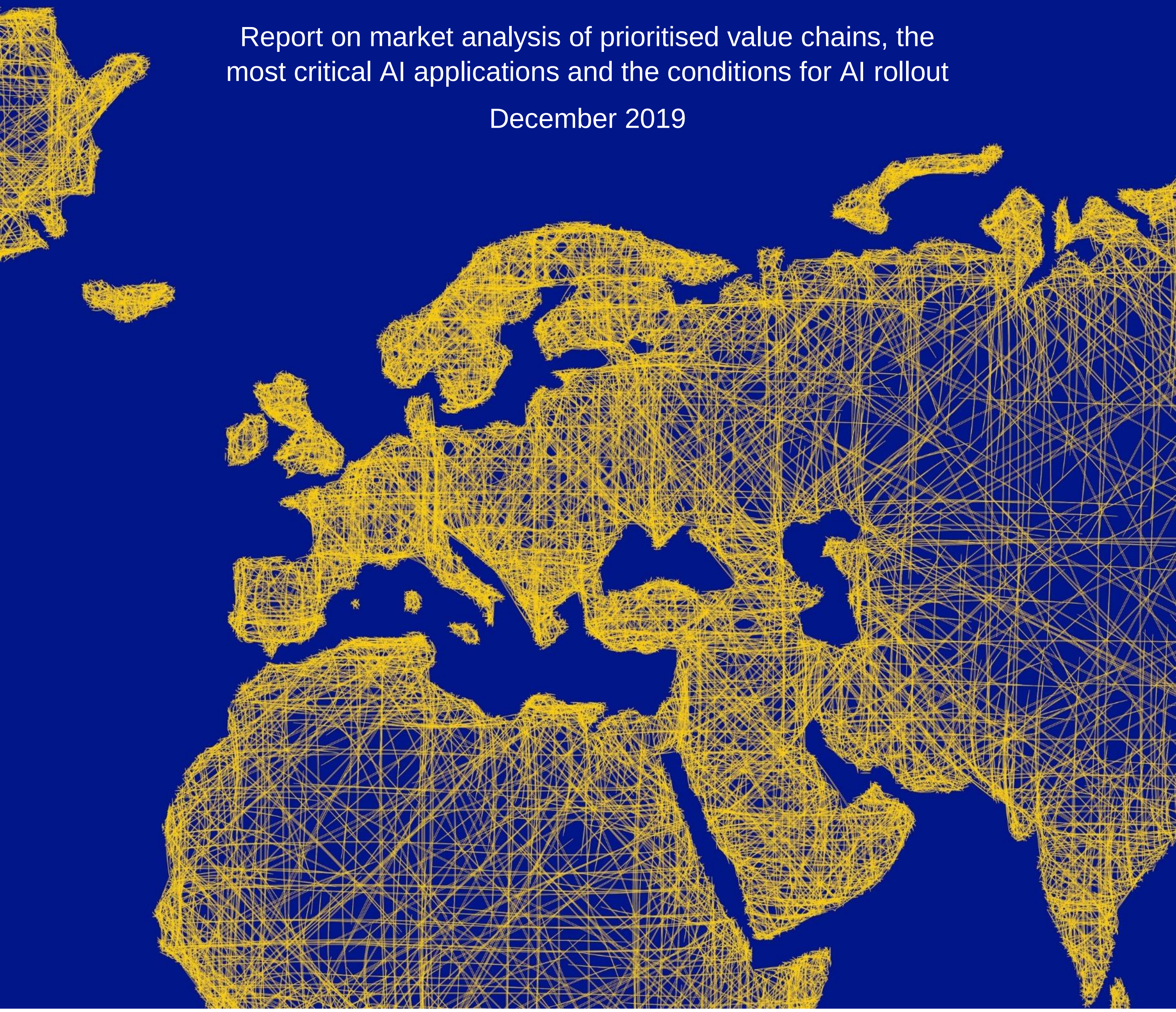
Artificial intelligence – critical industrial applications

Report on market analysis of prioritised value chains, the most critical AI applications and the conditions for AI rollout

December 2019



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Executive summary

Advanced artificial intelligence (AI) techniques are no longer a thing of the future. In the past several years, AI has not only moved to the top of the agenda for businesses, but also for policymakers, academic research institutions and the broader public. AI techniques are expected to bring numerous benefits in the form of added value for citizens, higher productivity, improved corporate performance and economic growth. At the same time, AI has the potential to disrupt existing business models, possibly displacing successful ones and impacting the way people live and work. To keep up with the evolution of AI and realise the competitive advantages it can provide, companies need to invest in technology and innovation. This poses a particular challenge for small and medium-sized enterprises (SMEs), which form the backbone of the European economy. Therefore, it is crucial that SMEs are given the best conditions to implement and capitalise on the value of AI applications.

Against this backdrop, EASME and DG GROW aim to identify the optimal mix of industrial policy measures that create a favourable framework for the development and uptake of AI applications by European SMEs, including a successful transition that fully embraces the benefits of AI and mitigates the risks associated with it.

The first part of this report constitutes an in-depth **evaluation of three prioritised strategic value chains:** the Industrial Internet of Things (IIoT), future mobility and smart health. For each strategic value chain, their core capabilities as well as the relevance of the respective sub-value chains to the EU-28 in terms of employment and economic value added are discussed. The analysis provides a quantitative assessment of the potential impact of AI on the three prioritised strategic value chains. It also discusses the role and relevance of SMEs in the respective strategic value chains and outlines further opportunities for capturing value. Lastly, the analysis assesses the competitiveness of the prioritised value chains in a global context. The following provides a condensed summary of our key findings for each value chain.

IIoT

- The IIoT value chain builds on core capabilities, namely (i) product and service development, (ii) supply chain and production planning, (iii) core production and (iv) after-sales/value-added services, supported and facilitated by (v) key enablers such as cybersecurity or IoT platforms.
- Given the large amount of potentially available data in manufacturing, the potential of AI to increase efficiency, fuel innovation and enable new

products, services and business models is huge. Currently, less than 1 per cent of potentially usable data is actually used in IIoT.

- According to the McKinsey Global Institute's AI use case database, the overall AI impact potential on the IIoT value chain in Europe is estimated at approximately EUR 200 billion. Core production (about EUR 80 billion) and supply chain and production planning (about EUR 70 billion) account for the largest shares.
- Because of a lack of talent, infrastructure and in some cases financing, as well as a limited understanding of AI potential, many SMEs face challenges applying AI. They also face increased competition from born digital SMEs/ start-ups that disrupt all parts of the value chain.
- The environment for AI could be improved in Europe. A global competitive-fit analysis of the European IIoT value chain reveals strong performance in research, on-par performance in skills and funding, but lagging performance in regulation and infrastructure dimensions.

Future mobility

- The future mobility value chain builds on four sub-value chains, namely (i) vehicles, (ii) mobility services and operations and (iii) infrastructure, interlinked by (iv) data platforms that serve as key enablers of the ecosystem.
- Within the future mobility ecosystem, the vehicles sub-value chain accounts for the highest share of economic value added (3.6 per cent of economic value added in the EU-28, or EUR 479.6 billion), as well as for the highest share of employment (3.3 per cent of employees in the EU-28, or 7.7 million) (Eurostat, 2019).
- According to the McKinsey Global Institute, the AI impact potential on the future mobility value chain is estimated at about EUR 300 billion. The highest AI impact potential was identified within mobility services and operations, coming in at approximately EUR 225 billion, followed by about EUR 70 billion and about EUR 5 billion for vehicles and infrastructure, respectively.
- The ongoing shift from mobility product revenue to mobility service revenue, as well as the emergence of an ecosystem in the supply of digital and non-digital infrastructure, opens up opportunities for SMEs to collaborate with incumbent players, i.e. OEMs.
- The global competitive-fit analysis of the European future mobility value chain reveals strong performance in research and improvement potential in funding, skills and regulation. The value chain is found to be on par with the US and China in terms of infrastructure.

Smart health

- The smart health value chain includes four sub-value chains as its major building blocks: (i) industry, (ii) health service provision, (iii) governance and (iv) administration/payors.
- Health service provision is by far the most important sub-value chain in Europe – from both an economic perspective (a value added of EUR 840.7 billion) and an employment perspective (19.3 million employees in total). It is followed by the industry sub-value chain (Eurostat, 2019).
- According to the McKinsey Global Institute, the overall AI impact potential on the smart health value chain in Europe is estimated at approximately EUR 120 billion – with the biggest impact on health service provision (about EUR 70 billion) and industry (about EUR 20 billion), followed by governance and administration/payors (about EUR 15 billion, respectively)
- The global competitive fit analysis reveals strong performance in research, on-par performance in skills and funding, but lagging performance in regulation and infrastructure.
- The opportunity for AI-enabled process automation in health service provision and the increasing awareness of preventive healthcare represent great value creation potential, especially for smart health start-ups.

The second section of this report contains in-depth **analyses of the most critical AI application** within each of the three prioritised strategic value chains: IIoT, future mobility and smart health. For each strategic value chain, a longlist of critical industrial AI applications that are already relevant and broadly used or that will soon become relevant and broadly used is created. Each AI application is described based on predefined dimensions (grouped according to the sub-value chain, AI capability used, how it works, examples). Next, the AI applications are prioritised based on a set of criteria that includes expert feedback and the economic relevance of the respective sub-value chains. Lastly, the prioritised AI applications are evaluated based on their social, environmental and economic impact. Thus, the analysis reflects some of the top priorities in the political guidelines of the newly elected European Commission, such as an economy that works for people, the European Green Deal, a Europe fit for the digital age, and a stronger Europe in the world. The following provides a condensed summary of our key findings for each value chain.

IIoT

- Overall, we identified 24 relevant AI applications. Three AI applications thereof belong to the **product and service development** sub-value chain, six to the **supply chain and production planning** sub-value chain, eight to the **core production** sub-value chain, six to the **after-sales/value-added services** sub-value chain and one to the **key enablers** sub-value chain.

- After the prioritisation of these 24 AI applications, we arrived at a shortlist of eight prioritised IIoT AI applications. One out of these eight AI applications is part of the product and service development sub-value chain, two belong to the supply chain and production planning sub-value chain and five are used within the core production sub-value chain.

- The impact assessment of prioritised AI applications beyond GDP revealed high economic impact potential (as the AI applications significantly contribute to increasing productivity, enhancing process efficiency and reducing cost), highly relevant environmental impact (as the AI applications reduce waste and allow for better use of resources) and – in part – significant social impact (as they improve safety in the workplace, help automate repetitive, physically demanding activities and create more meaningful work tailored to employees' skills).

Future mobility

- Overall, we identified 23 relevant AI applications in future mobility. Thereof, ten AI applications belong to the **vehicles** sub-value chain, eight to the **mobility services and operations** sub-value chain and five to the **infrastructure** sub-value chain.

- After the prioritisation of these 23 AI applications, we arrived at a shortlist of six prioritised future mobility AI applications. Two out of these six applications are part of the vehicles sub-value chain, three belong to the mobility and services operations sub-value chain and one is used within the infrastructure sub-value chain. Four of these AI applications are product innovations and two represent process optimisation approaches.

- The impact assessment of prioritised AI applications beyond GDP revealed high social impact potential for all six AI applications (e.g. enhanced road safety, fewer traffic accidents and more inclusive mobility), a positive impact on our climate (e.g. reduced pollution, energy consumption and congestion) as well as a positive economic impact (e.g. reduced maintenance or overall costs, enhanced productivity of drivers/commuters).

Smart health

- Overall, we identified 29 relevant AI applications in smart health. Thereof, four AI applications belong to the **industry** sub-value chain, 16 to the **health service provision** sub-value chain, seven to the **governance** sub-value chain and two to the **administration/payors** sub-value chain.

- After the prioritisation of these 29 AI applications, we arrived at a shortlist of seven prioritised smart health AI applications. Six out of the seven are part of the health service provision sub-value chain, one belongs to the governance sub-value chain. Three of these AI applications are product innovations and four represent process optimisation approaches.

- The impact assessment of prioritised AI applications beyond GDP revealed both high social impact (e.g. significant contribution to the well-being/health of individuals, considerable improvement of public health) and high economic impact potential (e.g. decreased healthcare [delivery] costs) for all seven prioritised AI applications. The environmental impact of the selected AI applications is less important and mostly indirect.

The **analysis of the conditions for rollout of the most critical AI applications** reveals that the major general barriers to AI adoption perceived by European SMEs include uncertain/only long-term return on investment, missing business cases, lack of digital/managerial skills and lack of access to external funding. The analysis also touches upon specific barriers that European SMEs see as particularly relevant within their respective strategic value chains. In a next step, the analysis highlights that policymakers can also support the adoption and rollout of AI by fostering specific AI enablers. These include digital absorption, innovation foundation, human capital, connectedness and labour market structure and flexibility. Based on the identified barriers and enablers, opportunities to accelerate the rollout of AI in Europe are analysed in a forward-looking SWOT analysis. The analysis reveals Europe's strong research landscape as a significant strength, its scattered and uncertain regulatory landscape in critical areas for AI rollout as one critical weakness, its increasing pool of digital talent as a great opportunity and its widening gap in digital/AI patents as a threat that should not be neglected. As both barriers and enablers are not AI-application specific, the analysis shows five high-priority policy domains to support both the development and deployment of AI in Europe. These include transparent and easy access to public funding, support of data exchange, enablement of learning and networking among stakeholders, promotion of the development of AI-relevant skills and fostering a more positive attitude towards AI. The analysis closes with potential actions that policymakers can take across these five policy domains for the AI application of autonomous driving.

Context of this report

AI has started to transform economies globally – but Europe needs to act to capture the full socioeconomic impact

An ongoing research effort by the McKinsey Global Institute (MGI) (MGI, 2018; MGI, 2019) estimates that if European industries act according to their existing assets and competencies (R&D ability, education, competition etc.), the set of current AI technologies has the potential to create additional economic activity of approximately EUR 2.7 trillion by 2030, after deducting the costs associated with transition and implementation. This relatively large potential could be one of the principal growth factors for Europe in the medium term, given its aging population as well as the difficulties in boosting investment in industry capital and real estate since the recent crisis.

However, it is important to note that this potential will be captured at different speeds and with varying impact across European countries. Furthermore, the acceleration of AI will impact labour market dynamics. At the industry level, European tech giants and digital natives are investing in and deploying AI technologies relatively broadly. However, the high-tech sector in Europe is relatively narrow compared to US digital platforms and other high-tech giants.

SMEs will have a crucial role to play in making AI a socio-economic success in the European economy

SMEs are the backbone of European economies. Yet they are struggling more than large companies to keep up with the pace of digital transformation. There are many reasons for this. Mostly, SMEs tend to be uncertain of the business case and lack enabling factors for the transition, such as employees with the necessary technical skills or large repositories of well-structured data (European Commission, 2018a; European Commission, 2018b). SMEs also fear poor or uncertain returns (MGI, 2017). Additionally, compared to larger companies, SMEs can only distribute the fixed-cost investment required for AI adoption across a smaller revenue base.

The EU has put AI at the top of its agenda, supporting growth among SMEs – but a solid European framework is still on the way

The European Commission has defined AI as one of the most strategically important technologies of the 21st century. There's already a strong foundation of EU initiatives and regulations in the field of automation and digitisation, including the overall Digital Single Market (DSM) strategy, the General Data Protection Regulation (GDPR), the High-Level Expert Group (HLEG), the Ethics Guidelines for Trustworthy AI and the policy and investment recommendations for trustworthy AI, as well as the European AI Alliance.

An important milestone was the *Communication on artificial intelligence for Europe,* which was published in April 2018 and defined three pillars of the European approach: (i) economic and industrial capacity, (ii) socioeconomic impact (skills and jobs) and (iii) a legal and ethical framework. In December 2018, the European Commission presented a coordinated action plan on AI along with EU Member States. This effort proactively brings together countries to collaborate on bold, joint EU actions. In April 2019, the European Commission's strategy *Building trust in human-centric AI* was released, with the objective of promoting a set of requirements for ethical AI, based on the ethical guidelines prepared by the AI HLEG. This strategy will enter its pilot phase in June 2019.

While SMEs will benefit from these initiatives, they nonetheless struggle with AI adoption. They tend to be uncertain about the business case for AI and lack enabling factors for the transition towards adopting AI, such as employees with the necessary technical skills or large repositories of well-structured data. Given the relevance of SMEs for the European economy, dedicated measures to support their AI adoption are needed to close the gap.

EASME and DG GROW aim to increase SME AI-adoption rates through industrial policy

EASME and DG GROW aim to identify the optimal mix of domains for industrial policy (business, financial, investment etc.) that creates a favourable framework for the development and uptake of AI applications by European SMEs. This includes a successful transition that fully embraces the benefits of AI while mitigating the risks associated with it.

Action in the identified policy domains will be supported by a communication strategy to raise awareness – amongst SMEs and citizens – of the benefits and limitations of AI to improve its acceptance. Overall, the effort will build on relevant existing European Commission activities.

This report is the first step in a series of analyses that facilitates the identification of domains for industrial policy

This report includes three deliverables of the EASME project 'Artificial intelligence – critical industrial applications': the market analysis of prioritised value chains (market analysis report), the analysis of the most critical AI applications (report on the most critical AI applications) and the analysis of the conditions for rollout of AI applications (report on conditions for the rollout of the most critical AI applications). The market analysis of the prioritised value chains presents an analysis of the role of AI and the relevance of SMEs in a set of three prioritised strategic value chains in Europe, namely IIoT, future mobility and smart health. The findings of this analysis then inform the identification of critical AI applications within the prioritised strategic value chains. These two analyses are used to develop a framework for a rollout concept for the most critical AI applications.

Moreover, a foresight scenario on the impact of AI in the relevant industrial sectors that are highly affected by the dynamics within the prioritised strategic value chains will be developed. This scenario will consider, in particular, the effects of AI on labour in the relevant industrial sectors.

Throughout the analyses, ‘AI applications’ should be understood as particular applications based on AI technology that are used in various industries and business contexts to help solve complex problems. The analyses focus on AI applications that are already or may become relevant within the prioritised strategic value chains in the near future.

The analyses outlined above will be combined with an assessment of existing European policies (‘policy baseline’) and notable policy gaps to deduce domains for industrial policy. The analysis of the role of AI and the relevance of SMEs in the three selected strategic value chains will thus inform the selection of policy domains in which action could be taken to support the development and deployment of AI among European SMEs.

A – Market analysis of prioritised value chains

0 APPROACH AND METHODOLOGY

The objective of this market analysis report is to provide an in-depth examination of the relevance of AI for a set of strategic value chains in the European economy. Moreover, the report also explores the role of and opportunities for competitive advantages for European SMEs within these strategic value chains. In doing so, the report lays the foundation for further analyses, including (i) the identification of the most critical AI applications within these strategic value chains and (ii) an exploration of the conditions for a full rollout of one cluster of these AI applications.

This chapter describes the approach and methodology that the project team applied to develop the analysis underlying this report. Specifically, it covers:

(1) The approach to selecting the set of strategic value chains to be analysed
(2) The approach to describing and mapping the strategic value chains, including their core capabilities
(3) The methodology for identifying the transformative impact of AI within each value chain
(4) The methodology for assessing the role of SMEs in each value chain.

Selection of prioritised strategic value chains for the project

The analysis presented in this report will focus on three prioritised strategic value chains, namely:

(1) IIoT
(2) Future mobility
(3) Smart health.

Strategic value chains are defined by the Strategic Forum for Important Projects of Common European Interest as holistic ecosystems of new technologies and innovation that are of strategic European interest for competitiveness and technological autonomy. Focussing the analysis on strategic value chains – rather than industries – enables this project to build on previous work by the Strategic Forum. Doing so thus avoids duplicating analyses already conducted by the Strategic Forum and further contributes to the identification of policy domains that is coherent with the EC’s overall industrial policy.

The analysis of the Strategic Forum focussed on a set of key strategic value chains. The Strategic Forum prioritised six such value chains from a pool of 36 due to (i) their relevance for a larger number of EU Member States and (ii) the potential for coordinated investments across EU Member States. These six value chains are IIoT, future mobility/CCAV, smart health, cybersecurity, hydrogen solutions and technologies and low-carbon industries.

For the purposes of this project, from these six strategic value chains, the three value chains mentioned initially (IIoT, future mobility/CCAV, smart health) were selected for in-depth analysis based on the following criteria (see Exhibit 1):

- Economic relevance of the value chain (in terms of GDP and employment)
- Impact potential of AI applications within the value chain
- Role of SMEs in the value chain
- Competitive fit of the value chain with the European economy.

EXHIBIT 1: SELECTION CRITERIA

Selection criteria for strategic value chain

Selection criterion		Description
A Economic relevance of SVC	GDP	▪ **Share of GDP affected:** share of EU28 GDP in industry sectors that are core to specific SVC ▪ **Expected impact of SVC on industries:** reflects the transformative impact of the SVC within the relevant industry sectors (e.g. does the SVC require adaptations of or fundamental shifts in business models?)
	Employment	▪ **Share of employment affected**: share of EU28 employment in industry sectors that are core to specific SVC ▪ **Expected impact of SVC on employment**: reflects the transformative impact of the SVC on employment within the underlying industry sectors (e.g. does the SVC endanger a large number of existing jobs?)
B AI impact potential		▪ Reflects the **expected role and relevance of AI** within the SVC (e.g. are **AI applications a key enabler** within the value chain?)
C Role of SMEs		▪ Reflects the **role of European SMEs within the strategic value chain** (e.g. do SMEs only play a minor role within the SVC, or are they **key players in the relevant industrial sectors** as well as **potential drivers of innovation and the application of AI in the SVC?)**
D Competitive fit		▪ Reflects the **strengths of the European economy** with respect to the specific SVC, e.g. the existence of **relevant industry ecosystems** as well as of **technological foundations** (innovation, R&D, institutions) to build a competitive SVC in the EU

SOURCE: ToR; project team

Based on the criteria described above, the project team evaluated the six strategic value chains identified by the Strategic Forum. To better quantify some aspects related to the economic relevance of these value chains (e.g. employment), the value chains were mapped to clusters of industries that are highly relevant to the respective value chain. The resulting assessment is presented in Exhibit 2.

EXHIBIT 2: EVALUATION OF SIX IPCEI STRATEGIC VALUE CHAINS

Evaluation of six IPCEI strategic value chains (1/2)

High | Medium | Low

A Economic relevance of SVC

Strategic value chains (SVCs) prioritised for IPCEI initiative[1]	Share of EU28 GDP affected[2]	Expected impact of SVC on industries	Share of EU28 employment affected[2]	Expected impact of SVC on employment
Clean, connected and autonomous vehicles (CCAV)	6%	Fundamental shift in transport industry from gas-fired, human- controlled to carbon-free, autonomous transport	6%	Core European industry sectors will have to succeed in this SVC or might struggle, e.g. automotive industry (OEMs and suppliers)
Cybersecurity	100% (indirectly)	Requires adaptation of existing business models (e.g. to cyberattacks) and enables new business models	100% (indirectly)	Without own cybersecurity compe-tencies, EU depends on third-party solutions, leading to a strategic disadvantage in the medium term
Hydrogen solutions and technologies	4%	Transformative changes in mobility and energy production from carbon-emitting to hydrogen-fuelled	3%	Shift to new fuels will require changes to qualifications, job profiles and activities in various transportation-related sectors
Industrial Internet of Things (IIoT)	17%	Holistic digital transformation of all manufacturing activities	15%	If IIoT is not implemented, excellent European manufacturing expertise and a high number of jobs will be lost to international competition
Low-carbon industries	5%	Transformative changes to specific industries (e.g. cement, chemicals, steel) to reduce carbon emissions	2%	Reduction of carbon emissions and associated technology shift (e.g. electrification) will require changes to qualifications and activities
Smart health	8%	Opens up new possibilities in healthcare provision, from innovation and therapeutics to care and services	9%	Telemedicine, surgical/care robots as well as smart medical devices will change health businesses' and professionals' activities

1 Reflects strategic relevance for EU; 2 Based on 2016 data. High: >50%; medium: 10-50%; low: <10%

SOURCE: Strategic Forum reports on SVCs; project team

SELECTION OF 24 FOCUS STRATEGIC VALUE CHAINS

Based on this criteria, we conducted a first analysis of the 6 SVCs (2/2)

High | Medium | Low

Strategic value chains (SVCs) prioritised for IPCEI initiative[1]	B AI impact potential	C Role of SMEs	D Competitive fit	E Fit with DG GROW's sector portfolio
Clean, connected and autonomous vehicles (CCAV)	AI is key enabler for automated mobility, but Europe is currently at a disadvantage especially in developing AI chips	Traditional supplier SMEs at risk; EU mobility start-ups lack funding and are not yet competitive with US or Israel	EU hosts a huge ecosystem of relevant players (9 out of top-20 suppliers globally) and R&D capabilities	Fits with automotive industry; industrial parts of aeronautics, maritime and space industries
Cybersecurity	AI is key for cybersecurity applications and vice versa – but currently too limited research into cybersecurity for AI applications	Strong, innovative EU SMEs and start-ups in the value chain, but currently lack capacity to scale up	EU with good R&D foundations, but challenges with transfer into business models	Fits indirectly (by indirectly affecting the whole economy)
Hydrogen solutions and technologies	AI is not a key enabler for hydrogen technologies, but will help to improve hydrogen solutions in the long term	EU with key technologies; SMEs and start-ups are key drivers of innovation in hydrogen technologies	EU leading in technological foundations (incl. patents) and applications along the full SVC	Fits with automotive ind., che-micals, pressure equipment and gas appl., ind. parts of aeronau-tics, maritime and space ind.
Industrial Internet of Things (IIoT)	AI is a key enabler for data analysis and for analytics-based decision making in this SVC	SMEs are key players in manufacturing technology, but are at risk due to high cost of setting up IIoT platforms	Strong EU position in advan-ced manufacturing (techno-logies); e.g. >30% of global market share in mech. eng.	Fits with electrical, electronic and mechanical eng., ind. parts of aeronautics, maritime and space ind., and automotive ind.
Low-carbon industries	AI is not a key enabler for innovation in low-carbon industries, but relevant for specific applications in the long term	SMEs and start-ups are not key drivers of innovation; SMEs' contribution to the sector's value-add is particularly low	Industry sectors of high relevance but key technological advances in early phase	Fits with construction and chemicals
Smart health	AI is a key enabler, e.g. in supporting medical diagnostics, managing patient and clinical data, and enhancing R&D	Increasing number of entrepreneurs; innovation driven by SMEs and digital health start-ups in particular	EU with leading players (e.g. pharma, med tech), strong innovation capacity and sophisticated health systems	Fits with healthcare industries (medical devices, pharma, biotech); DG GROW does not cover healthcare services

1 Reflects strategic relevance for EU

SOURCE: Strategic Forum reports on SVCs; project team

Building on this fact base, during a joint brainstorming session with the project team, the European Commission prioritised the three strategic value chains of IIoT, future mobility/CCAV and smart health. The IIoT value chain was selected due to its extremely wide applicability across the economy, the competitive advantage created by the European industrial ecosystem, and the importance of SMEs accessing IIoT expertise and platforms to remain competitive. The CCAV strategic value chain was chosen due to the fact that a large industrial sector is at risk if the transition to clean, connected and autonomous vehicles and modes of transport is not successful and because of the essential role that AI plays in enabling connected and autonomous mobility in particular. The smart health value chain, finally, was selected because of the crucial importance of ensuring effective and efficient healthcare provision in economies that face demographic challenges as well as fiscal constraints and the fact that there is a thriving and competitive ecosystem of digital health start-ups already established in Europe. Cybersecurity and adjacent service industries (e.g. insurance and payment providers) are considered enablers within each value chain.

Note that the CCAV strategic value chain is conceived of broadly as the ‘future of mobility’ ecosystem. Furthermore, the IIoT value chain is understood as focussing specifically on digitised manufacturing, rather than on matters related to infrastructure or smart cities.

Description of core capabilities of the value chain

Each strategic value chain is modelled as a structured ecosystem, which reflects the different functions that are performed by actors in the ecosystem. On a general level, this includes the development and production of relevant physical products (e.g. cars), as well as the provision of services (which may interact with the products, e.g. fleet management) and enabling functions (e.g. sensor networks and transmission infrastructure necessary for smart mobility). This functional ecosystem perspective was chosen over a sequential value chain visualisation to better reflect the fact that these ecosystem parts will interact at different times and in various ways along the value chain. Moreover, this mapping approach reinforces the project’s objective of fostering AI uptake amongst European SMEs by focussing the view on potential areas of AI impact within each strategic value chain.

The initial mapping was developed based on a review of relevant literature and related work, including the Strategic Forum’s work on the value chains (as part of the IPCEI effort). This mapping was then validated and refined through a series of interviews with internal and external experts, as well as in the breakout groups of the first multi-stakeholder workshop.

For each of the prioritised strategic value chains, the core capabilities are discussed and additional relevant information provided, including a description of the AI-related technologies and applications that are essential for each strategic value chain and that could bring transformative change to the strategic value chain overall.

Analysis of the transformative impact of AI in the value chain

To assess the transformative impact of AI within each strategic value chain, the two angles were considered:

(1) The economic relevance of the value chain sub segments
(2) The impact potential of AI within specific sub segments.

This approach reflects the fact that total impact from medium AI potential for a very large economic segment may surpass large AI potential for a relatively small segment.

Box 1: Assessing the impact potential of AI

AI technologies have the potential to create positive impact across many different aspects of our lives, which far surpasses mere economic growth. For instance, in the social domain, AI could contribute to greater fairness in society by reducing the impact of human biases or enable longer, more healthy lives through more targeted health care that emphasises prevention. In the environmental domain, AI could provide benefits such as increased resource efficiency (including energy consumption) in production processes or more sustainable modes for personal mobility.

While these non-economic benefits are clearly highly relevant and may even contribute to the adoption of AI, there is no one consensual, overarching framework for quantifying them. One reason for this is that there are no widely agreed units of measurement for social or environmental impact: measurements could range from the diversity of a firm's workforce (if AI were to de-bias hiring decisions) over the number of life years gained (if AI were to improve preventive care) to the amount of industrial waste (if AI were to increase the resource efficiency in production) or the reduction in CO_2 emissions (if AI were to enable sustainable mobility).

There are already numerous attempts to aggregate these diverse measures for social and environmental well-being into summary values, such as the OECD's Better Life Index or the Human Development Index. However, quantifying the incremental effect of AI technologies on such summary indices would be highly conjectural, as no reliable information across the entire application landscape is available yet.

With respect to economic impact, GDP provides a globally standardised, widely recognised concept that allows for quantification and aggregation of effects. We therefore use the lens of economic impact for an initial assessment of AI's impact potential across different value chain parts. A more in-depth perspective on the social and environmental impact potential is included in the detailed analysis of the most promising individual AI applications.

To assess economic relevance, the same metrics were used as in the prioritisation of the three strategic value chains. Value chain sub segments were evaluated regarding GDP contribution and employment (data source: Eurostat).

To assess the impact potential of AI, the project team utilised a dual approach. First, the team mapped relevant use cases from the McKinsey Global Institute's use case library to the segments of the prioritised value chains. This provides a simple count of the number of relevant use cases that exist in each area. Second, the project team used global MGI data on the effect of these applications to identify high-impact areas. These high-impact areas may differ from the pattern obtained by a simple count, since some AI applications would have an inherently higher impact potential than others. A more detailed and Europe-specific perspective on the impact will be developed as part of the foresight scenario.

Box 2: The MGI use case library

We build our analysis on MGI's library containing more than 440 use cases, covering 19 industries and nine business functions. The term 'use case' refers to the targeted application of technologies in the sphere of AI and automation to a specific business challenge, with a measurable outcome.

These use cases are rooted in the contractor's client work, about 30 per cent of which is with European clients. As AI adoption relies on a set of preconditions, such as the overall level of digitisation and the skill level of the working population, the use cases centre on the European countries' economies most advanced in these areas, such as the UK, Germany and Sweden. They include real-life examples of companies and public-sector organisations using a range of AI techniques as well as the potential application of these techniques in situations similar to those in which they have already been successfully deployed. For example, a pricing promotion use case in travel could be applied in other sectors, such as retail. This also means that speculative use cases involving the creation of entirely new product or service categories are not covered. Where possible, multiple instances of an individual use case were identified and analysed.

For each use case, the annual value potential of applying AI techniques across the entire economy is estimated by scaling the observed impact across the relevant business function and industry. This value potential could be captured by companies and organisations themselves, in the form of increased profits, or by their customers, in the form of lower prices or higher quality.[1] Estimates are based on the structure of the global economy in 2016.

1 For use cases that involve increasing revenue, such as those in sales and marketing, the economy-wide value potential in terms of the increased potential productivity of sales and marketing expenditures was

The analysis of the transformative impact of AI in the value chains builds on the contractor's knowledge and expertise, specifically as related to the prioritised strategic value chains, related industry sectors, application of AI technologies by businesses within these strategic value chains as well as strategies that businesses pursue regarding the adoption of AI technologies. Initial findings on the impact of AI in each value chain were then validated and refined through a series of expert interviews, as well as in the breakout groups of the first and second multi-stakeholder workshop.

Analysis of the role of SMEs in the value chain

For each prioritised strategic value chain, the roles of different value chain stakeholders were analysed, including SMEs, but also, e.g. research institutions, public-sector bodies or large corporations, within them. An overview was gained on which parts of the strategic value chain SMEs already play a role and what their contributions look like as well as where future opportunities or challenges may lie. This analysis follows the EC's definition of SMEs as enterprises with fewer than 250 employees and either a maximum turnover of EUR 50 million or a maximum balance sheet total of EUR 43 million.

In doing so, a differentiation can be seen between SMEs that are driving innovation within a strategic value chain or SMEs being affected by AI-induced changes within the value chain and established SMEs and start-ups or entrepreneurs. As for other components of the assessment, the results of this analysis are validated in a series of expert interviews and through multi-stakeholder workshops.

Next steps after the market analysis report

The analysis of the transformative impact of AI within each value chain will, in the next step, lead to the creation of a longlist of critical AI applications, which is mapped to the sub segments of each strategic value chain. Based on a set of criteria – including experts' assessment of the applications' relevance and their potential to generate economic, social and environmental impact – a short list of critical AI applications will be prioritised. Keeping these critical applications in mind, challenges potentially hindering uptake of the AI applications will be assessed, and conditions for rollout of these applications from a business perspective explored.

calculated, assuming that overall annual spend in the economy is fixed in a given year (rather than estimating the impact of higher revenues, which would have assumed that overall spending would increase).

1 INDUSTRIAL INTERNET OF THINGS (IIOT)

Summary of key insights

- The Industrial Internet of Things (IIoT) value chain should be thought of as the ecosystem bringing the Internet of Things to industrial manufacturing processes along the full spectrum of goods-production activities from product development to after-sales services.
- Given the large amount of potentially available data in manufacturing, the potential of AI to increase efficiency, enable new products, services and business models as well as to fuel innovation is huge. Currently, less than 1 per cent of potentially usable data is actually used in IIoT and more than 70 per cent of companies are struggling to scale solutions and capture the value.
- The IIoT value chain builds on five core capabilities, namely (i) product and service development, (ii) supply chain and production planning, (iii) core production, (iv) after-sales/value-added services, supported and facilitated by (v) key enablers such as cybersecurity or IIoT platforms.
- Use cases of AI application can be found along the full spectrum of IIoT activities and highlight the large economic potential of applying AI-based technologies. According to the McKinsey Global Institute's AI use case database, the overall AI impact potential on the IIoT value chain in Europe is estimated to approximately EUR 200 billion. Core production (about EUR 80 billion), including increased asset reliability and the deployment of robots and connected devices amongst humans, as well as supply chain and production planning (about EUR 70 billion) take the largest shares. AI-based demand forecasting can, e.g. allow automotive OEMs to reduce inventory for selective parts by 45 per cent.
- Stakeholders in IIoT range from multinational manufacturing giants to highly specialised niche market SMEs. The latter often dispose of deep technological knowledge and competences related to their niche products as well as their specific product markets.
- At the same time, SMEs face particular challenges applying AI because they often have a limited understanding of AI's potential for their specific context. Moreover, many of them lack AI-related skills and infrastructure, or are constrained by their small scale or in some cases financing. They further face increased competition from born-digital SMEs/start-ups that disrupt all parts of the value chain. Amidst other activities, embracing the potential of AI within their specific ecosystem of activities will allow them to defend their competitive edge.

- The environment for AI could be improved in Europe. A global competitive-fit analysis of the European IIoT value chain reveals strong performance in research, on-par performance in skills and funding but lagging in regulation and infrastructure dimensions.

Introduction

To support the European Commission in defining policies to further the competitiveness of European SMEs in the IIoT value chain, we will first describe its underlying structure. Subsequently, we discuss the economic relevance of its respective sub-value chains. Thirdly, we analyse the current and expected AI impact potential on the IIoT value chain. Fourthly, we investigate the role of SMEs in the ecosystem. Lastly, we discuss the competitiveness of the European IIoT value chain in a global context.

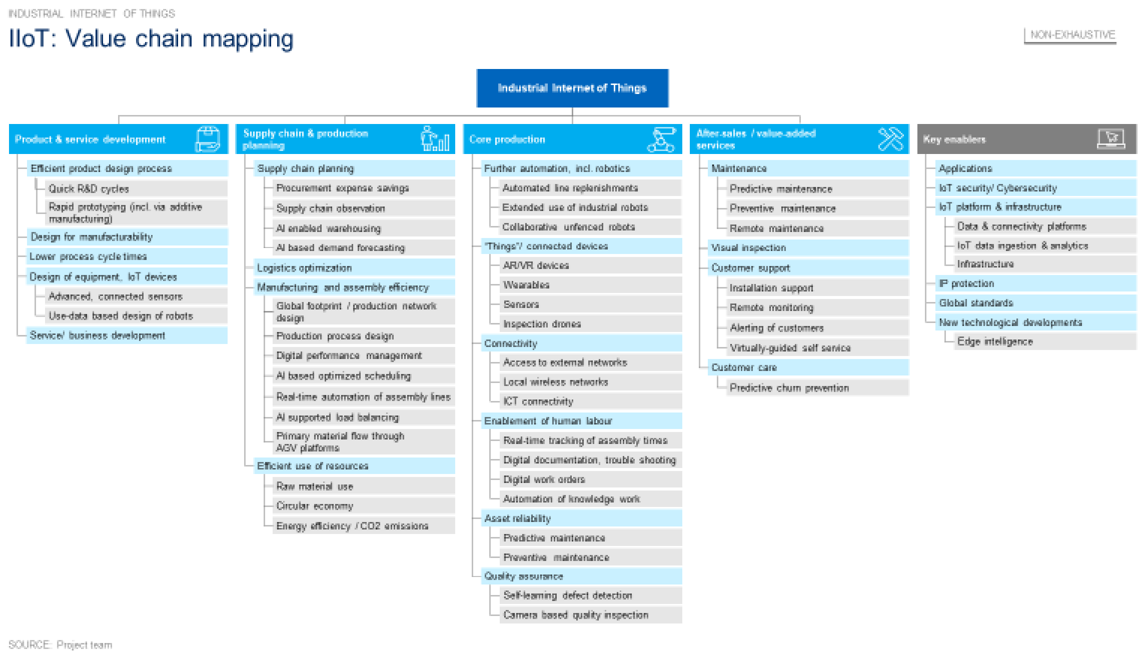
1.1 Core characteristics of the IIoT value chain

The strategic value chain IIoT is about the digitised manufacturing processes covering the full range of activities relevant to production from product development to after-sales services. Accordingly, the IIoT value chain is composed of the four core building blocks:

- Product and service development
- Supply chain and production planning
- Core production
- After-sales/value-added services.

A fifth building block, key enablers, serves as the underlying layer to the first four and contributes to their (technological) functionality and integration. All building blocks comprise closely integrated sub-value chains and each cover a wide range of functions and players. Exhibit 3 provides the corresponding value chain structure, detailing (non-exhaustively) which segments the aforementioned sub-value chains may encompass. Conceptually, the IIoT value chain should be thought of as an ecosystem, rather than a sequential chain.

EXHIBIT 3: IIOT VALUE CHAIN MAPPING



Product and service development

The building block product development encompasses the functions that are commonly associated with the development of products before actual large-scale production begins, focussing on the design process. Relevant segments of product and service development are the efficiency of the product design process itself, product optimisation and the design of IIoT relevant products, including specific equipment and devices. It also includes the overall development of data-enabled services and business models within the manufacturing sphere. Efficiency gains in the product design process can be obtained from an improved organisation of R&D cycles based on continuous evaluation processes and data-based learning from R&D processes as well as rapid prototyping processes. A deep analysis of manufacturing processes allows for the design of products for manufacturability and provides the basis for efficiency gains in larger-scale production either in processes or in use of resources. The design of IIoT relevant products entails the full spectrum of hardware for data generation, ranging from advanced, connected sensors to full-scale robots.

Throughout the IIoT value chain, major stakeholders are the manufacturers themselves. The cohort of manufacturers covers the full range of production processes from small lot manufacturing to mass-customised and high-volume production as well as very different numbers of variants per factory. It includes continuous and discrete manufacturing processes and takes the full range of players from small niche focussed or highly specialised players to global enterprises and mass-market manufacturers. The majority of the manufacturers do product development internally, however, there are also manufacturers active in contract manufacturing where this is not the case. Besides the manufacturers, major stakeholders in the building block of product development can be found in companies specialised on research and product development, be they established players or start-ups.

Supply chain and production planning

The building block supply chain and production planning covers all functions that surround the core production process. This includes the planning and management of the supply chain feeding the production, as well as the efficient operation of manufacturing processes. Moreover, this building block also encompasses aspects of resource efficiency (e.g. minimisation of waste) and logistics optimisation. The supply chain planning is about identifying the best suppliers, including increasing transparency on pricing, about monitoring the supply chain, detecting potential obstacles and taking active measures to prevent bottlenecks and secure in-time provisioning as well as about optimised warehousing and improved demand forecasting to replace the traditional extrapolations. Manufacturing and assembly efficiency entails all aspects of the design of the production process, including the linkages between different production locations that allows for an overarching steering of processes. Part of this are also the real-time automation of assembly lines, digital performance management and optimised load balancing. With respect to an efficient use of resources, measures can be taken to reduce the use of raw materials and increase energy efficiency. Also, recycling and other measures with respect to a circular economy play a role.

Besides the manufacturers themselves, the major stakeholders in supply chain and production planning are providers of transport and logistics as well as warehousing services. There are also specialised players offering services along this building block, from specific energy efficiency solutions to production process design software developers.

Core production

The building block core production then reflects aspects relating to the actual manufacturing of products on the shop floor. Thus, it includes functions relevant to the manufacturing process, such as automation, the employment of connected devices, their connectivity, measures to enable human labour as well as the reliability of the assets employed and the quality assurance of products. Automation, though already advanced, can be further extended, e.g. to cover automated line replenishments, towards an extended use of industrial robots as well as to the deployment of collaborative and unfenced robots that work in close collaboration with humans. With their increased sophistication and functionalities, even more connected devices can be used in production, including augmented/virtual reality (AR/VR) devices, wearables, sensors and inspection drones. Human labour will increasingly be supported on the shop floor. Beyond the equipment used to support humans, this includes providing employees with information and decision-taking support, e.g. flexible access to digital documentations and troubleshooting support, introducing digital work orders and even automating parts of the knowledge work that accompanies production. To allow for an active and real-time steering of production processes connectivity plays a vital role and this includes the set-up of specific networks as well as the infrastructure of, e.g. local wireless networks and broader network access. Asset reliability in the form of predictive or preventive maintenance plays a vital role for increasing production times and is of particular relevance in assets that are deployed intensively or that have a higher rate of attrition. Finally, device-enabled quality assurance can provide much higher accuracy of detecting defects, e.g. in the form of camera-based quality inspections.

The **major stakeholders** in core production are the manufacturers along the full spectrum of sizes. In addition, providers of IIoT services, such as sensor manufacturers, drone builders, etc. form part of the stakeholders. Also, included are those companies that are specialised on contract manufacturing and which thus do not have either their own product development nor their own after-sales activities.

After-sales/value-added services

The building block after-sales/value-added services comprises functions that are performed once the finished product performs its intended function. It includes aspects of product maintenance and inspection, as well as customer service and care. For many products, adjacent services play an increasing role with respect to value creation and in part business models switch from selling devices to providing services (e.g. from jet engines sales to engine operating time provisioning). Data-driven supervision and the analysis of machine data play a core role in enabling such shifts in business models and allow for predictive, preventive and remote maintenance of machinery. With respect to customer support and care, aspects like installation support and virtually-guided self-service as well as remote monitoring and the alerting of customers play relevant roles.

Besides the manufacturers themselves which increasingly extend their business models into the services sphere, the major stakeholders in *after-sales/value-added services* are the wide range of providers of repair and maintenance services. Especially with respect to durable, higher-value goods used to a large extent by private households – from heating systems to cars and white goods – there exist numerous local, decentralised repair and maintenance service providers.

Enablers

The building block *key enablers* comprises those elements that are conducive to the functioning of the entire IIoT value chain from product development to after-sales services and focus in particular on software, specific solutions and standards. IIoT platforms and infrastructure form one relevant segment providing structures to connect devices and collect data as well as enabling analytical insights. A wide range of applications makes data accessible and more generally forms the interface between users and data. The whole device and data infrastructure has to be protected by IoT security and cybersecurity measures to prevent theft of data as well as interferences and manipulations of the IoT infrastructure from non-authorised sources. The functioning of the IIoT activities is enabled by (global) standards that facilitate the interlinkages between processes, players and activities as well as simplify to combine data and to integrate devices. Current technological developments provide the driving force of further innovation, product and process improvements and new as well as advancing business models.

Divergence from the IPCEI IIoT analytical report

The structure of the IIoT value chain discussed in this market analysis report differs materially from the one outlined in the IPCEI IIoT analytical report. The description of the IIoT value chain in the IPCEI report relies on a sequential framework. It consists of four process steps, all of which flow into solutions and applications, spanning:

- Capturing data
- Transferring data
- Processing data
- Analysing data.

While we understand that this framework aims to account for the inherently sequential succession of process steps in creating value from data, we find that it fails to capture the richness of the environment in which the data processes take place, including the interlinkages between the building blocks of the ecosystem and the huge variety of business models that may arise from it. Additionally, enablers cannot be accounted for in a sequential framework as they serve as underlying layer across all process steps, i.e. cybersecurity plays a role in data processing but also in data transfer. This is not reflected in the IPCEI IIoT analytical report. Thus, we use a structure that encompasses all relevant players and enablers. It reflects current thinking of the project team and was both validated and refined where needed through expert interviews, workshop participants as well as in-depth desk research. This allows us to analyse, in detail:

- The current and future impact of AI on the IIoT value chain and thus on the full spectrum of manufacturing activities (the current manufacturing environment into which IIoT is embedded is not present in the IPCEI framework)
- Where and how structural shifts in the IIoT value chain have particular impact on European SMEs.

Links to other strategic value chains

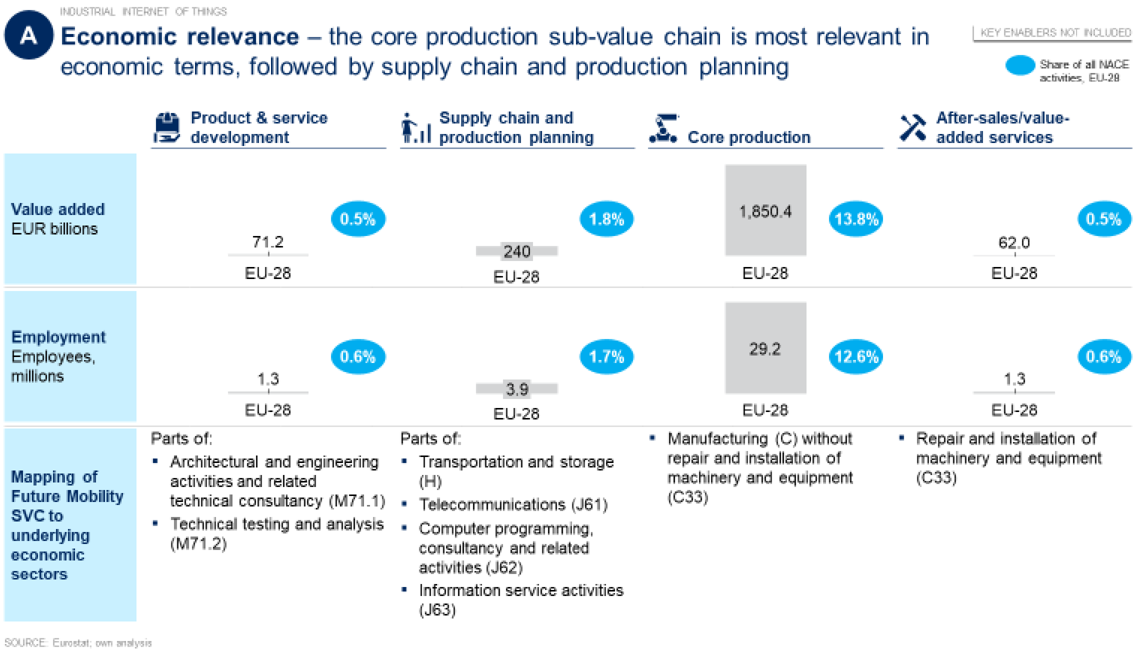
The IIoT value chain is interlinked with the clean, connected and autonomous vehicles value chain in two ways. Firstly, IIoT systems are already and will likely continue to be integrated into all stages of the vehicle manufacturing process, driving efficiency, improving quality and reducing cost. Secondly, IIoT enables the development of new products and services in the Future Mobility ecosystem, most notably autonomous driving technology. Autonomous vehicles rely on IIoT devices for data aggregation and V2X communication. Additional aspects relating to specific parts of the Future of mobility value chain can be found below.

The IIoT value chain is also interlinked with the smart health value chain, especially in the production of pharmaceuticals and medical devices. Moreover, IIoT-enabled products could enable process improvements in healthcare institutions such as hospitals.

1.2 Economic relevance

The four sub-value chains differ with respect to their economic relevance. The core production sub-value chain contributes 13.8 per cent (EUR 1.85 trillion) to the total economic value added within the EU-28 and accounts for 12.6 per cent of employment in the region (29.2 million employees). Core production is followed by supply chain and production planning, with a contribution of 1.8 per cent to total economic value added and 1.7 per cent to total employment in the EU-28. Product development and after-sales/value added services exhibit significantly less economic relevance, as can be deduced from Exhibit 4. All data was extracted from Eurostat for the last available year (2016). The sector mapping underlying the analysis is outlined in the bottom half of the exhibit. Key enablers are not quantified separately as they overlap significantly with all other building blocks of the IIoT ecosystem.

EXHIBIT 4: ECONOMIC RELEVANCE OF THE IIOT VALUE CHAIN



1.3 Current and expected AI impact in the IIoT value chain

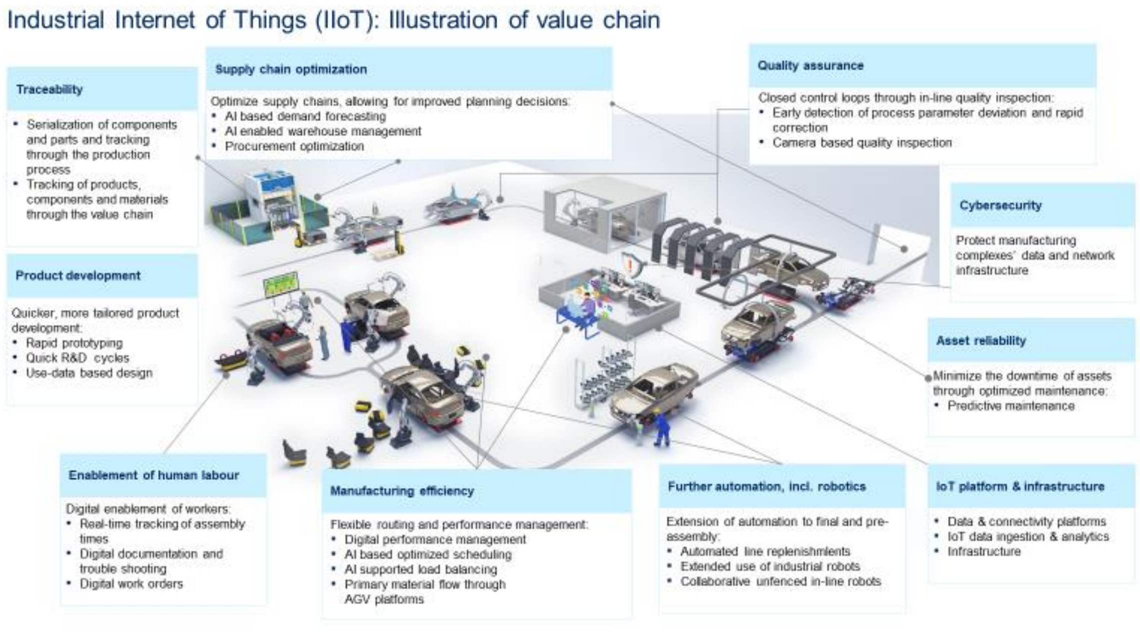
AI could greatly impact the transformation of manufacturing through an intensive use of data and the application of AI-based technologies. The McKinsey Global Institute estimates that currently only less than 1 per cent of potentially useable data is used in IIoT – much data is not even captured. In addition, more than 70 per cent of companies are struggling to scale solutions and capture the value according to an Analysis of McKinsey and the World Economic Forum (McKinsey (2019), Industry 4.0). AI-based applications have huge potential along the full value chain. In production planning, overall equipment effectiveness in machining is expected to improve by up to 80 per cent. In core production, there is a potential of 90 per cent improvement in defect detection through in-line quality inspections. Around 40 per cent capex savings can be achieved via flexible routing and performance management. In after-sales, AI provides an opportunity of up to USD 900 billion globally.

AI use cases

With regard to AI applications in IIoT, it is important to distinguish between the AI technology (e.g. a specific algorithm, usually developed by or in close collaboration with researchers), the datasets these technologies build on, and the application of both to solve a specific challenge. The challenges that can be solved by AI are often highly idiosyncratic and require a deep understanding of both the technology and the environment to which it is applied. This means that while large players may be able to develop AI applications for SMEs, these applications will need to be tailored to each individual SME's niche challenge to truly generate value. For example, a supplier of computer vision technology may offer a device able to detect tiny product anomalies that are invisible to the human eye – but the usefulness of the application depends on the SME's knowledge on which of these anomalies is irrelevant and which one may cause a product failure.

AI-powered IoT applications will likely transform all aspects of industrial ecosystems driving both process optimisation (i.e. making existing processes more efficient) and product innovation (i.e. creating new products and services). However, the degree to which AI impacts the value chain varies by sub-value chain and segment. Exhibit 5 depicts how AI might disrupt industrial production systems. It displays a production line in which machines and humans seamlessly work together, supported by AI-assisted quality assurance, and resource optimisation. Production is closely integrated with product development and equipment design, as well as supply chain planning. Parts and components are fully traceable, and downtime of assets is minimised through predictive maintenance. All digital nodes of the manufacturing complex are protected against cyberattacks.

EXHIBIT 5: ILLUSTRATION OF THE IIOT VALUE CHAIN



Product innovation

AI enables a large number of use cases that can already be found in specific settings today. Given that manufacturing processes generate a large amount of data that can be captured for analysis and insights generation and that the large majority of data is currently neither collected nor used, the current AI use cases should be considered as a small set of what may ultimately be available. This also is an indication of the large transformative potential that still lies ahead for using AI in manufacturing. The following example give a glimpse of the spectrum of use cases:

- In supply chain and production planning, AI can enable yield enhancements by identifying yield losses (products that have to be disposed/need rework) as well as the root causes of quality loss early on in the production process. Machine-learning systems allow to link process control data with quality control and yield data in real time and to analyse them in order to predict the locations of yield detractors. This helps identifying unknown problematic locations, e.g. in the physical design layout of individual microchips.
- In core production, AI enables human-machine collaboration in production making it possible for collaborative robots to work next to humans without additional safety guarding. Enhancements in object recognition and semantic segmentation in sensor technology as well as in voice interpretation allow robots to instantaneously and finely react to their environment. This implies safety guarding can be removed. Robots can be trained by ‘robot instructors’ to guide their movements.
- Also, AI enhances predictive maintenance. The manifold data generated in production can be used to extend asset life cycles and reduce breaks in the production process. Machine-learning techniques examine the relationship between a data record and the labelled output (e.g. failures) and create a data-driven model to predict those outcomes. Data records get more complex as data on sound, vibrations and other behaviours are increasingly being recorded.
- In key enablers smart clouds can be used to collect IIoT data, e.g. by connecting devices and collecting data from IIoT in a smart cloud environment. Such a smart cloud-based platform delivers a wide range of device and enterprise system connectivity protocol options, industry applications, advanced analytics and an innovative development environment. The platform focusses on interoperability of apps and standardisation of industry data.

Process optimisation

AI use cases with the focus on process optimisation can be found throughout the full value chain. The following will provide a few examples:

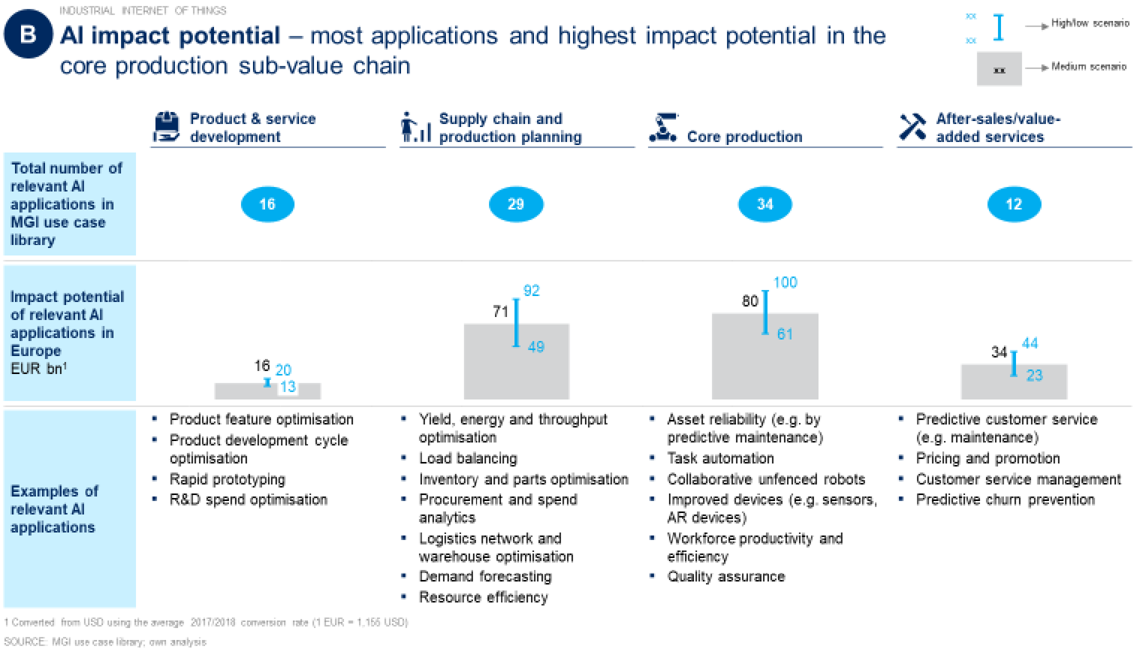
- In product development, AI-based methodologies can improve R&D project prioritisation and increase performance within individual projects by predicting outcomes of experiments to reduce experimental R&D costs (e.g. component testing, track testing), forecasting factors that might detract from performance as well as analysing communications and discovering patterns to improve team dynamics.

- In supply chain and production planning, AI-based demand forecasting will bring planning accuracy to a new level. Based on exploring the impact of a large number of variables, models can be built to predict demand. The increased planning accuracy allows, e.g. automotive OEMs to reduce inventory for selective parts by 45 per cent.
- In core production, AI-based technologies enable a new approach to quality control. Combining computer vision systems with machine learning algorithms allows to detect a wide range of defects, even at micrometre scale. Defects can be categorised correctly and products can be steered to the relevant repair units. Also, quality control processes can accompany products along the full production journey thus allowing to ensure higher levels of quality. Automotive OEMs inspect more than 2,000 vehicles per day at a speed of 10 seconds per vehicle.

Quantification of the AI impact potential for IIoT in Europe

To derive a first indication of the possible AI impact potential in the IIoT value chain in Europe, we draw on the MGI proprietary AI use case library. This library holds a collection of real-world applications of AI including the value that is created in the specific cases as well as the potential the rollout of the company-specific use cases has to other companies in the same industry and circumstances. To arrive at an estimate for the impact potential within the IIoT value chain, we aggregate the impact of those use cases which are linked to the application of IoT in manufacturing, grouped by sub-value chain. Use cases can generate impact in the form e.g. of gains in productivity through cost reductions or efficiency gains. Key enablers are again not quantified separately due to the considerable overlap with other segments. We note that the MGI use case library focusses on company-specific effects and does not account for the economic effects that go beyond companies. Thus, the total impact potential may be understated.

EXHIBIT 6: AI IMPACT POTENTIAL IN THE SUB-VALUE CHAINS OF IIOT



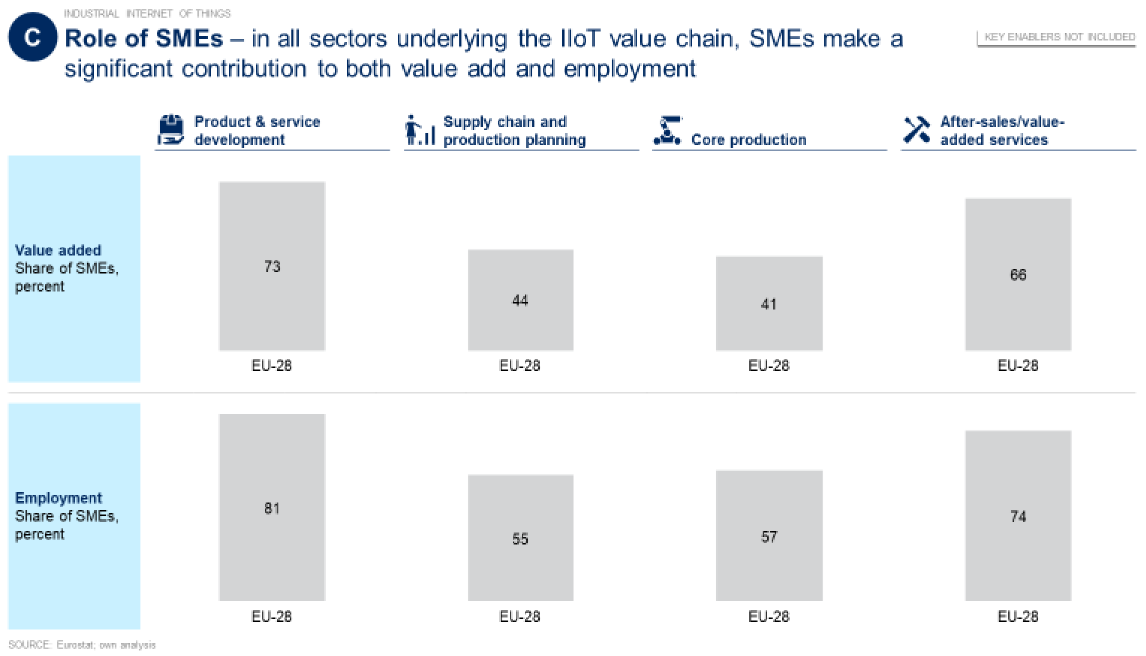
Amongst the four sub-value chains, the MGI use case library lists most applications for core production and supply chain planning. This directly translates into high potential AI impact, which comes in at EUR ~80 billion and EUR ~70 billion for core production and supply chain planning, respectively. A prominent core production use case is improved asset reliability, e.g. through predictive maintenance technology being applied to production equipment to reduce the amount of costly production downtime. Much less AI impact potential is found for product development and after-sales/value-added services.

We note that the numbers displayed in Exhibit 6 represent the AI impact that would be achievable if all companies within the ecosystem consistently followed the most advanced companies in the ecosystem in implementing AI applications. The numbers thus do not include potential economic value creation linked to the introduction of new AI-enabled IIoT businesses or business models. This is due to the structure of the MGI library, which is comprised of real and AI use cases which have been observed through the contractor's client work globally.

1.4 Role of SMEs in the IIoT value chain

The deployment of AI will impact European companies across all sub-value chains of the IIoT value chain, leading to new opportunities but also posing risks to 'traditional' business models. The impact of AI on SMEs is particularly delicate, because SMEs employ the vast majority of the workforce, as shown in Exhibit 7.

EXHIBIT 7: ROLES OF SMES IN THE IIOT SUB-VALUE CHAINS



We analysed the respective impact and changes on various types of SMEs in the ecosystem along three distinct categories of SMEs, namely **traditionalist, transitioning** and **born-digital SMEs.**

Traditional SMEs

Traditional SMEs are established SMEs which operate in traditional, mainly hardware fields of activity with rather low digitisation. Most of them lack a thorough understanding of the impact of AI on industrial processes, nor do they have a full perspective of the ongoing changes in the ecosystem they operate in. Traditional SMEs face the risk of disappearing as they lose their competitive edge and will be replaced by faster competitors, if they do not add relevant digital layers to their existing tools and machinery. While formerly the strategic advantage resided in superior hardware products, in the future the strategic advantage will be in developing and applying IIoT applications appropriately. This is underscored by the fact that highly idiosyncratic challenges will likely not be solved by 'plug-and-play'-type applications – instead, at least part of the development work will lie with the SMEs themselves.

Thus, traditional SMEs need to raise their ambition, and increase awareness for potential approaches. Additionally, they may lack talent, resources and functional infrastructure. However, many of them could directly benefit from readily available AI-based applications once they have established a strategy, which needs to be fully supported by the management. To overcome the skills gap, they may collaborate and cooperate with innovative SMEs from the wider ecosystem. Culturally, traditional SMEs have not yet fully incorporated that the data they generate as part of their business operations is of value and thus do not process and store it accordingly.

Transitioning SMEs

Transitioning SMEs have understood the impact potential of AI and begin to transition, albeit at different paces. For some transitioning SMEs applying AI in an industrial context is the logical consequence that follows from the digitisation of manufacturing activities. As more data is produced, it must be collected, analysed and used in a strategic way. By taking this step, SMEs can preserve their unique technical know-how and bring their competitive advantage to AI-enabled IIoT. Adding applications to the tools, sensors, machinery and other equipment they produce, SMEs ensure that their products continue to be integrated into the ecosystems they operate in.

Also, while there will be standardisation in IIoT platforms in the long run (e.g., because of network effects and economies of scale), applications – i.e. specific, tailored solutions that address a highly idiosyncratic challenge – that are based on those platforms will remain individual and thus a niche for SMEs to settle in. As the fixed costs of developing proprietary AI technology, platforms or the like are (in most cases) too high for SMEs, they will rely on offers available on the market. To succeed, SMEs must become fully aware of the strategic relevance of their data, including its value to different partners or customers, but also the risks and opportunities involved in sharing or selling data. As they are confronted with a huge range of applications, AI technologies and potential use cases, transitioning SMEs must make sensible decisions and designate clear priorities. In general, transitioning SMEs may use AI to

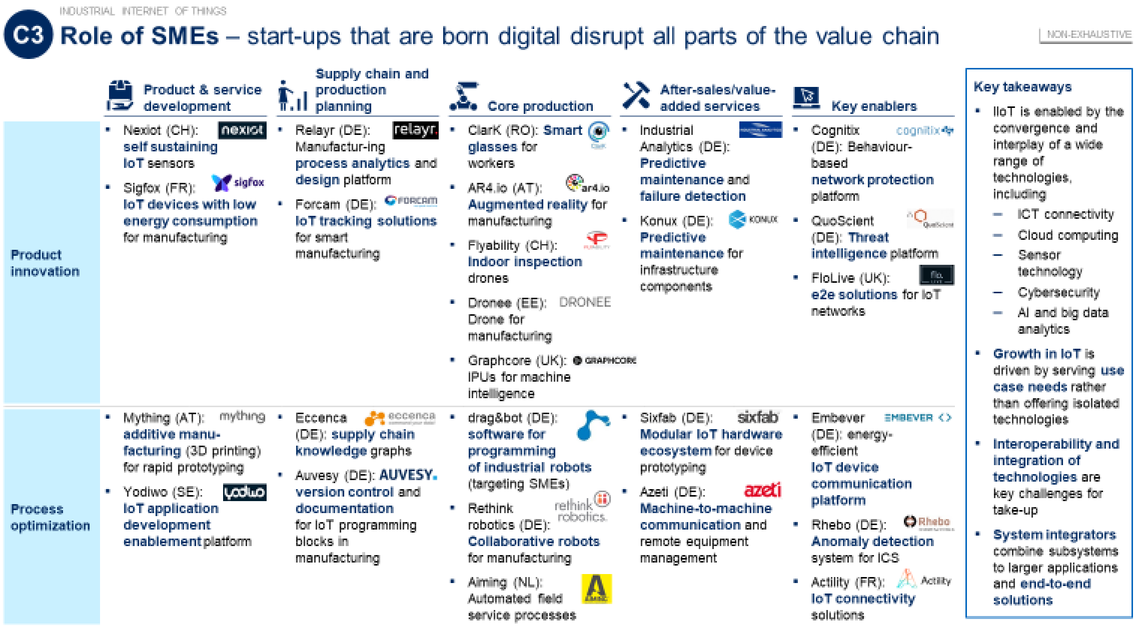
- Improve core processes, resulting in increased efficiency, or
- Innovate on product level.

While process optimisation is driven mostly within core production, product innovation is closely tied to the product and service development sub-value chain. Using machine and usage data allows SMEs to tailor products to customers' needs and to potentially increase margins, steering R&D processes and making use of rapid prototyping technologies allows them to accelerate product and service development cycles, which improves competitiveness. Those SMEs that have successfully transitioned can also be named reborn-digital SMEs.

Born-digital SMEs

Born-digital SMEs working on industrial IoT solutions inherently understand AI. They are mostly founded with the explicit purpose of addressing unmet needs of the ecosystem and need not necessarily come from the industry to which they supply the solution, i.e. these SMEs are sometimes pure play data engineering or software companies. Challenges for the born-digital SMEs are that they will require access to large sets of data to develop applications. Also, interoperability and integrability have to be addressed in order to scale specific applications for use in other contexts. In addition, they often lack a deep domain knowledge, i.e. understanding of processes, hardware tools and machinery ecosystems, including the data they produce. Key examples of European born-digital SMEs in the IIoT ecosystem are exhibited below (Exhibit 8). Their growth and success are driven by serving use case needs rather than isolated technologies. Thus, interoperability and integration of technologies are key challenges for take-up. Sometimes, system integrators combine subsystems provided by born-digital SMEs to larger applications and end-to-end solutions.

EXHIBIT 8: ROLE OF SMES IN THE IIOT VALUE CHAIN



SOURCE: Project team

1.5 Competitive fit of the IIoT value chain

Competitive fit of the overall IIoT value chain

The European strategic value chain of IIoT can build on a set of key strengths, which have been analysed in-depth as part of the Strategic Forum on Important Projects of Common European Interests. Specifically, it has been highlighted that

- There exist a wide range of institutionalised cooperation platforms, at both regional and European level (e.g. IoT European Research Cluster (IERC), Alliance of Internet of Things Innovation (AIOTI), IoT Action Plan for Europe, etc.
- Europe holds a competitive position regarding services and platform aggregators. The European Union is also particularly well placed in the field of embedded software & systems.
- The EU has world-class security ecosystem and world-leading companies in security components, hardware security modules and security software, as elaborated by the Task Force on Cybersecurity
- The Digital Transformation Scoreboard shows rapid adoption of IoT technologies

Concomitantly, we analysed the competitive fit of the IIoT value chain along a set of five dimensions, spanning:

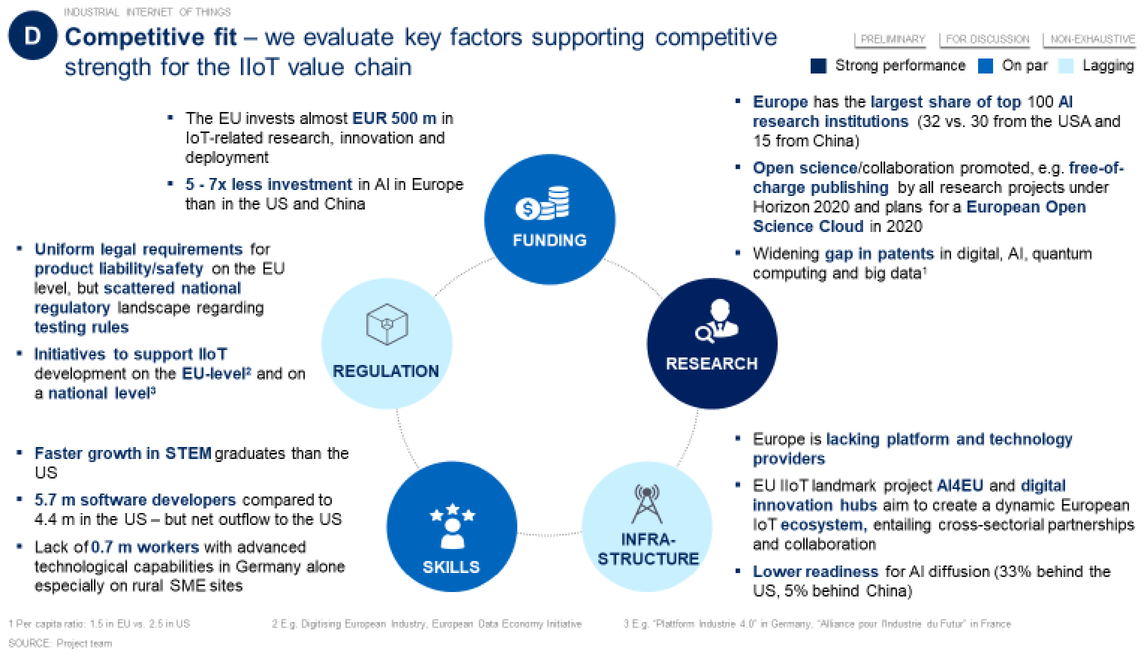
- Regulation
- Research
- Funding
- Infrastructure
- Skills.

We see a strong performance of Europe in research, with 32 of the top 100 AI research institutions being based in the region (compared to 30 in the US and 15 from China) which is supported by open science and collaboration effort. For example, under the Horizon 2020 framework benefit from free-of-charge publishing and there exist plans to implement the *European Open Science Cloud* in 2020.

In terms of IIoT funding and skills, Europe can build on an already advantageous position. Currently, the EU invests almost EUR 500 million in IoT-related research, innovation and deployment, which is complemented by numerous country level initiatives and a highly skilled workforce. As of now, the number of STEM graduates is growing faster in Europe than in the US and there are also more software developers in Europe than in the US (5.5 million versus 4.4 million; Atomico and Slush, 2017 – State of European Tech, 2017). However, despite the 5.5 million developers in Europe, it is estimated that the EU-28 will face a shortage of 500,000 software engineers by 2020 (nexten.10, 2018) – due to both increasing demand in Europe and a net outflow of talent to the US.

Regarding regulatory support and infrastructure Europe still lags the US and China. While there exist uniform legal requirements for product liability and safety on the EU level, national regulatory landscape is scattered when it comes to testing rules. Additionally, Europe is lacking platform and technology providers and the readiness for AI diffusion amongst European companies is found to be lower than in the US and China (33 per cent and 5 per cent respectively). To counter this, EU IIoT landmark projects such as AI4EU and the Digital Innovation Hubs aim to create a dynamic European IoT ecosystem, entailing cross-sector partnerships and collaboration. Exhibit 9 summarises the findings.

EXHIBIT 9: COMPETITIVE FIT OF THE IIOT VALUE CHAIN



Insights from expert discussions

In the context of the market analysis effort we have conducted interviews with numerous experts and asked them to share both their own view on the ecosystem as well as to echo the perspectives they hear as part of their client work. In the following we provide an excerpt of the key statements that shaped our discussions. The excerpt is structured along '*technological foundations', 'competitive landscape within Europe'* and *'role of SMEs'.*

Technological foundations

- ‘Given the **huge advance** of the US and China in deployable (i.e. market-ready) AI technologies, **Europe will not catch up** with established technologies and players **nor achieve a leading position**’.
- ‘Europe has **essentially lost the IT platform and infrastructure game** (e.g. Amazon Web Services) and is unlikely to win scale games in the future’.
- ‘SMEs can make use of a **wide range of software products** that are **easily accessible** to try and test how AI applications could be helpful (e.g. Google TensorFlow)’.

Competitive landscape within Europe

- ‘The **volume of data** (potentially) available from European plants **is comparable** to the data (potentially) available in plants in the US or China’.
- ‘To overcome knowledge entry barriers, SMEs can rely on a **wide spectrum of expertise** in Europe – in universities, applied research institutes etc. SMEs will **just have to reach out’.**
- **‘Basic AI competences and awareness** of AI potential/capabilities/functioning are **weak in wider European societies**, making it hard for entrepreneurs/SMEs to find their access to AI’.
- ‘The **wide-spread negative sentimen**t towards AI is a **main obstacle to its uptake** in Europe’.

Role of SMEs

- **‘SME leaders’ attitude** towards AI applications often seems to be **“waiting” rather than “tackling”** – this poses an increasing risk’.
- ‘SME’s **domain knowledge,** i.e. their technical expertise and knowledge of their manufacturing ecosystems, will remain an **unrivalled competitive advantage.** Based on this, SMEs have to take the next steps to AI adoption’.
- **‘Cooperation will be key** for European SMEs to succeed and they are used to doing it. **On their own, no SME will be able to compete** with the likes of “Nest”’.

2 FUTURE MOBILITY

Summary of key insights

- The future mobility value chain should be thought of as an ecosystem of closely integrated players and fluid industry boundaries spanning, amongst others, automotive, transport and infrastructure. More generally, the future mobility ecosystem includes all players which are involved in vehicle production, the moving of goods or people and adjacent services as well as the enablement of vehicle flows through hardware and software infrastructure.
- Major stakeholders in the future mobility value chain include OEMs and their supplier base, companies in the after-sales market, mobility platforms and (public) transport operators as well as telcos and system integrators. Regulatory bodies and authorities (i.e. cities) also have a key stake in the value chain.
- The future mobility value chain builds on 4 core capabilities, namely (i) vehicles, (ii) mobility services and operations and (iii) infrastructure, interlinked by (iv) data platforms that serve as key enablers of the ecosystem.
- Within the future mobility ecosystem, the vehicles sub-value chain accounts for the highest share of economic value added (3.6 per cent of economic value added in the EU-28, EUR 479.6 billion), as well as for the highest share of employment (3.3 per cent of employees in the EU-28, 7.7 million) (Eurostat, 2019).
- However, according to the McKinsey Global Institute's AI use case database, the overall AI impact potential on the future mobility sub-value chains in Europe is found to be highest within mobility services and operations, coming in at approximately EUR 220 billion. The potential impact for vehicles and infrastructure is estimated at about EUR 70 billion and about EUR 5 billion, respectively.
- To assess the varying impact of AI on SMEs in the future mobility ecosystem, they can be categorised into three types: 1) traditional SMEs lacking both the understanding of AI as well as a clear strategy to change that, 2) transitioning SMEs which have begun to adopt AI, partially because of their tight-knit integration into the wider mobility ecosystem and 3) born-digital SMEs which are founded with the explicit purpose of applying AI to disrupt a specific part of the mobility ecosystem.
- The ongoing shift from mobility product to mobility service revenue as well as the emergence of an ecosystem in the supply of digital and non-digital

infrastructure opens up opportunities for SMEs to collaborate with incumbent players, i.e. OEMs.

- A global competitive-fit analysis of the European future mobility value chain reveals strong performance in research (i.e. strong academic research landscape, AI patents), and improvement potential in funding (i.e. since 2010, approximately EUR 69 billion of investments into future mobility start-ups by the US compared to approx. EUR 3.8 billion by UK and France combined) as well as skills (i.e. estimated shortage of 500,000 software engineers in the EU-28 by 2020) and regulation (i.e. fewer trials and testing tracks, regulatory frameworks for vehicles assuming human driver). The European future mobility chain is found to be on par with the US and China in terms of autonomous vehicle infrastructure, which is concluded from a range of indicators spanning e.g. road quality, 4G network availability, electric charging density and ease of rollout for 5G networks (5G Deployment: State of Play, European Parliament; Autonomous Vehicle Readiness Index, KPMG).
- Europe can further build on its core strength in the delivery of product excellence and should partner with agile SMEs to innovate on mobility service excellence. To capture its full potential, Europe needs to facilitate the build-out of critical infrastructure to enable full-scale deployment of autonomous driving technologies.

Introduction

To support the European Commission in defining policies to strengthen the competitiveness of European SMEs in the future mobility ecosystem, we will first describe the core characteristics of the future mobility value chain. Subsequently, we will discuss the economic relevance of its respective sub-value chains. Thirdly, we will analyse the current and expected AI impact potential on the future mobility value chain. Fourthly, we will investigate the role of SMEs in the ecosystem. And lastly, we will discuss the competitiveness of the European future mobility ecosystem in a global context.

1.6 Core characteristics of the future mobility value chain

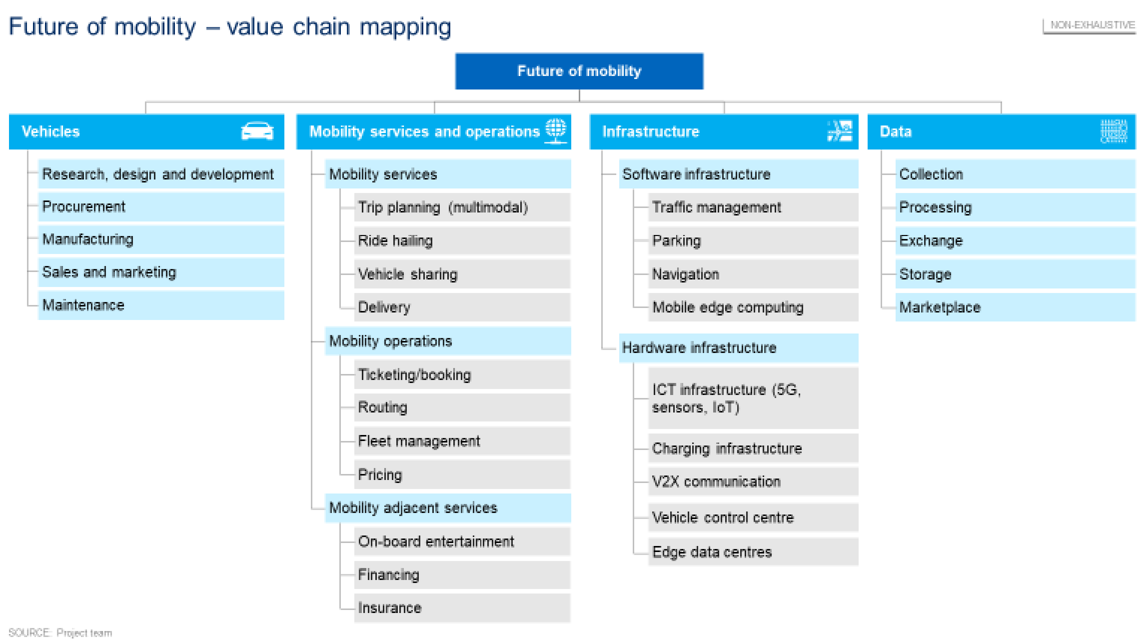
To enable the European Commission to define policies strengthening the competitiveness of European SMEs in the mobility market, we will first define the future mobility value chain and the relevant stakeholders to be addressed in the future.

The future mobility value chain is composed of four core sub-value chains, which will be discussed in detail below:

- Vehicles
- Mobility services and operations
- Infrastructure
- Data

Exhibit 10 provides the corresponding value chain structure, detailing (non-exhaustively) which sub segments the aforementioned sub-value chains may encompass.

EXHIBIT 10: MAPPING OF THE FUTURE MOBILUTY VALUE CHAIN



Vehicles

The vehicles sub-value chain is sequential in nature and encompasses all functions that are commonly associated with traditional goods production, ranging from design and R&D to manufacturing, maintenance and sales and marketing. In the future mobility context, autonomy and connectivity deserve special consideration when related to the vehicles sub-value chain, as they represent fundamentally new capabilities that will lead to structural shifts along the supplier base of the vehicles sub-value chain. As indicated in Exhibit 10, the focus of the after-sales market will shift from the core products business to connectivity services. System sales (on-board electronics, AV-enabling sensors, software etc.) will grow along with autonomous vehicle sales.

The major stakeholders along the vehicles sub-value chain resemble those of traditional automotive production. OEMs are closely integrated with tier 1 and tier 2 suppliers, all three of which work with system and plant integrators as well as machinery and equipment vendors. Stakeholders in sales, marketing and after-sales functions vary by type of vehicle produced and the service model in which they are deployed. The after-sales market for passenger cars is fragmented and customer facing for now. Car owners regularly take their cars to shops, often SMEs, for tune-ups and repairs. As more cars are used in shared services models, this may change structurally. For example, in a robo-taxi service model, fleet management is completely detached from the passenger, just as is the case now with e-scooters in shared micromobility service models.

Mobility services and operations

This sub-value chain is composed of three elements: (i) mobility services, (ii) mobility operations and (iii) mobility-adjacent services.

Mobility services encompasses all consumer-facing applications, platforms and products that offer customers point-to-point logistics as well as mobility planning solutions. These include, amongst other things, ride hailing, public transport and delivery services, all of which may be fully autonomous. Mobility operations, on the other hand, encompasses all functions that serve as supporting elements to the mobility services' set of platforms and includes pricing, routing and fleet management, amongst other functions. Mobility-adjacent services complement or enhance customer-facing mobility services as well as asset ownership and include insurance, automotive finance and on-board entertainment.

The mobility services sub-value chain does not fit a traditional sequential value chain framework but may instead be thought of as a set of platforms and operators. Within mobility services, AI will likely serve as a key enabler for product innovation, most notably leading to customer-facing services involving autonomous driving technology (e.g. robo-taxis, delivery robots, autonomous trucks). In mobility operations, on the other hand, AI-enabled innovation typically targets process optimisation, e.g. by means of using AI to develop dynamic routing algorithms. In the context of mobility-adjacent services, AI may target process efficiency and product innovation.

Key stakeholders in the mobility services sub-value chain include mobility-as-a-service (MaaS) platforms such as FREE NOW (formerly mytaxi), DriveNow and Voi, as well as (public) transport operators. Increasingly, both tech companies and OEMs are trying to capture value along the mobility services sub-value chain and thus also become key stakeholders. Along mobility operations, functions are partially integrated and also partly purchased by the mobility service providers. An ecosystem of specialised mobility analytics and data engineering companies is thriving in the mobility operations sub-value chain, supporting the customer-facing front ends of (public) transport operators and MaaS providers. Banks, insurers, OEMs as well as tech companies have a stake in mobility-adjacent services, as they are involved in the integration of new formats for insurance pricing, leasing and on-board entertainment.

Infrastructure

This sub-value chain is composed of a software infrastructure and a hardware infrastructure component. Software infrastructure encompasses solutions that enable functionality of hardware infrastructure elements. They are enhanced by advanced AI technologies, targeting, amongst other things, problems in traffic management, parking and smart charging. Hardware infrastructure, on the other hand, includes all physical functions that enable data aggregation, exchange and communication by and amongst the members of the ecosystem, spanning ICT infrastructure (5G, sensors, IoT devices), charging infrastructure and vehicle-to-everything (V2X) communication. It is worth noting explicitly that hardware and software infrastructure components are tightly integrated. For example, software providers that aggregate vehicle data to derive insights on parking or real-time traffic must have visibility on data formats used by OEMs and MaaS providers.

Key stakeholders in the infrastructure sub-value chain include OEMs, which integrate IoT devices into cars to aggregate data. This data is partly exchanged through telephone companies (telcos), which may own communication infrastructure as well as IoT platforms and shared-access data repositories. (Public) transport operators, cities and MaaS providers use a broad range of specialised companies to analyse usage of their networks and infrastructure. System integrators guarantee interoperability of data and tools as well as standardisation in communication.

Data

The three sub-value chains of vehicles, mobility services and operations and infrastructure are closely interconnected through the data sub-value chain, which serves as the core of the future mobility ecosystem and encompasses the key elements of aggregation, processing, storage/repositories, exchange and marketplace. The data sub-value chain underlies all processes in the future mobility ecosystem but can interlink various players and functions simultaneously, which is why no standard industry or value chain framework is applicable here. For example, OEMs may use locally generated (in-car) data on tyre pressure for the purposes of on-board diagnostics, or share that same data with insurers for dynamic pricing of premiums. The amount, type and format of the data that is processed, stored or shared, as well as the range of parties that have access to it and monetise it varies extremely, depending on the application and business case.

Key stakeholders in the data sub-value chain include all members of the future mobility ecosystem. Core concerns to all of them are the notions of data standardisation and application interoperability, i.e. it should be possible to scale specific applications for use in other contexts; this could be hindered by different interfaces, communication standards or IT structures.

Divergence from the IPCEI CCAV analytical report

The structure of the future mobility value chain discussed in this market analysis report differs materially from the one outlined in the IPCEI CCAV analytical report. The description of the CCAV value chain in the IPCEI report relies on a sequential framework, with specific emphasis on the 'clean' (i.e. environmentally friendly) aspect of CCAV. The IPCEI value chain only consists of four steps:

(1) Research, design and product development
(2) Inputs and production
(3) Marketing, sales and distribution
(4) After-sales services.

To us, this is one specific representation of the traditional value chain in vehicle manufacturing. However, in the context of this market analysis report, we decided to follow a structure that allows us to assess the future mobility value chain holistically, as an ecosystem. Thus, our structure encompasses all relevant players and enablers, including mobility services and operations as well as infrastructure and data. It reflects current thinking by the project team and was both validated and refined where needed through expert interviews and in-depth desk research. This allows us to analyse in detail:

- The current and future impact of AI on the future mobility value chain
- Where and how structural shifts in the future mobility value chain have particular impact on European SMEs.

We note that, in contrast to the IPCEI analytical report, we put less of an explicit emphasis on the 'clean' aspect within CCAV, as advanced AI technologies impact the 'connected' and 'autonomous' aspects more profoundly. However, this report also touches upon smart electric charging solutions.

Links to other strategic value chains

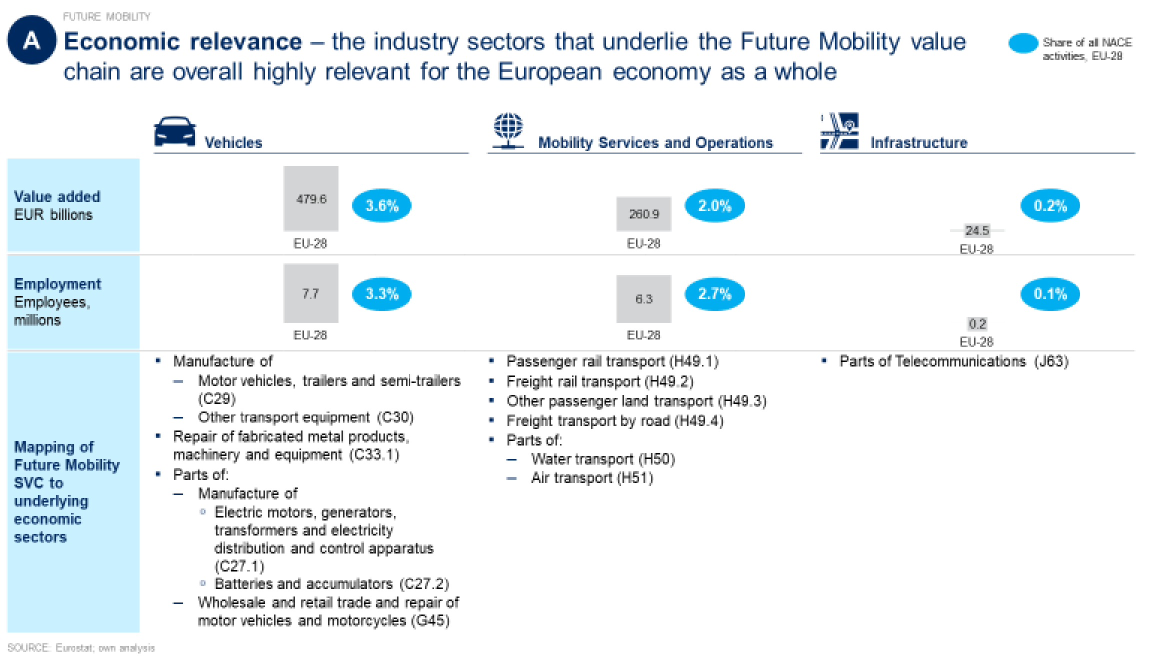
As discussed in Chapter 1.1, the future mobility value chain is interlinked with the IIoT value chain in two ways. Firstly, IIoT systems are integrated into the vehicle. Secondly, IIoT enables the development of new products and services in the future mobility ecosystem. It is worth noting that autonomous vehicles rely on IIoT devices for data aggregation and V2X communication. Other examples of IIoT-enabled product innovation can be found in the infrastructure sub-value chain, where smart traffic control systems build on real-time data aggregated by IIoT devices integrated into vehicles and road networks.

The future mobility value chain is also interlinked with the smart health value chain in all segments related to both passenger and public road safety. Prominent examples include sensors that detect driver fatigue to prevent crashes, and on-board sensors systems that autonomously send help requests if the vehicle has been involved in a car accident. These technologies are expected to evolve further to the point where cars could monitor a driver's vital parameters to detect dangerous medical events, such as a heart attack, and safely steer the vehicle out of traffic.

1.7 Economic relevance of the future mobility value chain

The four sub-value chains differ with respect to their economic relevance. The vehicle sub-value chain contributes 3.6 per cent (EUR 479.6 billion) to the total economic value added in the EU-28 and employs 3.3 per cent (7.7 million) of workers in the EU-28 region. It is followed by mobility services and operations and infrastructure with contributions of 1.9 per cent and 0.2 per cent to total economic value added and 2.7 per cent and 0.1 per cent to total employment in the EU-28 region, respectively. As the data block serves as an enabling layer to the first three, its economic relevance is not considered individually for this part of the analysis. All data was extracted from Eurostat for the last available year, 2016. The sector mapping underlying the data is outlined in the bottom half of Exhibit 11.

EXHIBIT 11: ECONOMIC RELEVANCE OF THE FUTURE MOBILITY SUB-VALUE CHAINS

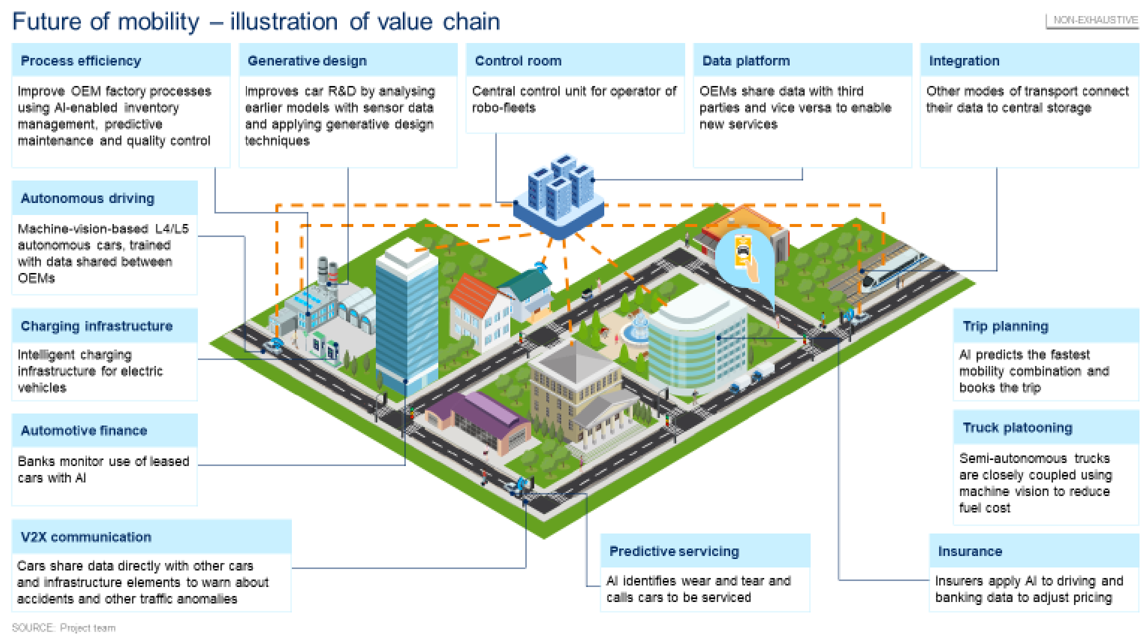


1.8 Current and expected AI impact in the future mobility value chain

AI use cases

AI has already found its way into many segments and will likely find its way into all segments of the future mobility value chain, driving both process optimisation and product innovation. However, the extent to which these technologies can and will be applied is likely to vary from function to function across sub-value chains. Exhibit 12 illustrates what AI-enablement in the context of the future mobility ecosystem may look like. It displays various types of autonomous vehicles, connected through vehicle control centres and intelligent road networks and powered by clean and intelligent electricity grids. Consumers seamlessly interact with mobility service providers and transport operators. Banks, insurance companies and OEMs monitor the use and condition of vehicles. Data is aggregated by and exchanged amongst a wide range of players in the ecosystem.

EXHIBIT 12: ILLUSTRATION OF THE FUTURE MOBILITY VALUE CHAIN



To assess the possible impact AI can have on the future mobility ecosystem, AI use cases will be grouped by ‘product innovation’ and ‘process optimisation’.

Product innovation

The bulk of AI-enabled product innovation is likely to be found in the mobility services sub-value chain, with services enabled by autonomous driving technology being the most prominent example. Amongst other things, this includes robo-taxis, trucking and last-mile delivery.

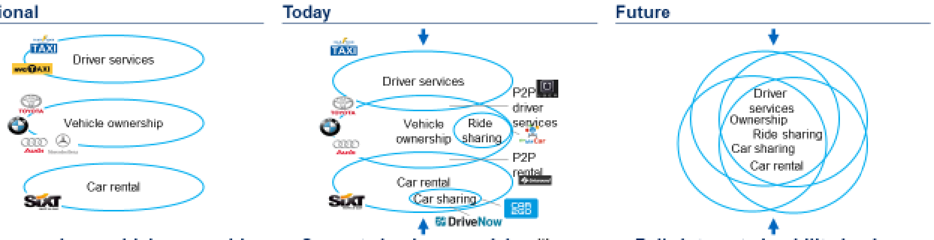
These AI applications will disrupt traditional business models in mobility services (Exhibit 13) and morph them into fully integrated platforms covering a wide range of customer needs. This will impact many transport and fleet operators while potentially unlocking value for disruptive business models in shared mobility, data-enabled (connectivity) services and the new vehicle technologies aftermarket (Exhibit 17).

EXHIBIT 13: MOBILITY LANDSCAPE – TRADITIONAL, TODAY AND FUTURE

In the future mobility ecosystem, business models merge to build hybrid forms of shared mobility offerings

Mobility landscape

	Traditional	Today	Future



	Traditional	Today	Future
Mobility offerings	▪ **Driver services, vehicle ownership,** and **car rental** as **separate business models**	▪ **Separate business models** with **partial overlaps** (e.g. P2P driver services at intersection between driver services and vehicle ownership) ▪ **New services emerge** as **differentiated version** of existing businesses (e.g. car sharing as differentiated version of car rental)	▪ **Fully integrated mobility landscape** with **blurred boundaries between business models** (e.g. vehicle ownership with contribution to shared AV fleet when not used) ▪ **Highly differentiated spectrum of offerings,** covering a broad range of customer needs and situations
Competitive dynamics	▪ **Limited competition** between suppliers of different mobility solutions	▪ **Increased competition** between traditionally separated models (e.g. increased pressure on taxi providers due to rise of P2P driver services)	▪ Competitive landscape **organised along shared mobility value chain** (rather than traditional organisation within business models)

SOURCE: Project team

Other examples of product innovation include voice-powered in-car entertainment systems, real-time parking information and multimodal mobility planning platforms.

Process optimisation

AI techniques targeting process optimisation are found throughout the vehicle sub-value chain, impacting procurement, maintenance, manufacturing and sales and marketing by improving:

- Tact times (by means of smart-picking algorithms and asset trackers)
- Quality (by means of machine-vision-powered quality control mechanisms)
- Customer experience (by means of interactive channels and bots)
- Working capital requirements (by means of reduced inventory levels through improved order-flow prediction)
- Predictability and business continuity (by means of analytics platforms for IoT data).

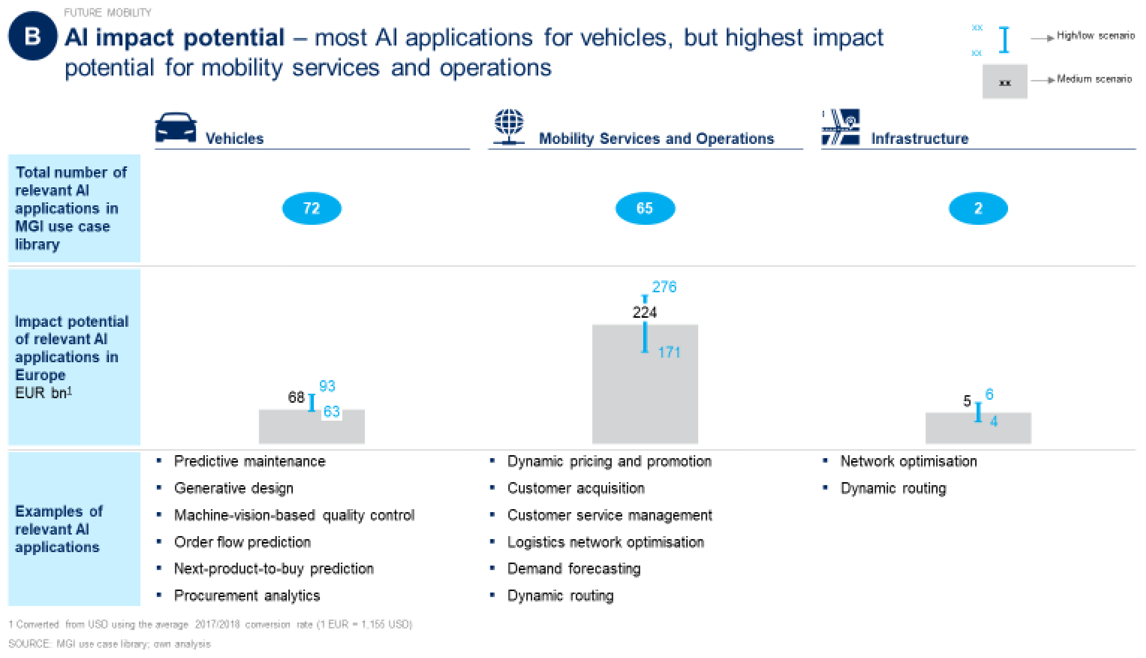
Most sub segments of mobility operations and software infrastructure also represent functions that either already are or likely will be enhanced by AI applications in the future. For example, machine learning may be applied to derive insights on ride demand, optimal routing and optimal physical distribution of vehicles (specifically in the micromobility context). Dynamic pricing algorithms, which have become an important element of ride-hailing economics, also build on advanced machine learning techniques. Additionally, AI will likely help support the electric charging infrastructure, providing intelligent solutions for distributing and allocating charging slots to cope with peak stress on the electricity grid.

Mobility-adjacent services constitute another domain of high AI impact potential. Specifically, within automotive insurance, AI can be used to automatically process claims, predict call centre capacity needs, automate customer calls and detect fraudulent activity.

Quantification of the AI impact potential for future mobility in Europe

As for the IIoT value chain above, we draw on the MGI AI use case library to derive a first indication of the possible AI impact potential in the future mobility value chain in Europe. This library holds a collection of real-world applications of AI including the value that is created in the specific cases as well as the potential the rollout of the company-specific use cases has to other companies in the same industry and circumstances. To arrive at an estimate for the impact potential within the future mobility value chain, we aggregate the impact of those use cases which are linked to the value chain. Use cases can generate impact in the form e.g. of gains in productivity through cost reductions or efficiency gains. We note that the MGI use case library focusses on company-specific effects and does not account for the economic effects that go beyond companies. Thus, the total impact potential may be understated.

EXHIBIT 14: AI IMPACT POTENTIAL OF THE STRATEGIC SUB-VALUE CHAINS IN FUTURE MOBILITY



Out of the three sub-value chains, the MGI use case library lists the most applications for vehicles; however, potential AI impact is found to be the highest for mobility services and operations, coming in at EUR ~200 billion. The least AI impact potential is found for infrastructure.

As for the methodology of assessing AI impact, it is worth noting that the library comprises use cases that have been observed though its client work globally. Thus, the AI impact figures for one use case only represent the achievable impact if all companies within one industry were to implement this specific AI use case. The potential impact added through new AI-enabled business models and service offerings is not included.

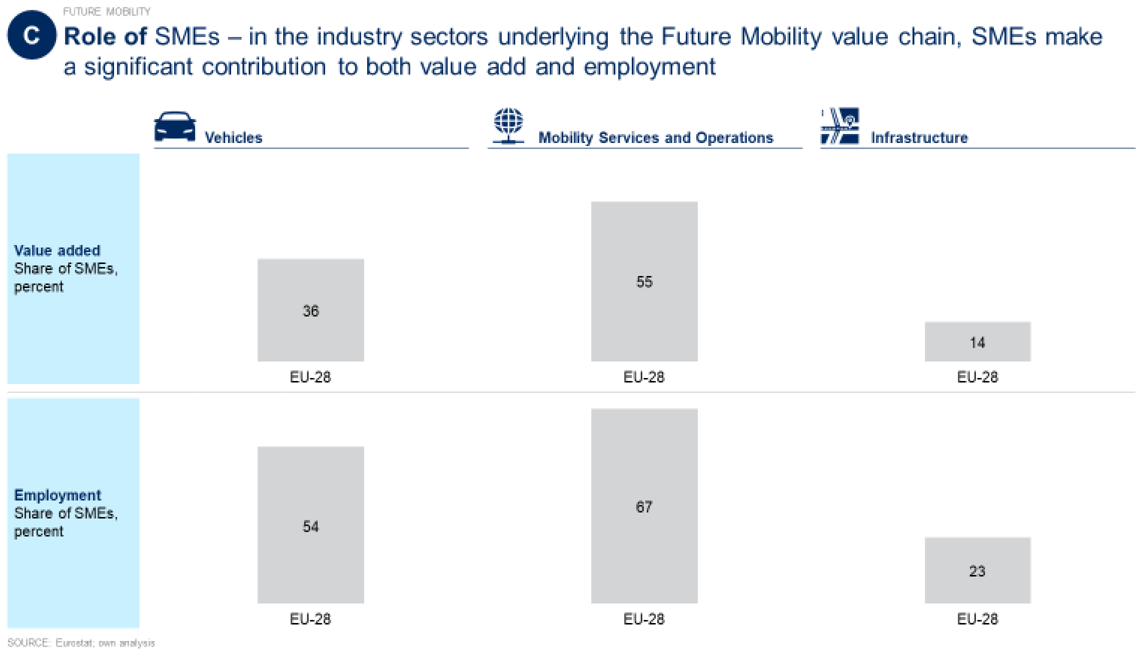
The potential AI impact within mobility services and operations is thus not higher than in vehicles because it includes new business models around robo-taxis and robo-delivery, but rather because within mobility adjacent services, many AI use cases have been identified for automotive insurance.

A transition to full autonomy also has wide-ranging implications for the traditional business models of OEMs and suppliers, whose profits will be compromised to the advantage of MaaS providers. This may be one of the reasons why OEMs have expanded outside their core of vehicle manufacturing to capture value in the mobility services sub-value chain. The efforts undertaken by various OEMs in this regard are described in more detail in the next section.

1.9 Role of SMEs in the future mobility value chain

The deployment of AI will impact European companies across all sub-value chains of the future mobility ecosystem, leading to new opportunities but also posing risks to 'traditional' business models. The impact of AI on SMEs is particularly delicate, because SMEs employ a significant share of the workforce, as seen in Exhibit 15.

EXHIBIT 15: ROLE OF SMES IN THE STRATEGIC SUB-VALUE CHAINS IN FUTURE MOBILITY



Against this background, we have analysed the role and challenges of SMEs along three distinct categories, namely traditional, transitioning and born-digital SMEs.

Traditional SMEs

Traditional SMEs are established SMEs that operate in, i.e. manufacturing, engineering services or after-sales, tend to lack a thorough understanding of the impact of AI. Most of them highlight the lack of a clear strategy for AI as one significant barrier to AI adoption, followed by lack of talent, resources and functional infrastructure. Key examples include specialised suppliers and automotive repair shops. As structural value chain shifts impact their business model, the industry may consolidate. While some will remain in their classic business model, others may become non-competitive.

Transitioning SMEs

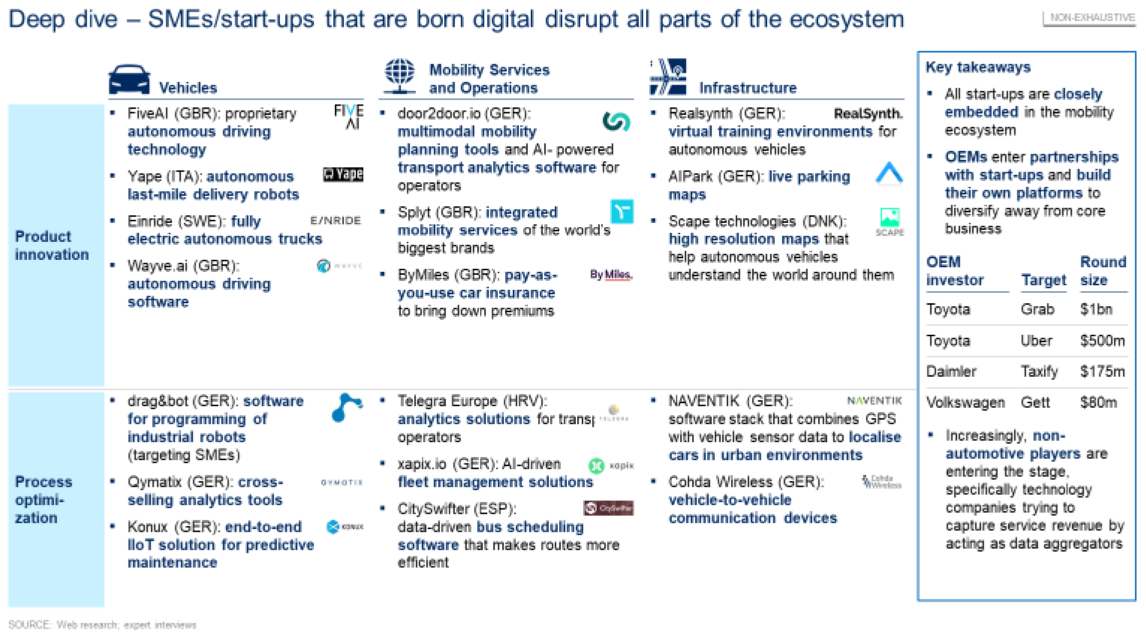
Transitioning SMEs have understood the impact potential of AI and have begun to transition, albeit at varying paces. In some instances, they are required to adopt new technologies because of their tight-knit integration into the wider mobility ecosystem; in other instances, they correctly foresee more abstract structural changes and are reacting accordingly. They are likely to benefit from the transition if it is successfully implemented. Key examples include specialised suppliers that may go from supplying a component for traditional cars to supplying components for autonomous vehicles. In general, they may use AI technology to:

- Enhance their current product portfolio and business model (e.g. a traditional bus operator chooses to integrate with an AI-enabled, multimodal mobility planning platform)
- Offer new products or services in their current markets (e.g. a telematics company adds an AI technology stack to offer a predictive traffic-management solution using the in-city tolling data it gathers)
- Create new products or services for adjacent markets (e.g. a parking management company decides to also offer smart charging solutions for electric vehicles and to monetise parking data through wider mobility platforms).

Born-digital SMEs

Born-digital SMEs understand AI and ‘think digital’. Often, they are founded with the explicit purpose of applying technology to solve a specific problem or address an unmet need in the mobility ecosystem. In some cases, they come from adjacent industries rather than automotive per se, i.e. they are pure-play data engineering and software companies. A sample map of European born-digital SMEs is displayed in Exhibit 16. Initially, these SMEs require access to large data sets to develop and train their solutions, which is one commonly cited challenge. Moreover, the interoperability and integrability of solutions poses a challenge, i.e. an AI-powered software product developed for one customer should ideally be scalable to other players, which might be hindered by differences in data and communication standards.

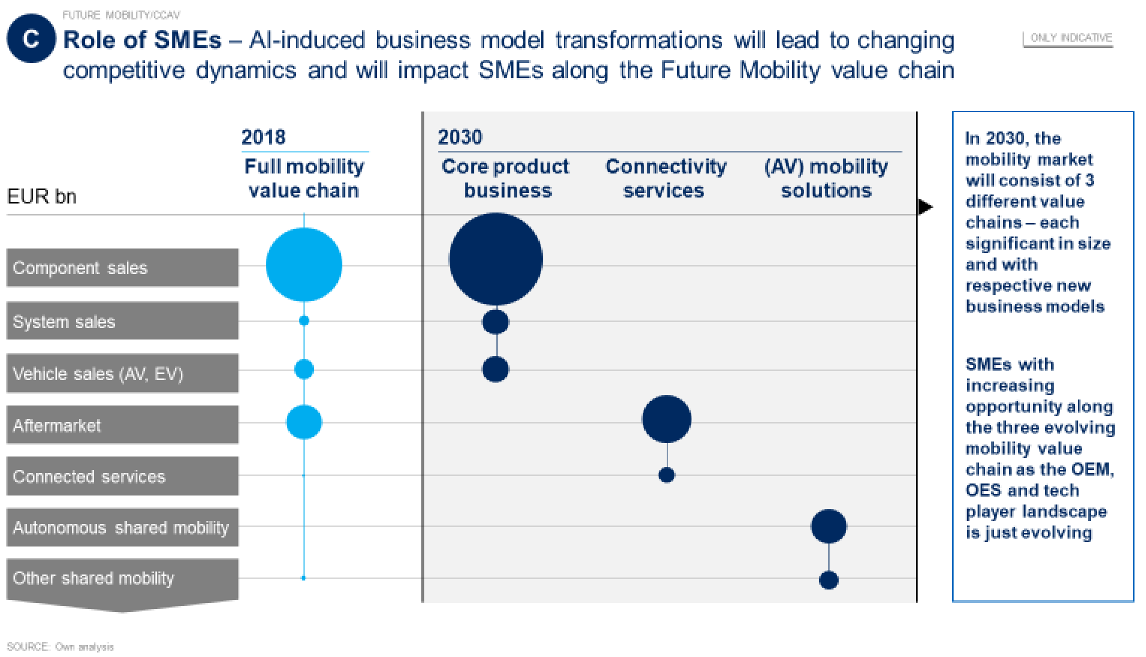
EXHIBIT 16: DEEP-DIVE ON THE ROLE OF SMES IN FUTURE MOBILITY



Further potential for SMEs in the future mobility value chain

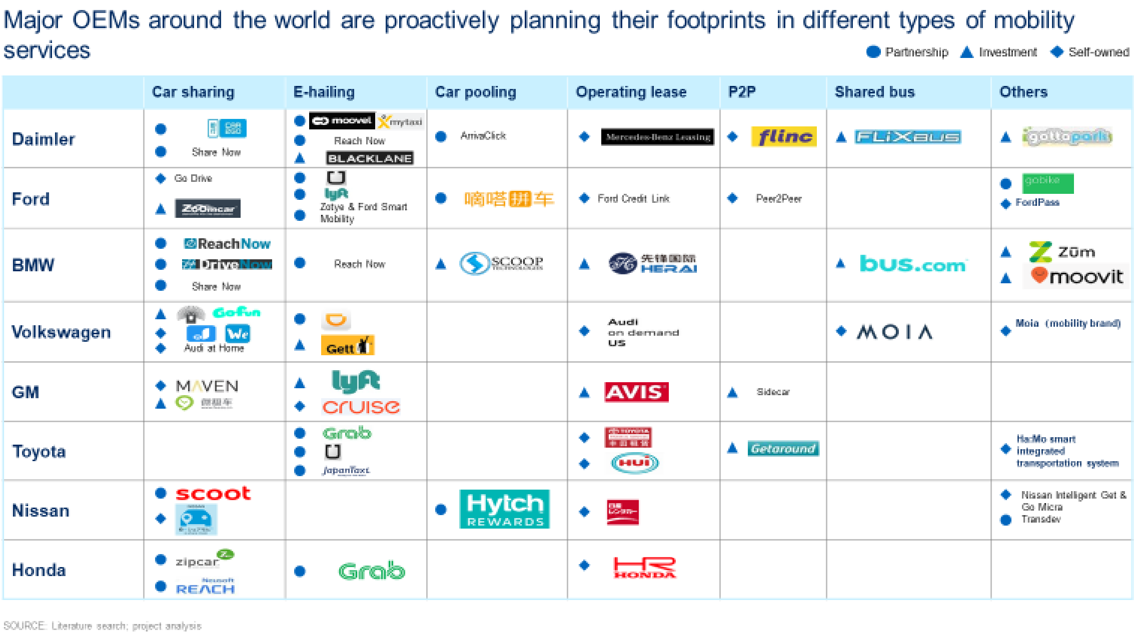
As the mobility value chain shifts from its traditional sequential structure to a more integrated form (Exhibit 17), this will likely change revenue pools and create opportunities for SMEs.

EXHIBIT 17: ROLE OF SMES AND AI-INDUCED BUSINESS MODEL TRANSFORMATIONS IN FUTURE MOBILITY



It can be observed that OEMs are undergoing business-model transformations in order to capture value in services, as seen in Exhibit 18. These changes open up opportunities for collaboration and the chance for both born-digital and transitioning SMEs to become partners or suppliers of digital infrastructure components. Additionally, the ongoing structural changes may even entail growth opportunities for traditional SMEs. For example, the development of smart charging infrastructure will likely require local reinforcement of the electricity grid, in which traditional SMEs could play a role. Fleet management for micromobility services will also likely require new B2B solutions, which could be locally championed by traditional SMEs.

EXHIBIT 18: ACTIVITIES BY MAJOR OEMS IN MOBILITY SERVICES



1.10 Competitive fit of the future mobility value chain

Competitive fit of the overall future mobility value chain

The European strategic value chain of future mobility can build on a set of key strengths, which have been analysed in-depth as part of the Strategic Forum on Important Projects of Common European Interests. Specifically, it has been highlighted that

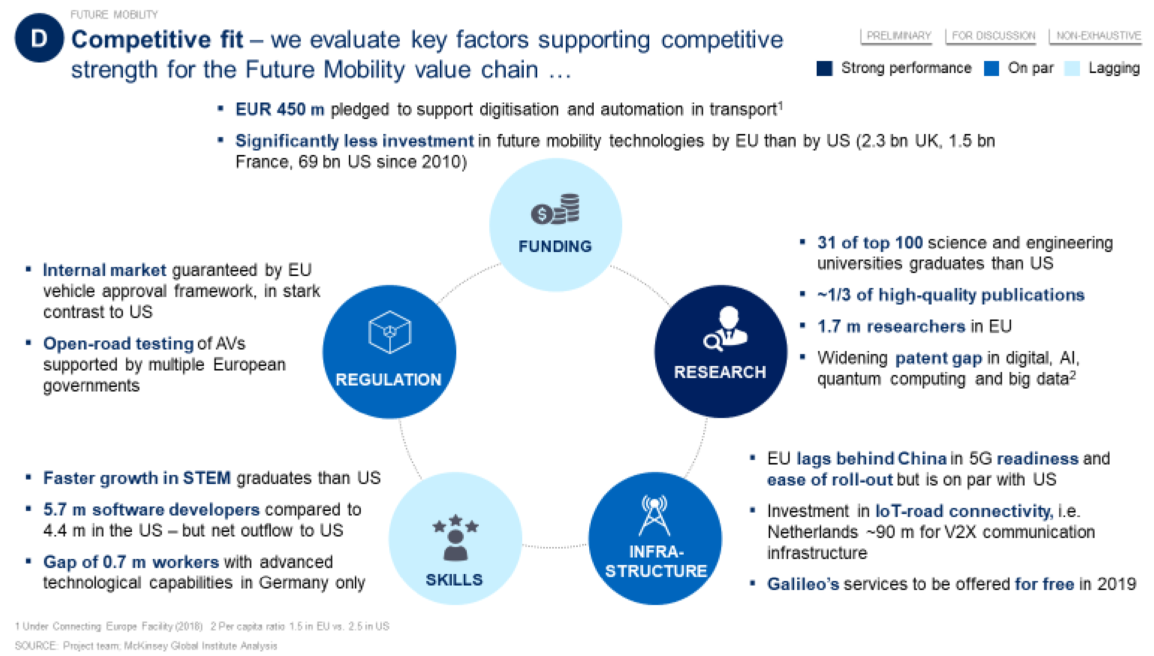
- The EU builds on advanced know-how when it comes to optimising the efficient use of electric car batteries
- The EU enjoys public and political support for sustainability and shifts towards newer types of mobility

- The EU follows a comprehensive approach for combining navigation, radar, sensor and visual detection technologies
- The EU has state-of-the art manufacturing capabilities and a large number of players in the CCAV ecosystem

Concomitantly, we analysed the competitive fit of the future mobility value chain along a set of five dimensions, spanning (see Exhibit 2):

- Regulation
- Research
- Funding
- Infrastructure
- Skills

EXHIBIT 19: COMPETITIVE FIT OF THE FUTURE MOBILITY VALUE CHAIN



Europe performs strongly in research, with more 31 of the world's top science and engineering universities being located on the continent (*Times Higher Education* World Reputation Rankings 2018).

However, in terms of funding, skills and regulation, Europe lags behind both the US and China. While the US and China have led investments of EUR 69 billion and EUR 40 billion in future mobility start-ups since 2010 respectively, the only two European countries in the top 10 are the UK with EUR 2.3 billion and France with EUR 1.5 billion worth of investments (McKinsey, *Race 205o – a vision for the European automotive industry,* p. 14). Overall, the EU only pledged EUR 450 million in 2018 to support digitisation and automation in transport under the Connecting Europe Facility.

The number of STEM graduates *is* growing faster in Europe than in the US, and there are also more software developers in Europe than in the US (5.5 million versus 4.4 million; Atomico and Slush, 2017 – State of European Tech, 2017). However, despite the 5.5 million developers in Europe, it is estimated that the EU-28 will face a shortage of 500,000 software engineers by 2020 (nexten.10, 2018).

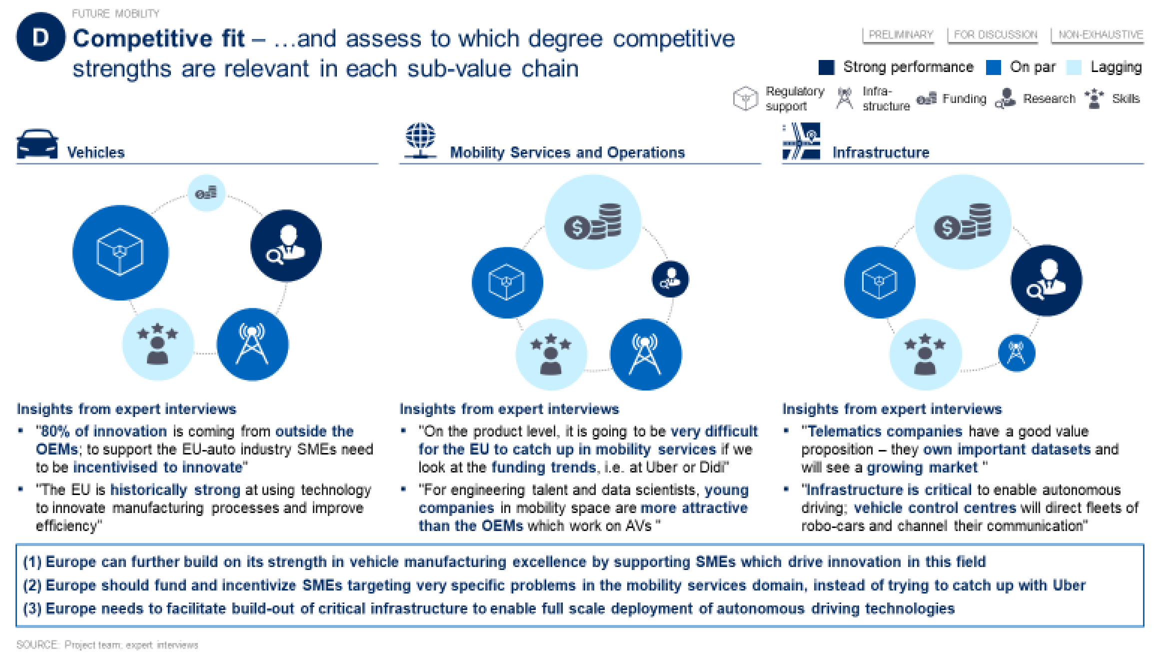
Regulations in Europe already support the development and testing of autonomous vehicles to some extent. The EU's C-Roads Platform and the European Commission's Single Platform for Cooperative, Connected, Automated and Autonomous Mobility (CCAM) encourage cross-border collaborations for the development and deployment of cooperative intelligent transport systems (C-ITS) and the verification of interoperability through cross-site testing. However, legal uncertainty remains, as current rules were established on the assumption that a vehicle is driven by a driver, testing and traffic rules are not legally harmonised across the EU member states, which has been addressed by the GEAR 2030 High Level Group. Additionally, the US remains a more favoured testing ground for autonomous vehicles than Europe.

Europe is on par with the US and China in autonomous vehicle infrastructure. Several European countries have funded projects and pilot projects on IoT road connectivity. For example, the Netherlands invested approximately EUR 90 million in the development of intelligent traffic lights with vehicle communication capabilities (*ITS in the Netherlands – progress report 2017,* p. 10). The readiness and rollout of 5G technology, one critical enabler of autonomous driving technology, is found to be ahead or on par with the US but lags behind China (European Parliament, *5G deployment – state of play in Europe, USA and Asia,* p. 25).

Competitive fit of the sub-value chains in future mobility

To get a deeper understanding of the competitive fit of the European future mobility value chain, we also assessed to what degree Europe's competitive strengths are relevant in each sub-value chain of the ecosystem (see Exhibit 20).

EXHIBIT 20: COMPETITIVE FIT OF THE SUB-VALUE CHAINS OF FUTURE MOBILITY



The competitiveness of vehicles relies critically on research and, even more importantly, on the industrialisation of research in autonomous driving technology. While many European OEMs conduct their own autonomous vehicle development programmes, US competitors, specifically Waymo, are way ahead in terms of product maturity. One challenge commonly cited by OEMs in this regard is attracting and retaining top software engineering talent. Additionally, regulatory support for open-road testing is key to the advancement of autonomous driving technology. As of 2019, the US has more cities that pilot or are preparing to pilot open-road testing than any other country (Aspen Institute; Bloomberg Philanthropies).

Within mobility services, funding does play a critical role and Europe lags behind in this regard. As of today, at least EUR 55 billion have been invested into ride-sharing technologies globally. However, much of this capital has been deployed by and into data-rich US tech giants with high capital markets valuations, which can afford to freely develop solutions without the immediate requirement of profitability (*Race 2050 – a vision for the European automotive industry,* p. 24). As more of these mobility services will involve autonomous vehicles, the enabling infrastructure becomes ever more important.

In infrastructure, both funding and regulatory support serve as pillars of competitiveness. Due to European fragmentation, regulatory support could help to enable integrability of communication and network infrastructure components, while the rollout of said components is capital intensive and thus requires considerable funding.

Insights from expert discussions

In the context of the market analysis effort we have conducted interviews with numerous experts and asked them to share both their own view on the ecosystem as well as to echo the perspectives they hear as part of their client work. In the following we provide three key statements per value chain that shaped our discussions.

Vehicles

- **'80 per cent of innovation** is coming from **outside the OEMs;** to support the EU-auto industry, SMEs need to be **incentivised to innovate**'.
- 'The EU is **historically strong** at using technology to innovate manufacturing processes and improve efficiency'.
- **'OEMs** see that they need to work with **platform players** or set up their own to capture **service revenue**'.

Mobility services and operations

- 'On the product level, it is going to be **very difficult for the EU to catch up in mobility services** if we look at the **funding trends**, i.e. at Uber or Didi'.
- 'For engineering talent and data scientists, **young companies** in mobility space are **more attractive than the OEMs** that work on AVs'.
- 'Since fleet management activities are conducted **locally**, **SMEs** can play an **important role**'.

Infrastructure

- '**Telematics companies** have a good value proposition – they **own important data sets** and will see a **growing market**'.
- '**Infrastructure is critical** to enable autonomous driving; **vehicle control centres** will direct fleets of robo-cars and channel their communication'.
- 'Cities are key stakeholders, they can **incentivise build-out** of infrastructure and **set rules locally**'.

3 SMART HEALTH

Summary of key insights

- The smart health value chain includes four sub-value chains as its major building blocks: (i) industry, (ii) health service provision, (iii) governance and (iv) administration/payors.
- Major stakeholders in the smart health value chain include suppliers in the broadest sense (e.g. pharma and med-tech companies), 'interface' actors (e.g. payors, policymakers), health service providers (e.g. hospitals, pharmacies) and end users (patients).
- The smart health value chain is closely linked and intertwined with the IIoT value chain (e.g. via the 'Medical Internet of Things'), but also has some links to the future mobility value chain (e.g. with regard to specialised drug transport and ambulance).
- Health service provision is by far the most important sub-value chain in Europe – from both an economic perspective (value added amounted to EUR 840.7 billion in 2016) and an employment perspective (19.3 million employees in total). It is followed by the industry sub-value chain. Governance and administration/payors are less important (Eurostat, 2019).
- According to the McKinsey Global Institute's AI use case database, the overall AI impact potential on the smart health value chain in Europe is estimated at approximately EUR 105 billion – with the biggest impact on health service provision (about EUR 70 billion) and industry (about EUR 20 billion).
- AI is of high value for the smart health value chain due to new product innovations (e.g. personalised treatment, prevention apps, teleconsultation) as well as due to process optimisation solutions (e.g. optimisation of surgery resources, quantitatively driven clinical trial decisions).
- SMEs in the healthcare sector are categorised into three types for analysing how they are affected by AI: 1) traditional SMEs lacking both strategy and resources in smart health (e.g. pharmacies, care facilities), 2) transitional SMEs implementing AI to enhance specific aspects of their health-related business model (e.g. local hospitals, medium-sized pharma and med-tech companies), and 3) born-digital SMEs disrupting all parts of the health value chain (i.e. start-ups that build on a fully digital business model from day one).
- The opportunity for AI-enabled process automation in health service provision and the increasing awareness of preventive healthcare represent great value creation potential, especially for smart health start-ups.

- A global competitive-fit analysis of the overall European smart health value chain reveals strong performance in research (e.g. strong academic research landscape and execution of clinical trials), on-par performance in skills (e.g. fast growing number of STEM graduates and strong IT talent pool) and funding (e.g. very good funding landscape for early research and development, limited access to venture capital for business scaling), but lagging in regulation (e.g. fragmented regulatory and reimbursement landscape across Europe, strict GDPR regulation) and infrastructure (e.g. low readiness for AI diffusion and very different degrees of digitisation of national health systems).
- The global competitive analysis on sub-value chain level showed: 1) the industry sub-value chain benefits from Europe's strong R&D position, but struggles with lack of venture capital funding, 2) the health service provision sub-value chain builds on a strong talent and skill pool, but digital skills urgently need to be implemented in university and training curricula to enable and drive innovation, 3) the governance sub-value chain is lagging behind in global competition due to both a weak infrastructure and missing regulatory support, 4) the administration/payors sub-value chain is hampered by Europe's weak position in infrastructure and regulation and therefore cannot leverage potential advantages (e.g. data insights generation by European insurers).

Introduction

The European population is aging and these changes in demographic structure will be the driving factor behind the successful implementation of AI in the smart health value chain. With 24 per cent of the population expected to be 65 or older by 2030 (18 per cent in 2018) and 4.1 per cent lower birth rates expected in 2030 compared to 2018 (MGI 2017, *Jobs lost, jobs gained,* p. 7), the demand for nursing personnel will rise, as will health expenditure. The current expenditure on health within the EU-28 amounted to 9.93 per cent of the GDP in 2016, remaining steadily above 9.5 per cent of the GDP since 2009 (World Bank 2019). Besides these societal challenges, the European pharma and med-tech industry is also struggling in a world of increasingly global competition. For example, the ever-increasing requirements for the approval of new drugs and medical devices is making it difficult to research new active ingredients for medications or to conduct clinical trials without profound costs. To successfully address all the challenges that Europe is facing in the healthcare sector, smart health innovations and applications are key.

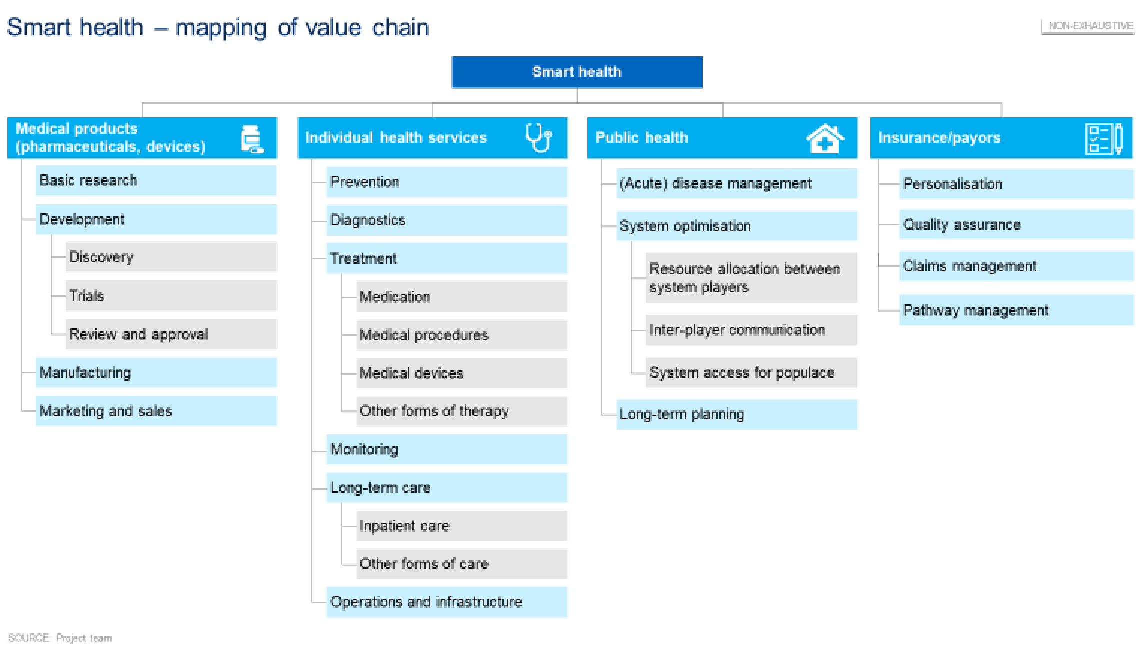
To support the European Commission in defining policies furthering the competitiveness of European SMEs in the healthcare market, we will first describe the core characteristics of the smart health value chain. Second, we will explain the economic relevance of each smart health sub-value chain. Third, we will analyse the current and expected AI impact potential on the smart health value chain. Fourth, we will investigate the role of SMEs in this value chain. And finally, we will present the results of the competitive-fit analysis of the European smart health value chain.

1.11 Core characteristics of the smart health value chain

Considering the overall project objective, we will describe the smart health value chain as a system of four sub-value chains (see Exhibit 21). The four strategic sub-value chains are:

- Industry
- Health service provision
- Governance
- Administration/payors.

EXHIBIT 21: MAPPING OF THE SMART HEALTH VALUE CHAIN



The industry sub-value chain can be thought of as reflecting the complete process, from research to the sale of new pharmaceuticals, medical devices and equipment. It comprises basic research on all health-related topics, development (including discovery, trials, review and approval of medicines), manufacturing and market access and lastly, marketing and sales of all medical products.

The health service provision sub-value chain is following a patient's health journey. The first step in healthcare is information and the prevention of risks to individual and public health. In cases of patients showing symptoms, the next step is diagnostics, followed by informed decisions by medical personnel on the necessary and adequate treatment. This encompasses medication, medical procedures, the use of medical devices, or other forms of treatment (psychological or physical therapy etc.). The last step in the treatment process is monitoring patients' return to health, subsequently circling back to the first step, information and prevention, or in some cases, transitioning to long-term care. Operations and infrastructure can be seen as supporting and enabling activities for the entire sub-value chain, as they include the optimisation of hospital operations, appointment scheduling, data documentation and distribution, as well as care delivery and patient experience.

The governance building block relates to public health from a regulatory or public-sector perspective. Here, four segments can be identified that are of major importance: catastrophe management covers public efforts related to preventing and combating risks to the health of the whole population, such as epidemics, widespread diseases, etc. System optimisation involves communication and resource allocation between stakeholders in the healthcare system (see below) as well as the very important aspect of system access for the whole population (e.g. connection of remote-area patients to healthcare services). Long-term planning includes all efforts to ensure the supply of young talent and skills as well as financial resources. The last segment in governance is health technology assessment, i.e. impact assessments of health technologies, procedures and aids based on scientific evidence, addressing the direct effects as well as unintended consequences of the technologies, which can be used to inform health policy decisions.

The last building block is administration and payors. This block spans several aspects of the health insurance system, namely insurance contracts, customer journeys and claims management.

Divergence from the IPCEI smart health analytical report

The structure of the smart health value chain introduced and elaborated upon in this market analysis report differs from the one outlined in the IPCEI smart health analytical report. The description of the smart health value chain in the IPCEI report mostly relies on a segmentation by type of technology or product. Accordingly, the authors differentiate between:

- Health data storage and analytics solutions
- Connected health devices and applications

- Smart health devices (smart injectors, smart pills, etc. that are unconnected smart health devices)
- Other forms of smart health applications (AR/VR, synthetic biology, 3-D printing, biotech/nanotech).

Prior to introducing their structuring logic, the authors also mention that their logic is only one possible approach to structuring the smart health value chain and that different market analysis reports have divided the smart health market by other criteria (e.g. by type of end-user or by field of application).

While the structure by type of technology or product was a helpful approach at the theme of the IPCEI report – as it provides an overview that is as comprehensive as possible of the smart health value ecosystem, with a strong focus on innovations and technological developments – we decided to follow a different structure in this market report for specific, carefully considered reasons. As this market report aims to not only give an overview of the rise and further development of the smart health ecosystem, but also particularly to provide in-depth insights into the transformation of the whole healthcare sector driven by smart health, we followed the widely-accepted structuring logic of the healthcare sector, distinguishing between major stakeholders (industry, health service provision, governance and payors) and their particular roles and tasks in the overall healthcare sector. Additionally, this structure helps us to best fulfil the two other objectives of this market report:

- To analyse in detail the current and future impact of AI on the smart health value chain (and its transformative impact on the healthcare sector in its entirety)
- To analyse in detail where and how smart health has a particular impact on SMEs in Europe.

The structure of the smart health value chain described above was of course validated and, further refined through multiple expert interviews (e.g. with SME experts) as well as in-depth desk research.

Major stakeholders in the smart health value chain

Major stakeholders in the smart health value chain can be divided into four distinct categories:

- Suppliers in the broadest sense
- ‘Interface’ actors
- Health service providers
- End users

Suppliers include all entities engaged in research, development and manufacturing of medication, (smart) health devices and medical equipment. Special attention shall be given to SMEs in a broad range of fields, such as health-tech start-ups, medium-sized medical devices, lab tech and pharmaceutical companies and research facilities and laboratories.

So-called ‘interface’ actors include payors (e.g. national health systems and insurance companies), policymakers and regulators who influence the approval, access and distribution of health products. With respect to the underlying necessity for data documentation and distribution, databases and dedicated marketplaces for health data should also be taken into consideration. Regarding the long-term planning segment, universities, nursing schools and other educational facilities are also important stakeholders to keep in mind.

Health service providers refer to primary care facilities and adjacent healthcare services. Hospitals, clinics, doctors’ offices, therapy and rehabilitation centres, as well as other care facilities (e.g. homes for the elderly) and services (e.g. outpatient nursing) belong to the primary care facility category. Pharmacies and medical supply stores (e.g. stores for orthopaedic products) fall into the adjacent healthcare service category.

Lastly, end users are all patients in the healthcare system who are addressed at least once along the strategic value chain. As they become better informed about their own health and fitness, addressing issues like access to and ownership of data becomes increasingly more important in order for the entire data-backed value chain to be sustainable.

Links to other strategic value chains

The smart health value chain has several links to the other value chains discussed in this report. As there is a dedicated ‘Medical Internet of Things’ (MIoT), it is not surprising that the smart health value chain is closely linked and at certain points intertwined with the IIoT value chain. Stakeholders in the supplier category and the building block industry as a whole are best suited for IIoT developments and applications. Every aspect of the development and manufacturing of medical products can be reflected in some form by IIoT processes and activities (e.g. the automation and optimisation of experiments, manufacturing of wearables). The treatment segment is influenced by IIoT as well, as there are various potential AI applications that make use of IIoT, ranging from interconnected surgical equipment and hospital monitoring devices to wearable health systems and intelligent implants. What’s more, the automation of routine tasks in all industries (related to developments in IIoT) can drastically reduce occupational risks and diseases (EU OSHA 2019, p. 6), which inevitably has a positive effect on the smart health value chain. Regarding logistics and transportation in different segments of the value chain (e.g. specialised drug transport, ambulances, care/nursing services), the future mobility value chain impacts parts of the smart health value chain.

1.12 Economic relevance of the smart health value chain

The four sub-value chains of smart health differ with regard to their economic relevance (see Exhibit 22). The health service provision sub-value chain is the most relevant one for the EU-28, both in terms of value added (EUR 840.7 billion) and employment (19.3 million employees). It is followed by the industry sub-value chain, which is, in fact, characterised by a higher value-added-per-employee ratio than health service provision. The administration/payors sub-value chain is less important (data for private insurers: EUR 39.7 billion value added, 0.5 million employees; data for public insurers is not available from Eurostat). For the governance sub-value chain, figures for value added and number of employees and other similar data splits are not available as it represents public entities. To get at least a basic understanding of the relevance of this sub-value chain, the total government spending on health of the EU-28 can be used, which amounted to EUR 1.06 trillion in 2016 (all data was extracted from Eurostat for the last available year, 2016).

EXHIBIT 22: ECONOMIC RELEVANCE OF THE SUB-VALUE CHAINS IN SMART HEALTH

SMART HEALTH

A **Economic relevance** – health service provision is the most relevant sub-value chain in terms of value added and employment

Share of all NACE activities, EU-28

	Industry	Health service provision[1]	Governance	Administration/payors[2]
Value added EUR billions	163.1 EU-28 (1.2%)	840.7 EU-28 (6.3%)	1,060.0 Total EU-28 government spending on health	39.7 EU-28 (0.3%)
Employment Employees, millions	1.6 EU-28 (0.7%)	19.3 EU-28 (8.3%)	N/A	0.5 EU-28 (0.2%)
Mapping of Future Mobility SVC to underlying economic sectors	▪ Manufacture of basic pharmaceutical products and preparations (C21), irradiation, electromedical and electrotherapeutic equipment (C26.60), medical and dental instruments and supplies (C32.50) ▪ Parts of: – Computer programming (J62.01), facilities management activities (J62.03) – Other IT and computer service activities (J62.04) – Information services (J63)	▪ Human health activities (Q86) ▪ Residential care activities (Q87)	▪ Regulation of the activities of providing health care, education, cultural services and other social services, excluding social security (O84.12) ▪ Public order and safety activities (O84.24) ▪ Fire service activities (O84.25)	▪ Non-life insurance (K65.12) ▪ Compulsory social security activities (O84.30)

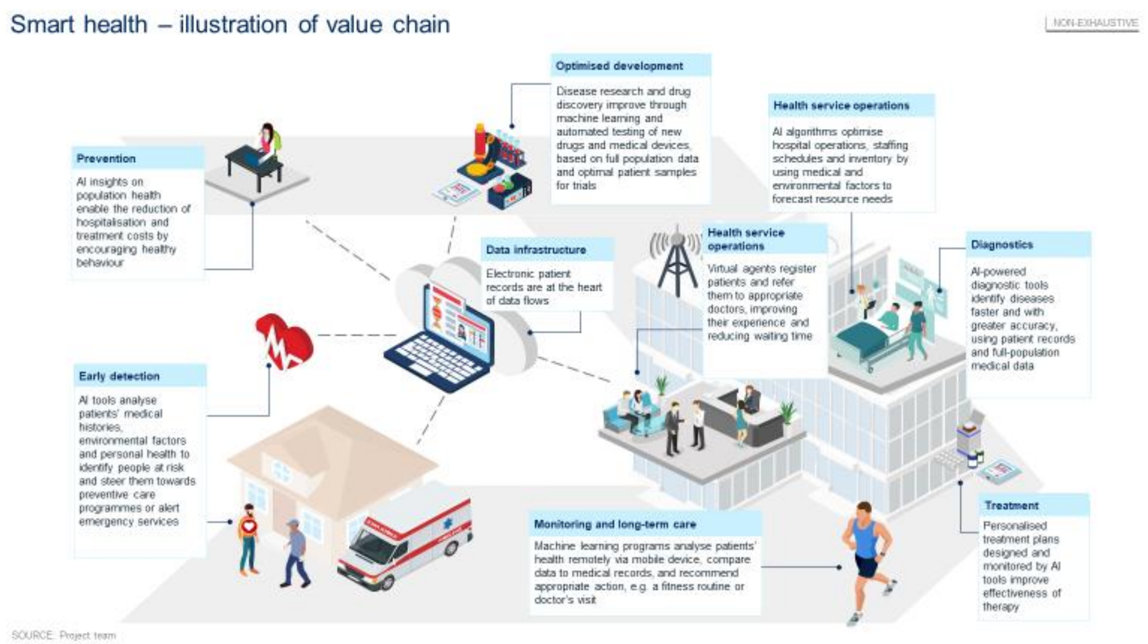
1 Calculation based on summarised data for "residential care" and "social work activities without accommodation" sectors 2 Includes only private insurers

SOURCE: Eurostat; own analysis

1.13 Current and expected AI impact in the smart health value chain

The individual building blocks and segments of the smart health value chain all reflect activities that are being carried out today and are either already enhanced by AI applications or will be in the future. For example, AI-powered diagnostic tools may help increase the speed and accuracy of disease recognition, building on historical medical data and patient records. Telemonitoring of patients' health, recovery progress and medication needs using AI may greatly increase the effectiveness of rehabilitation programmes. AI-based workflow optimisation in hospitals and care facilities may drastically improve care and the patient experience while reducing costs (see Exhibit 23 for possible ways that AI might be implemented in the healthcare sector).

EXHIBIT 23: ILLUSTRATION OF THE SMART HEALTH VALUE CHAIN



A McKinsey study prepared in partnership with the German Managed Care Association (BMC) suggests that EUR 34 billion could potentially be gained in Germany alone through the adoption of digital and AI technologies (McKinsey Digital 2018, *Digitizing healthcare opportunities for Germany,* p. 9). This amounts to 12 per cent of the national health and care expenditures in 2018. For this study, the authors analysed the potential value that could be captured through 26 digital solutions and then quantified this potential for healthcare in Germany.

To provide a structured overview of the possible impact AI can have on health operations, expenditure and GDP, AI use cases and their potential impact will be organised by 'product innovation' and 'process optimisation'.

Product innovation

Innovative products in applied healthcare have the potential to improve individual health and reduce the risk of disease. For example, in the UK, EUR 3.8 billion could be saved using AI to provide preventive care and reduce nonelective hospital admissions (MGI 2017, *Artificial intelligence – the next digital frontier?,* p. 23f). Telemonitoring as a remote continuation of treatment of patients can significantly improve the healing process and reduce relapses or adverse effects, as well as reducing necessary doctor-patient face time. The telemonitoring of patients with chronic diseases can be expected to deliver a total added value of EUR 3.3 billion in Germany alone (McKinsey Digital 2018, p. 9).

Teleconsultation could also ease the staffing shortage, particularly in rural areas. This solution could offer up to EUR 4.4 billion in potential value in Germany (McKinsey Digital 2018, *Digitizing healthcare opportunities for Germany,* p. 9). London-based Babylon Health's AI can interpret symptoms and medical questions through a chatbot interface and provide recommendations on the next steps to take for urgent but non-life-threatening conditions. Similar applications are provided by German health insurer Ottonova and Berlin-based health platform Ada Health.

Process optimisation

Using data sets from the whole population and different non-health-related sources (like climate data or water quality measurements), AI could generate insights for improved catastrophe management in the governance building block of the value chain. AI has the ability to forecast the probable region, impact, at-risk patients and necessary precautions against the next outbreak of certain diseases.

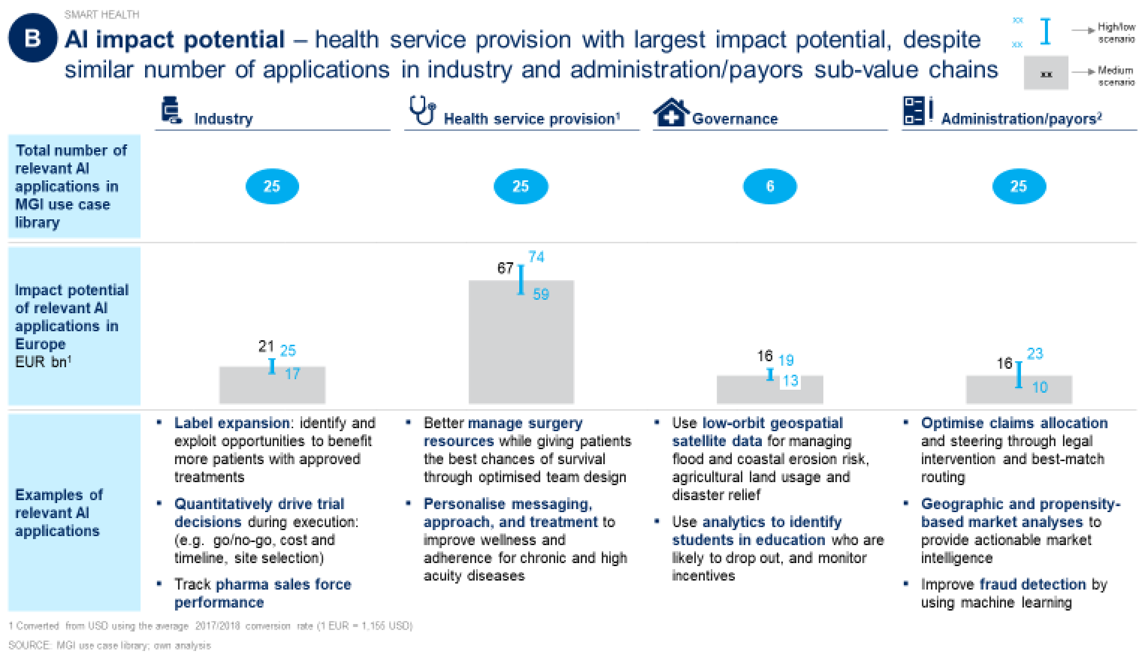
AI-aided diagnostics based on full population data sets could improve the quality and consistency of diagnoses significantly by considering patient and family history, lifestyle data and public health data. Medical imagery and testing analysis that is aided by computer vision and deep learning is quicker and more reliable, as it is able to compare many more data sets to a patient being screened than a human doctor could in the same amount of time.

AI can also help automate routine processes, accelerate lengthy procedures and increase productivity in hospital operations. Patient triage could be optimised significantly, using virtual agents as first points of contact and automating documentation. Full implementation of AI in this context could lead to 30 to 50 per cent greater productivity for nurses, as well as up to 2 per cent GDP savings for operational efficiencies in developed countries (MGI 2017, *Artificial intelligence – the next digital frontier?,* p. 23f).

Quantification of the AI impact potential for smart health in Europe

As for the IIoT value chain above, we draw on the MGI proprietary AI use case library to derive a first indication of the possible AI impact potential in the smart health value chain in Europe. This library holds a collection of real-world applications of AI including the value that is created in the specific cases as well as the potential the rollout of the company-specific use cases has to other companies in the same industry and circumstances. To arrive at an estimate for the impact potential within the smart health value chain, we aggregate the impact of those use cases which are linked to the value chain. Use cases can generate impact in the form e.g. of gains in productivity through cost reductions or efficiency gains. We note that the MGI use case library focusses on company-specific effects and does not account for the economic effects that go beyond companies. Thus, the total impact potential may be understated.

EXHIBIT 24: AI IMPACT POTENTIAL IN THE SUB-VALUE CHAINS OF SMART HEALTH



AI has the biggest impact potential on the health service provision sub-value chain. The 25 relevant use cases we identified have an overall average impact of EUR ~70 billion. For this service-intensive sub-value chain, the example use cases mainly address optimisation of resources and workflows at hospitals, but also improve the wellness and medication adherence for chronic and high-acuity diseases via personalised messaging, approaches and treatment.

Whereas the industry sub-value chain also presents a total of 25 relevant use cases, the average AI impact potential only amounts to EUR ~20 billion, which is only about one third of that from health service provision. Example use cases include label expansion of approved treatments to other patient groups or the optimisation of drug discovery and clinical trials.

For the other two sub-value chains, governance and administration/payors, the AI impact potential is considerably lower. Six use cases in the governance sub-value chain result in EUR ~16 billion in AI impact potential (e.g. using low-orbit geospatial satellite data for managing risk of natural catastrophes). The administration/payors sub-value chain resulted in a comparable impact potential (EUR ~16 billion) despite the considerably higher number of use cases, 25. One very good example use case for administration/payors is the AI-based optimisation of claim allocation for health insurers.

As a final note on this section, we would like to emphasise that this is only an initial estimation of the AI impact potential on smart health. In an expert discussion during one of our workshops, a consensus was reached that the AI impact potential could in fact be ‘high’ across all sub-value chains, especially given AI’s considerable potential for creating societal welfare, e.g. in the governance part of the value chain. A reason for the different observed impact potential in the first model could be the higher presence of early adopters of AI applications in the industry and health service provision parts of the value chain. We will further investigate this in this project’s foresight scenario workstream.

1.14 Role of SMEs in the smart health value chain

The deployment of AI brings various advantages to European SMEs, but also poses risks to ‘traditional’ business models and value chains. In the context of the smart health value chain, the fragmentation of national healthcare markets, the availability, access and use of health data, lack of clarity on regulatory pathways for digital health products and the scalability of operations can be identified as some of the key challenges to the successful deployment of AI. New demographic structures, flexible enterprise structures and lower margins are potential drivers of SME adoption of AI technologies and the reasons for competitiveness amongst leading, innovative SMEs.

General risks for SMEs in the smart health value chain

Cross-border competition in primarily national frameworks is one of the biggest obstacles for SMEs who want to operate and offer products across borders. Additionally, the fragmented landscape of solution providers may create even more complexity or deter the adoption of AI technologies. Microenterprises like doctors’ offices in particular give greater consideration to the short-term effects and costs of new technology before implementing a given technology. With three or more solution providers to choose from for a given service (e.g. appointment scheduling apps), the acceptance or rejection of the service by the patient is an unpredictable risk for the doctor's office. Similarly, patients' reservations about the use of AI and their personal data in healthcare must first be overcome by the service provider implementing the technology (e.g. the doctor offering teleconsultation) before the SME can successfully deploy AI at scale. From an organisational perspective, AI implementation in SMEs is often hemmed by fears of job loss and replacement (EU OSHA 2019, p. 7).

SMEs developing tools for medical use may have difficulties with product registration, reimbursement, procurement, distribution channels, health technology assessment and access to R&D incentives (Horgan et al. 2018, p. 4). That is why they tend to offer either a specialised product/service with broad and cross-border reach or a more diversified portfolio with small reach, mostly operating on a national, regional or even local level.

On another note, SMEs tend to lag behind large multinational companies in access to latest knowledge in AI technology and technological development as well as scale-up. An AI app for checking symptoms does not have to be redeveloped from scratch for each country. It makes little sense for SMEs to invest heavily in developing similar apps for their own use. Developing these apps is a job for organisations that have an international base and, thus, will find it easier to achieve the necessary scale to make their effort worthwhile (McKinsey Digital 2018, p. 9). Yet, experience has shown that tech giants' appetite for larger shares of a given market grows quickly, and they strive for dominant market positions. Mergers and acquisitions make it easy for large companies to adopt the innovations of smaller players, while SMEs need to profile themselves against large corporations in order to stay competitive and/or stay independent.

To provide more specific insights into the role of SMEs in the smart health value chain and particularly the impact of AI on SMEs, we will differentiate between three different types of SMEs (traditional, transitioning and born digital) in the following sections (just as for IIoT and future mobility).

Traditional SMEs

Established SMEs with traditional business models, a rather low degree of digitisation and no prior experience with AI applications (e.g. pharmacies, physicians' offices, care facilities) usually lack both the skills and resources to adopt AI technologies. This means that firstly, they lack the capacity to thoroughly understand the impact of AI and develop a clear AI strategy. For example, they struggle to identify those business areas with the biggest impact potential from AI-driven solutions. Additionally, they lack internal innovation resources and expertise, mainly depending on external sources for digital innovation.

On the other hand, traditional SMEs also the lack financial resources and talent/skills to innovate their business model or transform it into a fully digital business model. First, they usually do not have access to health data to develop AI business models. Second, they lack the funds to invest in building digital and AI capabilities internally (e.g. training of employees). Finally, they face severe challenges in the global race for digital talent, struggling to attract external expertise to the company.

Transitioning SMEs

Transitioning SMEs mostly implement AI to enhance specific aspects of their operations, rather than disrupting the entire business. In some instances, they are required to adopt new technologies because of their tight-knit integration into the wider smart health value chain (e.g. hospitals, insurers, laboratories). Usually, they have understood the impact potential and are at the beginning of their transformation journey. However, they need to decide on the right approach (building from scratch versus using existing solutions). Some of the key challenges they face are adapting their organisational culture to AI (Fountaine, McCarthy and Saleh, 2019), but also, as for traditional SMEs, having access to sufficient financial resources (both upfront and continuously) to integrate AI technologies as well as to fill the gap in digital skills. To better understand what is meant by transitioning SMEs, we will describe two examples of these SMEs in more detail.

Traditional local hospitals struggle today with delayed and inefficient operations (both medical and business) as well as a lack of talent supply, overworked staff and long waiting hours for patients. In future, they will also face reduced patient influx due to patient mobility and teleconsultation. AI can be of high value for local hospitals to manage these challenges. To leverage this potential, they need to integrate AI solutions into their business model. These include solutions to automate and accelerate routine processes (like patient registration and triage), solutions to reduce overall waiting and admin time, and solutions to optimise staffing schedules and resource inventories according to patient forecasts. Even more radical innovations will be the use of service robots in in-patient and day-patient care as well as surgical robots for minimally invasive procedures.

Medium-sized pharma and med-tech companies are currently facing discovery and trial procedures that are lengthy and expensive, often spanning many years. They also are at a disadvantage compared to big pharma and med-tech companies in terms of scaling and resources. Transitioning medium-sized pharma and med-tech companies will benefit from the automation of repetitive and routine tasks in experiments, as this will free up significant time for tasks that need human social skills and interaction. In addition, the implementation of AI-aided insight generation from large data sets will allow for predictive research and skipping certain repetitive process steps.

Born-digital SMEs

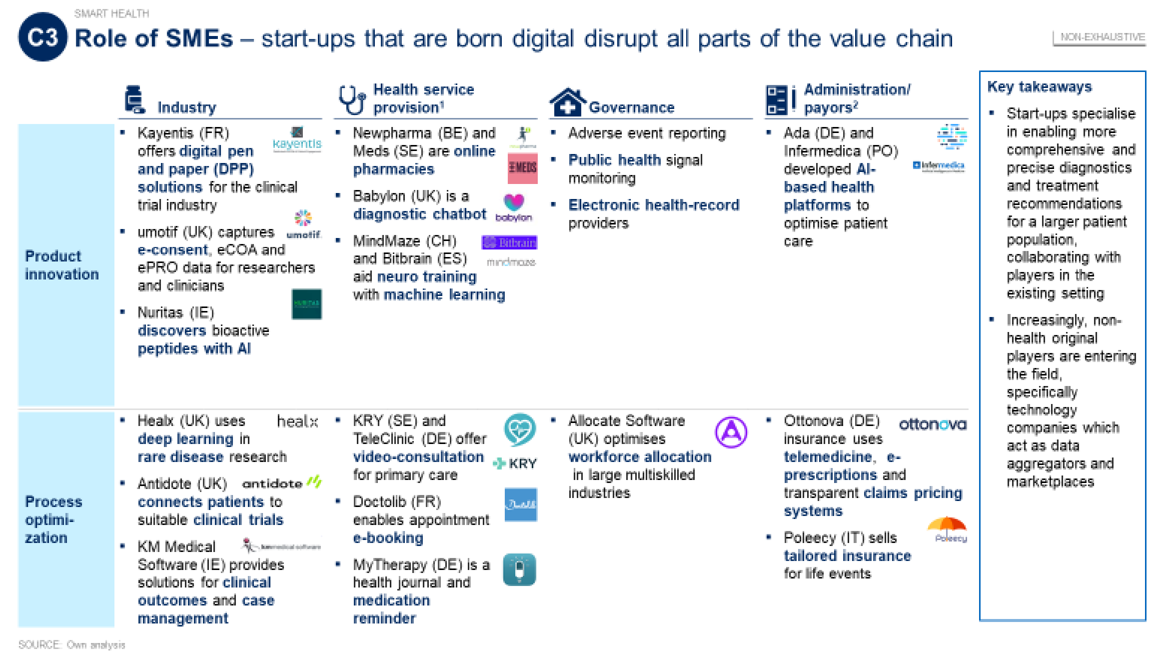
Born-digital SMEs are usually start-ups that build on a fully digital business model from day one and disrupt all parts of the value chain. These start-ups specialise in things like enabling more comprehensive and precise diagnostics and treatment recommendations for a larger patient population. Notably, some digital SMEs/start-ups that had no reference to health in their original business model are now entering the smart health value chain. Specifically, these are technology companies that act as data aggregators and marketplaces. In the following, we will give some examples of born-digital SMEs in the smart health value chain.

MindMaze is a Swiss neuroscience unicorn that builds intuitive human-machine interfaces through its breakthrough neuro-inspired computing platform. They apply machine learning to help stroke victims retrain their minds and bodies, helping patients regain motor functions 35 per cent faster. They also make use of 3-D virtual environments as well as augmented reality, tailoring them to the patient's preferences and needs. Real-time multisensory feedback enables performance monitoring and engages patients in their therapy.

Interconnected implants and 'beyond the pill' medical products as well as specialised wearables monitor different patient input data (blood pressure, clotting, sugar levels etc.) and recommend countermeasures in case of anomalies or health deterioration. There are several start-ups and entrepreneurs that build open-source solutions for AI-powered insulin injectors (like OpenAPS), using data from their continuous glucose monitors (CGM) and insulin pumps, automating insulin delivery based on the CGM's measurements. In 2014, a father and husband of type 1 diabetes patients founded Bigfoot Biomedical, an automated and cloud-connected closed-loop artificial pancreas device. It is currently pending FDA review and approval, and commercial production is set to launch in 2020.

Further examples of born-digital SMEs in the smart health value chain are depicted in Exhibit 25.

EXHIBIT 25: ROLE OF SMES IN THE SUB-VALUE CHAINS OF SMART HEALTH



Further potential for SMEs in the smart health value chain

Personal spending is shifting significantly amongst aging populations, with increased expenditures on healthcare and personal services like personal care. This is creating significant demand for a range of occupations, including doctors, nurses and health technicians. Up to 130 million new jobs in healthcare-related professions are expected to be added globally by 2030 because of aging populations and rising incomes (MGI 2017, *Jobs lost, jobs gained,* p. 7). The MGI study suggests that aging demographics could create demand for 51 million to 83 million workers globally (55 per cent direct and 45 per cent indirect) in healthcare occupations that focus on taking care of the elderly, such as home health aides, personal care aides and nursing assistants (p. 59). As the care sector is strongly dominated by SMEs, this has significant growth potential for them – which can only be leveraged with partly digitised business models – in line with the arguments provided in the previous sections.

As described above, the impact of telemonitoring is significant, and even more so for SMEs like doctors' offices. Reducing doctor-patient face time would save considerable resources for doctors and patients in remote areas.

While small margins and high costs of scale-up make some forms of R&D unattractive for big pharma, it leaves the playing field open for SMEs. The rewards for SMEs are substantial, especially in areas like orphan drugs (medicines for rare conditions – life-threatening or chronically debilitating diseases that affect less than 1 in 2,000). Authorised orphan drugs benefit from ten years' protection from market competition in the EU once they are approved, which makes rare-disease research a prime target for SME innovators (Horgan et al. 2018, p. 9).

Overall, the effective and efficient provision of all healthcare-related services is essential in aging societies that also face fiscal constraints. Including healthcare services, the healthcare sector makes up around 14 per cent of the EU-28 GDP, based on 2016 data. The EU already has a thriving, competitive ecosystem of digital health start-ups, especially in B2B and B2G, as well as large innovative pharmaceutical and medical companies. Further facilitating the development of the smart health value chain in Europe is therefore likely a promising strategy.

1.15 Competitive fit of the smart health value chain

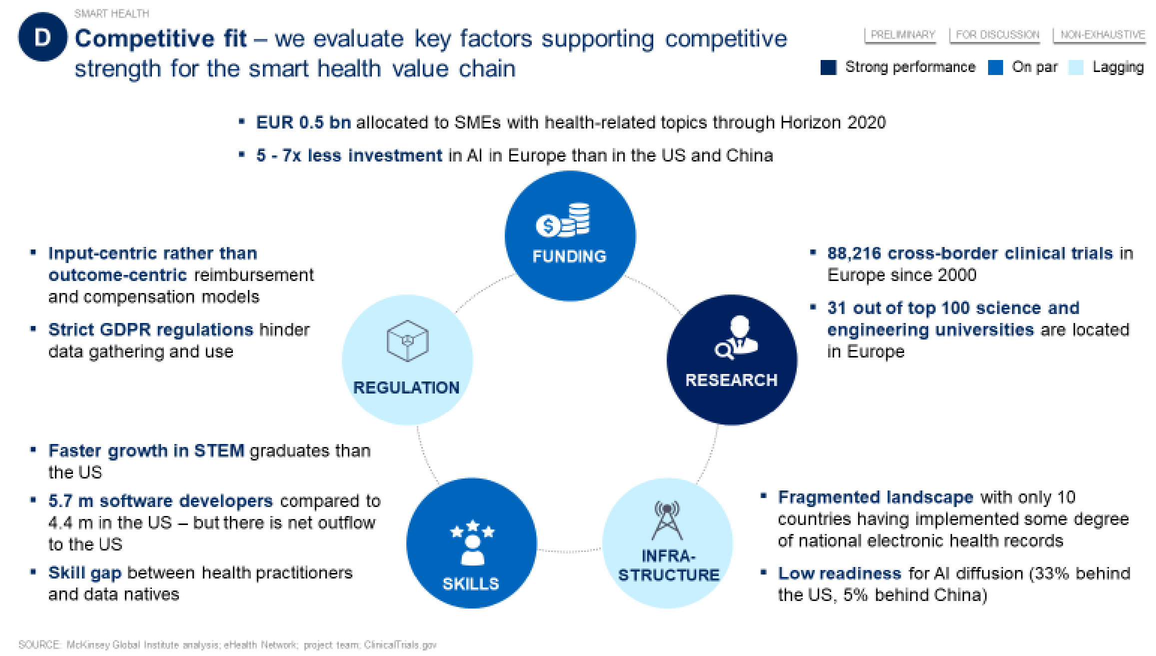
Competitive fit of the overall smart health value chain

The European strategic value chain of smart health can build on a set of key strengths, which have been analysed in-depth as part of the Strategic Forum on Important Projects of Common European Interests. Specifically, it has been highlighted that

- The EU has expertise in collecting health data
- The EU has a strong commitment to ethics
- The EU has a relatively stable regulatory environment

We analysed the competitive fit of the smart health value chain using the same framework as for IIoT and future mobility (see Exhibit 26). The results show that Europe's performance in smart health research is strong; more than 88,000 cross-board clinical trials are being or have been carried out in Europe and 31 of the world's top science and engineering universities are located in Europe (ClinicalTrials.gov; *Times Higher Education* World Reputation Rankings 2018).

EXHIBIT 26: COMPETITIVE OF THE STRATEGIC VALUE CHAIN OF SMART HEALTH



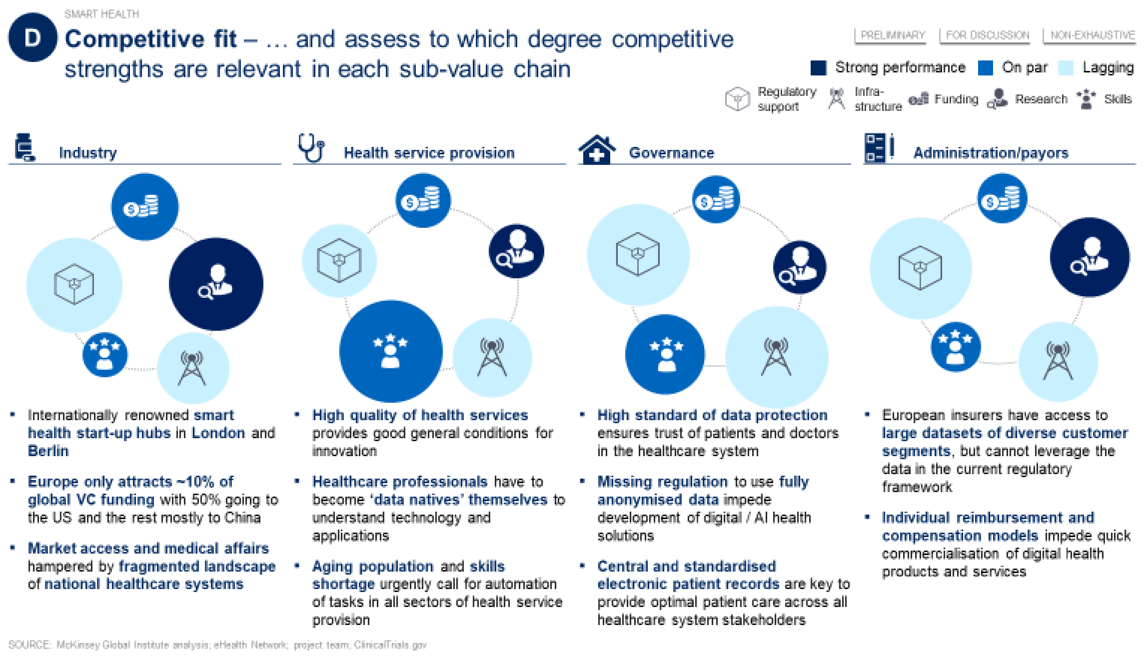
In funding and skills, Europe is still on par with the global competition. The Horizon 2020 programme has dedicated a large amount of funding (EUR 0.5 billion) to SMEs involved in health-related topics; nevertheless, Europe's investments in AI are only 15 to 20 per cent of the amount that the global AI leaders China or the US invest. The number of STEM graduates is growing faster in Europe than in the US and there are also more software developers in Europe than in the US (5.5 million versus 4.4 million) (Atomico and Slush, 2017 – State of European Tech, 2017). However, despite the 5.5 million developers in Europe, it is estimated that the EU-28 will face a shortage of 500,000 software engineers by 2020 (nexten.10, 2018). For the smart health value chain, we also see a particular skills gap between health practitioners and data natives.

Europe is lagging behind the global smart health competition when it comes to regulation and infrastructure, and there are clear barriers to the growth of smart health on the continent: The recent, strict General Data Protection Regulation (GDPR) lacks clarity or at least creates great uncertainty about how to use fully anonymised health data. The approval process for smart health applications takes far too long. For many products and applications, it takes more than 12 months. The process needs to be considerably faster (e.g. less than six months) as start-ups are not able to bridge such long time periods without generating revenue from their products. Reimbursement and compensation models are input-centric rather than outcome-centric (i.e. the current reimbursement system is based on fee-for-service, and not on the positive patient outcomes of the provided services), and also differ considerably between EU member states (Horgan et al. 2018, p. 4f; McKinsey 2019, *Unlocking AI in healthcare,* p. 55). However, SMEs lack resources to build internal expertise on each national reimbursement system. For the infrastructure sub-value chain, the fragmented landscape of national health systems within the EU (e.g. only 10 EU member states have implemented national electronic health records to at least some degree) as well as the low readiness for AI diffusion in Europe clearly hinder the successful uptake of smart health (McKinsey 2019, *Unlocking AI in healthcare,* p. 55).

Competitive fit of the sub-value chains in smart health

To get a deeper understanding of the competitive fit of the European smart health value chain, we also assessed to what degree Europe's competitive strengths (particularly in research, but also in funding and skills) are relevant in each sub-value chain of the overall smart health value chain (see Exhibit 27).

EXHIBIT 27: COMPETITIVE FIT OF THE SUB-VALUE CHAINS OF SMART HEALTH



The **industry** sub-value chain benefits from Europe's strong research position, which is essential for its successful future development. A very positive aspect here is the fact that Berlin and London have become internationally renowned smart health start-up hubs. However, as the smart health industry requires clarity on regulatory support, e.g. in terms of market access and medical affairs, Europe's weak position here is threatening the industry's competitiveness. Additionally, the fact that only 10 per cent of global venture capital funding is funnelled into Europe versus 50 per cent into the US as well as a large majority going China shows that European smart health start-ups have a clear disadvantage when it comes to scaling their business models (McKinsey 2019, *Unlocking AI in healthcare,* p. 55).

The most important competitiveness factor for the health service provision sub-value chain is skills. Whereas Europe can build on a mature foundation here, there is a clear need for more digital natives to fill healthcare service positions in order for the field to have a better understanding of technology and applications. Some EU Member States have started to implement initiatives focussing on including digital skills either on vocational training or in schools or university curricula. However, national government bodies can still increase their support here. At the same time, an aging population and skill shortages urgently highlight the need for the automation of tasks in all sectors of health service provision (McKinsey Digital 2018, p. 8).

For governance, Europe's rather weak position in both infrastructure and regulatory support are problematic, as these two competitive factors are the most relevant for this sub-value chain. Clarity on regulations surrounding the use of fully anonymised health data is urgently needed in order to apply such data to the development of AI or digital health solutions in general. At the same time, the introduction of EU-wide, standardised, electronic patient records is key to providing optimal patient care by all healthcare system stakeholders (McKinsey Digital 2018, p. 8).

The competitive fit of administration/payors relies on regulatory clarity, infrastructure and research. Whereas European insurers have access to large sets of health data of diverse customer segments, they cannot leverage that data in the current regulatory framework. Moreover, the individual reimbursement and compensation models impede the quick commercialisation of digital health products and services (Horgan et al. 2018, p. 4).

Insights from expert discussions

In the context of the market analysis effort we have also conducted several interviews with smart health experts and asked them to share both their own view on the ecosystem as well as to echo the perspectives they hear as part of their client work. In the following we provide an excerpt of the key statements that shaped our discussions. The excerpt is structured along '*access and use of health data', 'reimbursement for digital health solutions in Europe'* and *'SMEs'.*

Access and use of health data

- **'Access and use of health data** are **much more difficult and restricted** in Europe compared to the US'.
- 'Data privacy standards are much higher in Europe compared to the US – which is absolute positive. However, we **need a clear legal framework how anonymised health data can be used** to further develop digital health solutions'.

Reimbursement for digital health solutions in Europe

- ‘The **fragmented regulatory and reimbursement landscape** is one of the biggest problems in Europe – not only for SMEs and particularly start-ups, but also for the large pharma and med-tech companies’.
- ‘We need a new **fast-track approval process for digital health solutions in Europe.** The maximum process time should not exceed six to twelve months. The US has recently implemented a new regulatory process that takes into account the particularities of digital health solutions and ensure faster approval, and therefore market introduction of digital health products’.

Role of SMEs

- ‘SMEs struggle most with the **investments that are required to leverage insights from data.** Required investments are very high until its value is demonstrated’.
- ‘There is a **strong smart health start-up ecosystem in Europe**, with centres in London and Berlin. However, **European start-ups** particularly focus on **services for patients** (e.g. prevention, symptom checkers), **start-ups with disruptive digital business models** with a focus on diagnostics are not well represented in Europe, but are **located in the US’.**

B – Analysis of the most critical AI applications

0 APPROACH AND METHODOLOGY

The objective of this report is to identify critical industrial AI applications as well as those that could potentially become critical for the European economy in the future within the three prioritised strategic value chains. 'Critical AI applications' are defined in line with the tender specifications of this project *'[AI applications] which are important for the European economy, and in which Europe has the strength to become a global AI leader, based on its current strong industrial and research leadership and vibrant start-up ecosystem and developer community'*.

The most critical AI applications presented in this report are clustered based on the three prioritised strategic value chains analysed in depth in the market analysis report, namely:

(4) Industrial IoT
(5) Future mobility
(6) Smart health.

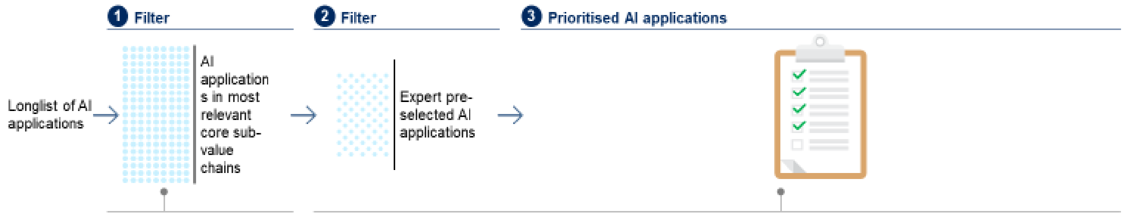
Firstly, we created a longlist of critical industrial AI applications for each of the three strategic value chains that were already relevant and broadly used or that would soon become relevant and broadly used. This means that we did not include any AI applications that were still in the early phase of development or were only used in experimental settings. Thus, the created longlists were only snapshots, valid for the time at which this report was created. Due to the intense research on and development of AI and the overall high speed of AI technology diffusion, new critical industrial AI applications will become relevant and used in all three strategic value chains in future.

We described each AI application based on predefined dimensions (AI capability used, how it works and examples). Next, within each strategic value chain, we grouped these AI applications according to the sub-value chain within each strategic value chain. We specified the business problem they were meant to solve, the innovation type (product innovation or process optimisation) and the underlying AI technology/capability that was being employed. Such technologies/capabilities may include natural language processing (NLP), natural language generation (NLG), speech recognition, machine learning, decision management, virtual agents, robotic process automation and computer vision.

In the next step, we defined a set of criteria to select and prioritise the AI applications in the structured lists by following a two-step approach for the prioritisation (see Exhibit 28).

EXHIBIT 28: PRIORITISATION PROCESS OF AI APPLICATIONS

We prioritise the list of AI applications in a 2-step process and assess their impact along 3 dimensions – social, environmental and economic impact



Selection criteria	**Relevance of sub-value chains**	**Expert/survey-based pre-selection of AI applications**	**Social impact**	**Environmental impact**	**Economic impact**
Data sources	Expert evaluation from 1st workshop McKinsey assessment	Expert evaluation from 2nd workshop Results from SME survey	Expert interviews McKinsey reports External reports	Expert interviews McKinsey reports External reports	MGI use case library McKinsey reports External reports
Metrics	Economic relevance AI impact potential Role of SMEs Competitive fit	Qualitative expert feedback Ratings from SME survey	Qualitative assessment of impact on individual well-being and prosperity, e.g. ▪ Personal health ▪ Personal security ▪ Social capital	Qualitative assessment of impact on environmental aspects, e.g. ▪ Climate change ▪ Pollution ▪ Waste ▪ Natural capital	Quantitative assessment of impact in terms of ▪ Potential value add ▪ Potential employment impact

SOURCE: Project team

In the first step, we filtered the AI applications that were particularly relevant for the core sub-value chains within the respective strategic value chain. The core sub-value chains were already defined in the market analysis as part of this report and characterised based on their economic relevance, the potential impact of AI, the role of SMEs and their competitive fit. The second filter included the expert feedback on the longlist of AI applications. Experts evaluated the AI applications based on their overall relevance for the strategic (sub-) value chain, status of development, number of use cases and the respective impact potential. This preselection was part of the second multi-stakeholder workshop that took place on 11 July 2019 in Brussels. We also included a longlist of AI applications for each strategic value chain in our SME survey (that took place 20–22 August 2019) and asked the participants to select the top three AI applications for their respective value chain. After applying these two filters, we arrived at a shortlist of the most relevant AI applications for each strategic value chain.

In the second step, we evaluated the prioritised AI applications based on their social, environmental and economic impact. To this end, we built on McKinsey and external reports as well as on expert interviews and used both qualitative information and quantitative data. This approach reflected some of the top priorities in the political guidelines of the new European Commission, e.g. an economy that works for people, the European Green Deal, a European fit for the digital age, and a stronger Europe in the world.

1 INDUSTRIAL INTERNET OF THINGS (IIOT)

Summary of key insights

- Overall, we identified 24 relevant AI applications in the IIoT value chain. Three AI applications thereof belong to the product and service development sub-value chain, six to the supply chain and production planning sub-value chain, eight to the core production sub-value chain, six to the after-sales/value-added services sub-value chain and one to the key enablers.

- Out of these 24 IIoT AI applications, 9 are product innovations and 15 are characterised as process optimisations.

- We prioritised the list of the overall 24 IIoT AI applications in a two-step process (relevance of the respective sub-value chain and expert feedback) and assessed their impact along three dimensions (social, environmental and economic impact).

- After applying these filters, we arrived at a shortlist of eight prioritised IIoT AI applications. One out of these eight AI applications is part of the product and service development sub-value chain, two belong to the supply chain and production planning sub-value chain and five AI applications are used within the core production sub-value chain.

- The impact assessment of prioritised AI applications beyond GDP revealed a high economic impact potential (as the AI applications significantly contribute to increasing productivity, enhancing process efficiency and reducing cost), a highly relevant environmental impact (as the AI applications reduce waste and allow for a better use of resources) and – in parts – a significant social impact (as they improve safety at the workplace, help automate repetitive, physically demanding activities and create more meaningful work tailored to employees' skills).

1.1 Analysis of the relevant AI applications in the IIoT

Based on literature research, expert interviews and one multi-stakeholder workshop, we identified 24 relevant AI applications for the IIoT value chain. This list of AI applications is not exhaustive, but covers all AI applications that are in use and have shown significant impact along the value chain.

We identified:

- Three AI applications for the product and service development sub-value chain

- Six AI applications for the supply chain and production planning sub-value chain
- Eight AI applications for the core production sub-value chain
- Six AI applications for the after-sales/value-added services sub-value chain
- One AI application in the area of key enablers.

As can be expected, the majority of AI applications in the IIoT value chain focusses on making the key elements of the production process more effective, i.e. humans, machinery and processes. As a consequence, these applications are mainly found in the supply chain and production planning as well as the core production sub-value chains.

For humans, key applications are about enablement and deployment. A seamless interaction between humans and robots allows for improved working conditions, in particular with respect to repetitive and physically demanding activities. Providing relevant information instantaneously enables employees to focus on the tasks to be accomplished rather than on identifying the information needed. Also, employees can be guided to the activities where they are most needed or that best fit their skill profiles.

With respect to machinery, key applications are about reliability and control systems. Increasing asset reliability, e.g. by means of predictive and preventive maintenance, can significantly contribute to higher production run-times as well as process stability. Analysing relevant machine data along the production process allows for optimisation of the deployment of single machines as well as whole process steps. Also, AI technologies such as image recognition significantly improve process steps such as quality assurance, often seamlessly integrating this into the production process.

Process improvements cover the full value chain. They start with product design and do not stop with product sales, thus touching on after-sales services. Smart product design can enable an efficient production process. Production and logistics processes can be optimised based on tracking parts and collecting relevant data. Sophisticated demand forecasting allows for processes to be streamlined and inventory to be optimised – whether for parts or end products – and predictive and preventive maintenance with respect to end products allows for after-market cost control and enhanced quality.

Among the 24 specific IIoT AI applications, 9 are product innovations whereas 15 are characterised as process optimisations. Clearly, both aspects are of high relevance. Using AI technologies for process efficiency has significant impact and so does the introduction of new products, e.g. robots, sensors or image recognition tools. For more detailed information on all 24 identified IIoT AI applications, see the table on the following pages.

Product and service development

No	AI application	Description	AI capability used	Innovation type	Source
1	AI-based suggestions for product design	▪ AI learns valid design patterns and reduces all possible versions to the relevant ones ▪ Combination of two neural networks, one that creates new designs by optimising an objective function and another that validates the generated design on meeting target requirements. GANs require careful balancing of the networks' dominance over each other and are perceived as very complex AI	▪ Insight generation from complex data	Product innovation	▪ MGI, Artificial Intelligence – The Next Digital Frontier? ▪ McKinsey, Artificial Intelligence in Advanced Industries – Top Artificial Intelligence Use Cases for AI clients
2	Focussed product development	▪ Predict adverse drug effects and drug interactions prior to clinical trials using structured and unstructured data sources (e.g. FDA datasets, insurance records, systems biology and EMRs), thereby reducing after-market interventions	▪ Insight generation from complex data	Process optimisation	▪ MGI, Artificial Intelligence – The Next Digital Frontier?
3	R&D effectiveness	▪ AI-based methodologies to improve R&D project prioritisation and increase performance within individual projects by 1) predicting outcomes of experiments to reduce experimental R&D costs (e.g. component testing, track testing); 2) forecasting factors that might detract from performance; 3) analysing communications and discovering patterns to improve team dynamics	▪ Insight generation from complex data	Process optimisation	▪ McKinsey Digital, Smartening up with Artificial Intelligence (AI) – What's in it for the Industrial Sector? ▪ MGI, Artificial Intelligence – The Next Digital Frontier?

Supply chain and production planning

No.	AI application	Description	AI capability used	Innovation type	Source
4	AI-based procurement expenditure savings	▪ AI automatically combines and harmonises spend data from different sources and across different legal entities to identify identical parts for savings potential ▪ Machine-learning systems can be trained to detect data cues and extract relevant product data. Image recognition and natural language processing allow the extraction of technical requirements from documents, including images to match products and prices	▪ Insight generation from complex data ▪ Language processing, text and audio analytics	Process optimisation	▪ McKinsey, Artificial Intelligence in Advanced Industries – Top Artificial Intelligence Use Cases for AI clients
5	Parts tracking	▪ Tracking of products, components and materials through the production process allows for process control and optimisation ▪ Combining sensors with indoor positioning solutions for an instant overview of all components	▪ Insight generation from complex data	Product innovation	▪ McKinsey, Supply Chain 4.0 – Digitization of the Supply Chain
6	AI-based demand forecasting for reduced inventory	▪ AI enables demand forecasting as a complex function of a large number of variables ▪ Random forest and gradient boosting optimisation enable the inductive exploration of the impact of a large number of variables on demand and build an algorithm for demand modelling. This can help increase planning accuracy (i.e. required buffers) as well as availability	▪ Insight generation from complex data	Process optimisation	▪ McKinsey Digital, Smartening up with Artificial Intelligence (AI) – What's in it for the Industrial Sector? ▪ McKinsey, Artificial Intelligence in Advanced Industries – Top Artificial Intelligence Use Cases for AI clients

No.	AI application	Description	AI capability used	Innovation type	Source
7	AI-enabled yield enhancements	▪ Identify yield losses (products that have to be discarded/need rework) as well as the root causes of quality loss early on in the production process ▪ Using machine-learning systems to link process control data with quality control and yield data in real time, and to analyse them to predict the locations of yield detractors. This enables the identification of unknown problematic locations, e.g. in the physical design layout of individual microchips	▪ Insight generation from complex data	Product innovation	▪ McKinsey Digital, Smartening up with Artificial Intelligence (AI) – What's in it for the Industrial Sector? ▪ McKinsey, Industry 4.0 – Capturing value at scale in discrete manufacturing
8	Optimised sourcing	▪ Optimising the portfolio of suppliers (e.g. with respect to 'make or buy' decisions, spot versus contract purchases) through dynamic understanding of raw material price volatility, real-time view of supply and demand at regional level, and global transparency on organisational-level spending data	▪ Insight generation from complex data	Process optimisation	▪ MGI, Artificial Intelligence – The Next Digital Frontier?
9	Dynamic supply network analysis	▪ Connecting the full spectrum of relevant supply data, including tracking of positions, stock level, etc. to allow for real-time analysis. This can bring about an instantaneous perspective on the supply chain and thus enables the detection of critical developments early on	▪ Insight generation from complex data	Process optimisation	▪ Multi-stakeholder workshop participants

Core production

No.	AI application	Description	AI capability used	Innovation type	Source
10	AI-enhanced predictive maintenance	▪ Use the manifold data generated in production for extended asset life cycles ▪ Machine-learning techniques examine the relationship between a data record and the labelled output (e.g. failures) and create a data-driven model to predict those outcomes. Data records get more complex as data on sound, vibrations and other behaviours are increasingly being recorded	▪ Insight generation from complex data	Product innovation	▪ Smartening up with Artificial Intelligence (AI) – What's in it for the Industrial Sector? Digital McKinsey ▪ Artificial Intelligence in Advanced Industries – Top Artificial Intelligence Use Cases for AI clients, McKinsey

No.	AI application	Description	AI capability used	Innovation type	Source
11	AI-based in-process quality inspection	▪ AI-based image and video analytics to automate and improve quality control processes, i.e. identifying defective parts ▪ Deep-learning architecture of a convolutional neural network allows for the processing of images and automatic extraction of patterns and features from images, based on which distinctions between defective and non-defective products can be made, even for changing defects and model architectures	▪ Insight generation from complex data ▪ Image recognition and video analytics	Process optimisation	▪ Smartening up with Artificial Intelligence (AI) – What's in it for the Industrial Sector? Digital McKinsey ▪ Industry 4.0 – Capturing value at scale in discrete manufacturing, McKinsey ▪ Artificial Intelligence in Advanced Industries – Top Artificial Intelligence Use Cases for AI clients, McKinsey
12	AI-based asset quality inspection	▪ AI-based quality control of cars along their journey in the production process ▪ Computer vision systems combined with machine-learning algorithms enable the detection of a wide range of defects, even at micrometre scale. By categorising these defects correctly, cars are steered to the relevant repair for early-in-process correction	▪ Insight generation from complex data ▪ Image recognition and video analytics	Process optimisation	▪ Industry 4.0 – Capturing value at scale in discrete manufacturing, McKinsey

No.	AI application	Description	AI capability used	Innovation type	Source
13	AI-based human machine collaboration in production	▪ Collaborative robots work next to humans without additional safety guarding ▪ Enhancements in object recognition and semantic segmentation in sensor technology as well as in voice interpretation allow robots to instantaneously and precisely react to their environment. This means safety guarding can be removed; robots can be trained by 'robot instructors' to guide their movements	▪ Insight generation from complex data ▪ Image recognition and video analytics ▪ Language processing, text and audio analytics	Product innovation	▪ Smartening up with Artificial Intelligence (AI) – What's in it for the Industrial Sector? Digital McKinsey ▪ Industry 4.0 – Capturing value at scale in discrete manufacturing, McKinsey
14	Production lot optimisation	▪ Optimise production runs (i.e. how many units are produced every time a stock keeping unit (SKU) is produced) to reduce total landed costs and increase agility/service ▪ Trade-off between changeover costs every time there is a switch to a new SKU and inventory holding costs for producing more at a time	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ Industry 4.0 – Capturing value at scale in discrete manufacturing, McKinsey
15	Optimised labour deployment	▪ Increase equipment utilisation through optimised labour force scheduling ▪ Deploy digital performance management solutions to boost team collaboration and efficiency	▪ Insight generation from complex data	Process optimisation	▪ Industry 4.0 – Capturing value at scale in discrete manufacturing, McKinsey

No.	AI application	Description	AI capability used	Innovation type	Source
16	Automated line replenishments	▪ Guarantee availability of all relevant specific parts at the right time and spot in the production process ▪ Use machine learning to determine timing of goods' transfer	▪ Insight generation from complex data ▪ Machine learning	Process optimisation	▪ Industry 4.0 – Capturing value at scale in discrete manufacturing, McKinsey ▪ Artificial Intelligence – The Next Digital Frontier? MGI Discussion Paper
17	Commissioning, ramp-up and optimisation of complex machinery	▪ Digital twinning and virtual commissioning allow for understanding and analysing the physical object's behaviour in real time, in specific conditions, within the holistic production environment etc.	▪ Insight generation from complex data	Product innovation	▪ Workshop participants

After-sales/value-added services

No.	AI application	Description	AI capability used	Innovation type	Source
18	AI-based asset quality inspection	▪ AI-based image analytics allows for automation and improvement of accuracy of visual inspection and residual value estimation for used cars ▪ Deep-learning model based on image recognition, vehicle and meta-data like mileage as well as configuration enables residual values of cars to be predicted by classifying physical damages to a car's exterior and interior while avoiding labour-intensive inspection activities	▪ Insight generation from complex data ▪ Image recognition and video analytics	Product innovation	▪ MGI, Artificial Intelligence – The Next Digital Frontier?
19	Remote monitoring	▪ Leverage remote on-board diagnostics and connectivity to retrieve critical 'usage data' and errors to identify technical issues early (e.g. for new car models) ▪ Allows OEMs to promptly intervene in software/hardware updates when a malfunction is detected (based on car sensors/actuators) and optimise response time to potential recall campaigns	▪ Insight generation from complex data	Process optimisation	▪ MGI, Artificial Intelligence – The Next Digital Frontier?
20	Predict sales of maintenance services	▪ Use machine learning to predict sources of servicing revenues and optimise sales efforts	▪ Insight generation from complex data	Process optimisation	▪ MGI, Artificial Intelligence – The Next Digital Frontier?

No.	AI application	Description	AI capability used	Innovation type	Source
21	Sales forecast optimisation	▪ Use AI-based system to significantly improve sales forecasting and thus production scheduling, stock allocation etc. ▪ AI-based system (e.g. feed-forward neural networks) automatically learns complex functions among over 100 input variables based on historic data and identifies key dependencies	▪ Insight generation from complex data	Process optimisation	▪ McKinsey, Artificial Intelligence in Advanced Industries – Top Artificial Intelligence Use Cases for AI clients
22	Customer profiling	▪ Based on creating many characteristics for each customer, use machine-learning models to identify patterns of churn customers, for example, (and develop respective campaigns), or highly demanding customers	▪ Insight generation from complex data ▪ Machine learning	Process optimisation	▪ Multi-stakeholder workshop participants ▪ McKinsey, Artificial Intelligence in Advanced Industries – Top Artificial Intelligence Use Cases for AI clients
23	Price setting of new/existing products	▪ Analysing the full spectrum of available data and information relevant for pricing decisions and implementing it for price setting in real time	▪ Insight generation from complex data	Product innovation	▪ Multi-stakeholder workshop participants

Key enablers

No.	AI application	Description	AI capability used	Innovation type	Source
24	Smart cloud to collect IIoT data	▪ Connecting devices and collecting data from IIoT in a smart cloud environment ▪ Smart cloud-based platform delivers a wide range of device and enterprise system connectivity protocol options, industry applications, advanced analytics and an innovative development environment; system focusses on interoperability of apps and standardisation of industry data	▪ Insight generation from complex data	Product innovation	▪ McKinsey, Internet of Things market segmentation and player archetypes ▪ IoT World Today, Link

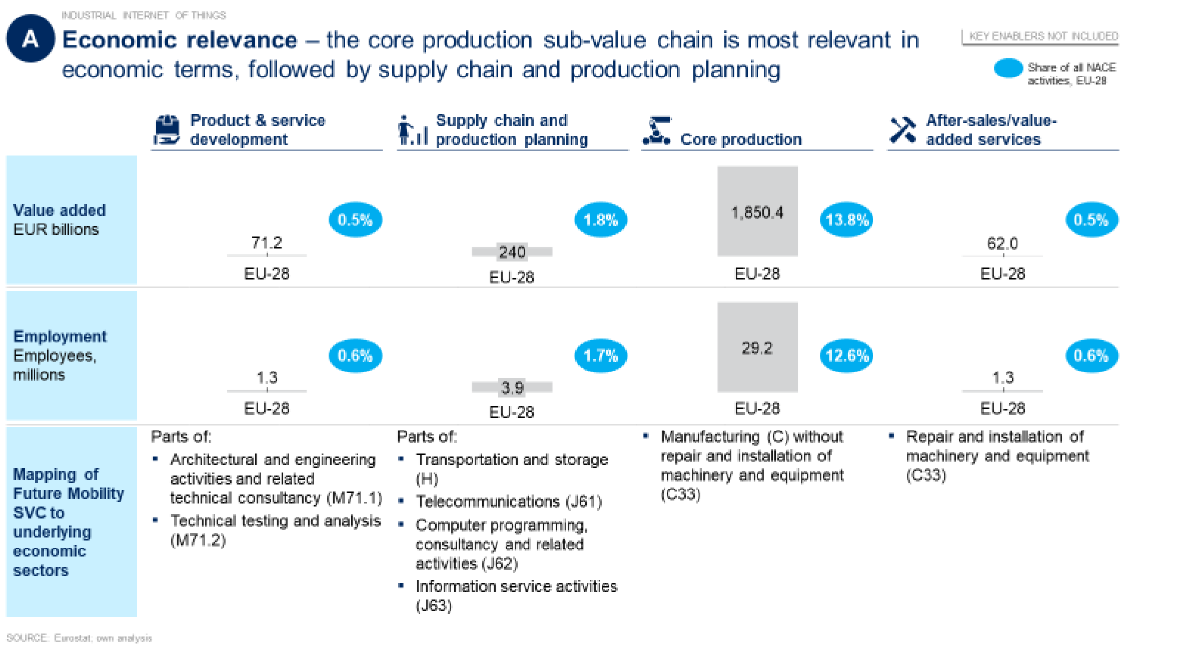
1.2 Prioritisation of the longlist of AI applications in the IIoT

To narrow down the list of AI applications to those considered most impactful and therefore most relevant, we followed a two-step approach. Firstly, we prioritised the 24 IIoT value chain AI applications according to the economic size of the specific sub-value chains they belong to as well as expert feedback. This expert feedback includes contributions of the participants from the multi-stakeholder workshop, the feedback we received from various experts as well as the input of over 100 SME survey participants. Secondly, we assessed the impact of the AI applications along the three dimensions of social, environmental and economic impact.

Step 1: Relevance of sub-value chains

We used the economic size of the respective IIoT sub-value chains as a first filter for the prioritisation of the IIoT AI applications (see Exhibit 29 for economic relevance of IIoT sub-value chains). As core production is by far the most relevant sub-value chain, all AI applications within this sub-value chain were rated as 'highly relevant'. The supply chain and production planning sub-value chain was rated 'medium relevance' due to their lower contribution to value added and employment. The product and service development as well as the after-sales and value-added services sub-value chains were only rated 'low relevance' due to their very low contribution to value added and employment.

EXHIBIT 29: ECONOMIC RELEVANCE OF THE SUB-VALUE CHAINS IN IIOT



Step 2: Expert pre-selection of AI applications at second multi-stakeholder workshop and via SME survey

The second step of prioritisation relied on expert judgement. The first part of the preselection draws on inputs from the second multi-stakeholder workshop, conducted jointly with the European Commission, industry experts and project team on 11 July 2019.

During this workshop, participants emphasised in particular the potential positive impact of the following AI applications:

- **AI-based suggestions for product design.** Participants highlighted that this application is relatively stand-alone as it is not embedded in full-range production processes. Also, it can be scaled from testing to sophisticated methods. Both aspects may facilitate a comparably easy take-up.

- **AI-based demand forecasting for reduced inventory.** Participants considered this to be a classic example and obvious ‘candidate’ for optimisation, e.g. by applying AI technologies. Given the large quantity of inventory data, it should be easy to implement.

- **Optimised sourcing.** Participants emphasised the large potential benefits of creating transparency in the market and the resulting wider economic advantages with respect to intensified competition and innovation. Again, the availability of data was emphasised.

- **AI-based human-machine collaboration in production.** Participants were very confident about the realisation of intensified human-machine collaboration on the production floor. Among the manifold advantages, e.g. with respect to automating physically demanding tasks, they also acknowledged the additional space created by eliminating security distances and fences on the production floor.

- **Optimised labour deployment.** Participants emphasised in particular the universality of this AI application. Companies across industries and size classes can benefit from this application, which is also scalable depending on the technological sophistication applied.

- **Remote monitoring.** Participants highlighted the added value created by the integration of sensors, e.g. in mass-produced vehicles. It allows manufacturers to learn more and more quickly, including about the use of the product as well as specific features, and provides the basis for establishing a different customer relationship, as the producer can actively and preventively reach out.

Participants also evaluated 17 predefined IIoT AI applications (positive versus negative impact).

In addition to the collection of expert feedback within the second multi-stakeholder workshop, a list of 16 IIoT AI applications was also included in our SME survey.[1] We asked the SMEs to select the top three IIoT AI applications out of the list presented. Detailed results are included in the appendix.

After applying the filters outlined in Step 1 and Step 2, we arrived at a shortlist of eight prioritised IIoT AI applications (see Table 1). Five out of these eight AI applications are part of the *core production* sub-value chain, three belong to the *supply chain and production planning* sub-value chain and one belongs to the *product and service development* sub-value chain. Four AI applications are product innovations and four represent process optimisation approaches.

[1] The number of AI applications integrated in our SME survey was limited to 16 per strategic value chain due to technical and methodological constraints.

Steps 1 and 2 – Relevance of sub-value chain and expert feedback:

TABLE 1: PRIORITISATION OF AI APPLICATIONS IN IIOT – RELEVANCE OF STRATEGIC SUB-VALUE CHAIN AND EXPERT FEEDBACK

No.	AI application	Filter 1 – strategic sub-value chain	Filter 2a – expert feedback	Filter 2b – SME survey	Result after Filters 1 and 2
1	AI-based suggestions for product design	Low	High	High	In
2	Focussed product development	Low	Medium	Medium	Out
3	R&D effectiveness	Low	Medium	Medium	Out
4	AI-based procurement expenditure savings	Medium	Medium	Medium	Out
5	Parts tracking	Medium	High	Medium	In
6	AI-based demand forecasting for reduced inventory	Medium	High	High	In
7	AI-enabled yield enhancements	Medium	Medium	Medium	Out
8	Optimised sourcing	Medium	High	Low	Out
9	Dynamic supply network analysis	Medium	Medium	n/a	Out
10	AI-enhanced predictive maintenance	High	Medium (high attention, ambiguous)	Medium	In
11	AI-based in-process quality inspection	High	Medium	High	In

No.	AI application	Filter 1 – strategic sub-value chain	Filter 2a – expert feedback	Filter 2b – SME survey	Result after Filters 1 and 2
12	AI-based asset quality inspection	High	Medium	Medium	In
13	AI-based human-machine collaboration in production	High	High	Medium	In
14	Production lot optimisation	High	Low	Medium	Out
15	Optimised labour deployment	High	High	Low	In
16	Automated line replenishments	High	Medium	n/a	Out
17	Commissioning, ramp-up and optimisation of complex machinery	High	Medium	n/a	Out
18	AI-based asset quality inspection	Low	Low	Medium	Out
19	Remote monitoring	Low	High	Low	Out
20	Predict sales of maintenance services	Low	Medium	n/a	Out
21	Sales forecast optimisation	Low	Medium	n/a	Out
22	Customer profiling	Low	Medium	n/a	Out
23	Price setting of new/existing products	Low	Medium	n/a	Out
24	Smart cloud to collect IIoT data	Low	Low	High	Out

Step 3: Impact assessment of prioritised AI applications beyond GDP

The 11 prioritised AI applications in the IIoT can be analysed with regard to impact that goes beyond traditional metrics related to revenue or cost. Thus, we examined their impact along the three dimensions of:

- Social impact
- Environmental impact
- Economic impact.

For all eight AI applications in the IIoT, we identified high environmental and economic impact potential. With respect to the environment, the AI applications contribute to significant reductions in waste and a more efficient use of resources and space. As AI applications fundamentally change, e.g. quality control processes, faulty products are discovered earlier and can either be repaired directly or are taken out of the production process sooner. Optimal shop floor design and the deployment of unfenced robots contribute to a reduction in the shop floor area needed and respective savings in maintenance and the use of land. With respect to economic impact, AI applications contribute significantly. They have a large potential to increase productivity, e.g. by steering the production process better, supporting the interaction between robots and humans or optimising the deployment of workers within the process. They can also reduce cost, e.g. by decreasing downtimes of machines and stabilising production processes as well as reducing inventories. Furthermore, product development can be much better aligned to production processes.

Many AI applications also have significant social impact. The social impact in the IIoT value chain mostly refers to the well-being of workers. The interaction with robots or automated quality control processes can unburden employees from tedious, often physically demanding and repetitive tasks. AI can also help allocate workers to the tasks they are most skilled at. Moreover, supporting employees with the instantaneous provision of relevant information lets them focus on working in their areas of expertise instead of spending time searching, which is more rewarding.

The detailed findings for the prioritised AI applications in smart health are summarised in Table 2.

TABLE 2: EVALUATION OF PRIORITISED AI APPLICATIONS IN THE IIOT BEYOND GDP IMPACT

No.	AI application	Social impact	Environmental impact	Economic impact	Source
1	AI-based suggestions for product design	▪ n/a	▪ Design can be chosen to be less resource intensive and more stable, thus increasing longevity and usage ▪ Examples have seen a 50 per cent weight reduction of a cabin partition	▪ Potential reduction in development lead times ▪ Benefit from better design (for the specific context)	▪ See above
5	Parts tracking	▪ n/a	▪ Reduces waste or loss (e.g. lost parts) ▪ Increases resource efficiency as unnecessary logistics are reduced	▪ Saves cost as production process runs more smoothly, thus avoiding lags/ standstills ▪ Enables a central steering of distribution and early detection of potential challenges for the production process	▪ See above
6	AI-based demand forecasting for reduced inventory	▪ n/a	▪ Less storage facilities need to be built and maintained; specific cases see inventory reductions of up to 45 per cent ▪ Lower inventories also benefit from less waste, e.g. products that may never be sold	▪ Reduced inventories lower working capital and thus the need for financing ▪ More accurate forecasting improves production scheduling, product configuration, stock allocation and marketing effectiveness, for each saving cost	▪ See above

No.	AI application	Social impact	Environmental impact	Economic impact	Source
10	AI-enhanced predictive maintenance	▪ Reduces the number of spontaneous breakdowns, therefore decreasing potential risks for employees ▪ As predictability of repair improves, employees have to spend fewer extra/non-standard hours in maintenance work	▪ Reduces waste as less production takes place at non-optimal deployment of machinery (e.g. up to 40 per cent reduction in waste)	▪ Increases throughput of production processes as the reliability and stability of the entire process increases ▪ Lets machines run in their most effective modes, thus reducing efficiency losses; prolongs longevity of machines ▪ Maintains high quality of outputs	▪ See above
11	AI-based in-process quality inspection	▪ Spares employees from engaging in tedious and highly repetitive tasks where they have a higher rate of failure than machines	▪ Allows for early-in-process repair work when repair is still an option and faulty parts potentially need not be discarded ▪ Parts that cannot be repaired are sorted out immediately, thus avoiding additional use of resources as the process would have continued	▪ Increases quality of output and thus saves on expensive activities of repair, maintenance and return deliveries as well as the cost entailed in client interactions resulting from faulty products ▪ Higher guaranteed levels of quality potentially provide room for increased margins ▪ Speeds up quality control processes and allows for learning in process	▪ See above
12	AI-based asset quality inspection	▪ Directs workers to the location of defects and lets them spend their time addressing defects, which is more meaningful than searching for them	▪ Avoids wasting resources, as many more parts are repaired and potential replacements take place early on in the process	▪ Constant quality control enables a significant increase in productivity, as repair and adaptations take place within the production process, thus reducing coordination, sorting and reintegration of products into the production process	▪ See above

No.	AI application	Social impact	Environmental impact	Economic impact	Source
13	AI-based human-machine collaboration in production	▪ Direct interactions between humans and machines are made safer and spare humans from potentially health-harming activities (e.g. performing repetitive tasks, carrying heavy items) ▪ Workers' satisfaction with their job can be expected to increase	▪ Elimination of robot-only areas within factories saves space and makes more productive use of buildings	▪ Human-machine collaboration increases productivity, e.g. through the more reliable delivery of product parts, better picking, reduction in travel time ▪ Capex expenditures are reduced as the need for fences diminishes ▪ Reduces the cost of leaves of absence of employees due to illness	▪ See above
15	Optimised labour deployment	▪ Work becomes more meaningful to workers, thus potentially increasing their mental well-being	▪ Reduces use of paper (e.g. for documentation) within the factory	▪ Process efficiency increases as workers are better equipped with the relevant information for their activities (e.g. digital documentation, drawings, trouble-shooting guides and checklists) and are active where they are needed most ▪ Tasks given to workers take better account of a specific worker's strengths and skills, increasing individual performance	▪ See above

2 FUTURE MOBILITY

Summary of key insights

- Overall, we identified 23 relevant AI applications in future mobility. Thereof, ten belong to the **vehicles** sub-value chain, eight to the **mobility services and operations** sub-value chain and five to the **infrastructure** sub-value chain.

- Out of these 23 future mobility AI applications, eight are product innovations and 15 are characterised as process optimisations.

- We prioritised the list of the 23 overall future mobility AI applications in a two-step process (relevance of the respective sub-value chain and expert feedback) and assessed their impact along three dimensions (social impact, environmental impact and economic impact).

- After applying these filters, we arrived at a shortlist of six prioritised future mobility AI applications. Two out of these six are part of the vehicles sub-value chain, three belong to the mobility and services operations sub-value chain and one is used within the infrastructure sub-value chain. Four are product innovations and two represent process optimisation approaches.

- The impact assessment of prioritised AI applications beyond GDP revealed high social impact potential for all six AI applications (e.g. enhanced road safety, fewer traffic accidents, more inclusive mobility), a positive impact on our climate (e.g. reduced pollution, energy consumption and congestion) as well as a positive economic impact (e.g. reduced maintenance or overall costs, enhanced productivity of drivers/commuters).

1.3 Analysis of the relevant AI applications in future mobility

Based on an extended literature search, expert interviews and one multi-stakeholder workshop, we identified 23 relevant AI applications for the future mobility value chain. Of course, this list of AI applications is not exhaustive, but includes relevant AI applications that are either already in use or at least in the testing phase and are of relevance for at least one of the three sub-value chains in future mobility.

We identified:

- Ten AI applications for the vehicles sub-value chain

- Eight AI applications for the mobility services and operations sub-value chain
- Five AI applications for the infrastructure sub-value chain.

Out of these 23 future mobility AI applications, eight are product innovations and 15 are characterised as process optimisations. For all sub-value chains, we identified a higher number of process optimisations than product innovations. However, this does not mean that AI will not be an innovation driver in the future mobility value chain. We see great product innovations (like L4/L5 autonomous driving and robo-delivery). But AI is currently a great driver for process optimisations, and highly important for large companies and SMEs when optimising their internal processes and product and service portfolios.

In the following tables, we provide detailed information on all 23 identified future mobility AI applications. Afterwards, we present more details on model AI applications for both product innovations and process optimisations.

Vehicles

No.	AI application	Description	AI capability used	Innovation type	Source
1	**AI-enhanced predictive maintenance**	▪ The manifold data generated in production is used for extended asset life cycles ▪ Machine learning techniques examine the relationship between a data record and the labelled output (e.g. failures) and create a data-driven model to predict those outcomes. Data records get more complex as data on sound, vibrations and other behaviours are increasingly being recorded	▪ Insight generation from complex data ▪ Image recognition and video analytics	Process optimisation	▪ McKinsey, Artificial intelligence – automotive's new value-creating engine, Link
2	**Generative design**	▪ AI-based suggestions for product design lead to structures with superior performance metrics ▪ A set of constraints on the part to be engineered is defined; software calculates millions of possible configurations and an algorithm iteratively learns which of them constitute solutions to problems	▪ Insight generation from complex data	Product innovation	▪ Expert interviews ▪ BMW company website, Link
3	**Predictive service**	▪ Use of on-board diagnostic tools in a vehicle to anticipate the need for service ▪ Software learns about the normal operating mode and detects anomalies; sensor data comes directly from the vehicle	▪ Insight generation from complex data ▪ Automated decision making	Product innovation	▪ McKinsey, Artificial intelligence – automotive's new value-creating engine, Link

No.	AI application	Description	AI capability used	Innovation type	Source
4	**Upselling and rebate reduction**	▪ Improvements to cross- and upselling after purchase based on analytics ▪ AI-powered systems build on ERP and CRM data to predict cross-selling opportunities (e.g. for vehicle add-on features)	▪ Insight generation from complex data	Process optimisation	▪ McKinsey, Artificial intelligence – automotive's new value-creating engine, Link
5	**L4/L5 autonomous driving**	▪ Driverless vehicles, operating fully autonomously, enabled by machine vision ▪ Sophisticated sensors, machine vision systems and huge training data sets enable cars to observe their surroundings and react fully autonomously to impulses	▪ Automated decision making	Product innovation	▪ McKinsey, Change vehicles – how robo-taxis and shuttles will reinvent mobility, Link ▪ McKinsey, Autonomous-driving disruption – technology, use cases, and opportunities, Link
6	**Inventory management**	▪ AI-optimised picking and sorting algorithms for better warehouse management ▪ Asset trackers, IIoT- and ERP data can help optimise the way in which products are arranged on shelves, i.e. minimise the cumulative picking time for frequently assembled part combinations	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ McKinsey, Artificial intelligence – automotive's new value-creating engine, Link

No.	AI application	Description	AI capability used	Innovation type	Source
7	**AI-based asset quality inspection**	▪ AI-based image analytics to automate and improve the accuracy of visual inspection and residual value estimation for used cars ▪ Deep-learning model based on image recognition, vehicle data and metadata like mileage and configuration to predict the residual value of cars by classifying physical damages to their exteriors and interiors while avoiding labour-intensive inspection activities	▪ Insight generation from complex data ▪ Image recognition and video analytics	Process optimisation	▪ Expert interviews ▪ ProovStation company website, Link
8	**Next-product-to-buy prediction**	▪ AI can be used to personalise the sales experience ▪ By analysing customers' demographics, transaction histories and online activities, AI can help generate tailored product recommendations ▪ The first automotive OEMs are experimenting with AI-enabled up- and cross-selling. They're comparing customers' specific configurations with historic ones to identify similar configurations and predict which additional vehicle features a customer would most likely be willing to buy	▪ Insight generation from complex data	Process optimisation	▪ McKinsey Center for Future Mobility, How to win tomorrow's car buyers – artificial intelligence in marketing and sales, Link
9	**Targeted advertising**	▪ Targeted advertising may improve lead generation, and conversion rates, and reduce overall marketing spend	▪ Insight generation from complex data ▪ Virtual agents	Process optimisation	▪ McKinsey, Artificial intelligence – automotive's new value-creating engine, Link

No.	AI application	Description	AI capability used	Innovation type	Source
10	**Crash test simulation**	▪ Reduction of costly real-life crash tests through AI-enabled virtualisation of and simulation during the R&D phase	▪ Insight generation from complex data	Process optimisation	▪ McKinsey, Artificial intelligence – automotive's new value-creating engine, Link

Mobility services and operations

No.	AI application	▪ Description	AI capability used	Innovation type	Source
11	**Digital customer engagement**	▪ Improvements in customer experience and lead generation ▪ AI can be used to tailor the digital customer experience, predict customer behaviour and help with automated customer support systems (in the form of chatbots)	▪ Virtual agents ▪ Insight generation from complex data	Process optimisation	▪ Capgemini Research Institute, Accelerating automotive's AI transformation
12	**Mobility planning and analytics**	▪ Multimodal transportation planning software ▪ Navigation/route planner giving real-time recommendations on which transportation connections to take, integrating all modes of public transport and shared mobility services with the back end of mobility analytics features (can also be used to analyse the effectiveness of public transport infrastructure)	▪ Insight generation from complex data ▪ Virtual agent	Product innovation	▪ MDPI Sustainability 2019, Vol. 11, p. 189 ▪ European Parliament, briefing, Artificial intelligence in transport ▪ Expert interviews ▪ Door2door company website, Link

No.	AI application	▪ Description	AI capability used	Innovation type	Source
13	**Robo-delivery**	▪ Autonomous robots deliver goods in urban areas ▪ Machine vision and autonomous driving technologies are used to guide the robots along delivery route (on pedestrian walkways, for now)	▪ Automated decision making	Product innovation	▪ McKinsey, Autonomous-driving disruption – technology, use cases, and opportunities, Link ▪ McKinsey, Parcel delivery: the future of last mile, Link
14	**Truck platooning**	▪ Reduction in fuel consumption and improvement in traffic efficiency through close coupling of heavy-goods vehicles ▪ Lead truck driven by a human driver, while the other trucks keep a minimal distance behind each other and replicate the moves of the first truck using V2V communication and machine vision systems	▪ Automated decision making	Process optimisation	▪ Autonomous-driving disruption – technology, use cases, and opportunities, Link ▪ McKinsey, Distraction or disruption? Autonomous trucks gain ground in US logistics, Link

No.	AI application	▪ Description	AI capability used	Innovation type	Source
15	**Fleet management**	▪ Optimise redistribution of vehicles, routing, ride allocation and drop-off points ▪ Various machine learning techniques can help turn ride-history data into insights on where more fleet capacity should be directed, where drop-off points should be located, how rides should be allocated etc.	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ McKinsey, Artificial intelligence – automotive's new value-creating engine, Link ▪ Autonomous-driving disruption – technology, use cases, and opportunities, Link ▪ European Parliament, briefing, Artificial intelligence in transport
16	**Automotive finance**	▪ AI-supported credit/loan risk prediction ▪ Machine learning system that allows for the consideration of factors such as bankruptcy, previous car-payment records and time spent living at current residence	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ Wall Street Journal, Link

No.	AI application	▪ Description	AI capability used	Innovation type	Source
17	**Automotive insurance**	▪ -enabled car inspection feature, e.g. in a mobile app. The app allows customers to buy or renew policies and it also simplifies the process of making a repair claim ▪ In case of a lapsed policy, the app uses AI to divide vehicle images into frames and identify the various parts of the car to look for damage. In most cases the AI module can make a judgement very quickly	▪ Image recognition and video analytics ▪ Insight generation from complex data	Process optimisation	▪ Microsoft, Link
18	**Parking analytics**	▪ Real-time parking suggestions through AI-powered analytics ▪ Software considers parameters such as traffic data, weather or events/social indicators and uses machine learning to predictively analyse the parking situation and make recommendations	▪ Insight generation from complex data	Product innovation	▪ Expert interviews ▪ Bosch company website, Link

Infrastructure

No.	AI application	▪ Description	AI capability used	Innovation type	Source
19	**Traffic management**	▪ AI-powered analytics software that helps to reduce and eliminate congestion on roads ▪ Software uses real-time (IoT) data from cars, road networks and weather stations to generate insights on where congestion is likely to occur and simulates countermeasures	▪ Insight generation from complex data	Process optimisation	▪ Strategy&, Link
20	**Smart charging**	▪ Smart charging software that helps smooth peaks in electric vehicle energy usage and stabilises the energy grid ▪ The software predictively analyses supply and demand and allows electric vehicles to be charged only as much as they need, taking individual driving data into account	▪ Insight generation from complex data	Product innovation	▪ Strategy&, Link ▪ McKinsey, Artificial intelligence – automotive's new value-creating engine, Link
21	**HD mapping**	▪ AI-based generation of high-definition maps and road environments that can be used for autonomous vehicle training, simulation and driving purposes ▪ An algorithm takes images and lidar data to render and label 3-D environments down to the centimetre	▪ Insight generation from complex data ▪ Image recognition and video analytics	Product innovation	▪ Expert interviews ▪ Deepmap company website, Link

No.	AI application	▪ Description	AI capability used	Innovation type	Source
22	**Virtual training data generation**	▪ Virtual training data generation allows autonomous vehicle software to be tested in a virtual environment rather than physically on the road ▪ Testing in this virtual environment is time and cost efficient	▪ Insight generation from complex data ▪ Image recognition and video analytics	Process optimisation	▪ Capgemini, Link
23	**Deep natural anonymisation**	▪ Enables companies to use publicly recorded camera data for autonomous vehicles while remaining compliant with data regulations	▪ Insight generation from complex data ▪ Image recognition and video analytics	Process optimisation	▪ Brighter AI company website, Link

Product innovation

Some of the most relevant AI-enabled product innovations can be found in the mobility services sub-value chain, the most prominent example being services enabled by autonomous driving technology. These include robo-taxis, trucking and last-mile delivery:

- **Robo-taxis**
  On the consumer side, autonomous ride-hailing services have the potential to free up time that drivers would normally spend behind the wheel, which can in turn be used more productively. It is also expected that L4/L5 autonomous cars will reduce the number of car accidents and bring down the cost per passenger mile.

- **Robo-delivery**
  Autonomous ground vehicles or drones are set to play an important role in addressing the common challenges of last-mile delivery, which include a shortage of workers, congestion in large cities and long distances in rural areas. The last mile's share of total logistics costs often amounts to more than 50 per cent (McKinsey, *Parcel delivery – the future of last mile,* p. 6).

These AI applications will disrupt traditional business models in mobility services (see Exhibit 13 in the market analysis part of this report) and morph them into fully integrated platforms covering a wide range of customer needs. This will impact many transport and fleet operators while potentially unlocking value for disruptive business models in shared mobility, data-enabled (connectivity) services and the new vehicle technologies aftermarket (see Exhibit 17 in the market analysis part of this report).

Other examples of product innovations include voice-powered in-car entertainment systems, real-time parking information and multimodal mobility planning platforms.

Process optimisation

AI techniques targeting process optimisation can be found throughout the vehicle sub-value chain, impacting procurement, maintenance, manufacturing and sales and marketing. They improve:

- Tact times (by means of smart-picking algorithms and asset trackers)
- Quality (by means of machine-vision-powered quality control mechanisms)
- Customer experience (by means of interactive channels and bots)
- Working capital requirements (by means of reduced inventory levels through improved order-flow prediction)

- Predictability and business continuity (by means of analytics platforms for IoT data).

A McKinsey study looking at automotive OEMs shows that optimised processes along the value chain pose great value creation potential (McKinsey, *Artificial intelligence – automotive's new value-creating engine,* p. 16). The biggest opportunities here surround levers that impact the cost of goods sold. The largest absolute cost reduction effects are thus found in manufacturing (15 per cent improvement), procurement (4 per cent improvement) and supply chain management (16 per cent improvement). Moreover, AI has the potential to improve OEMs' sales and marketing expenditures by 13 per cent (through both more efficient spending as well as top-line growth).

Most subsegments of mobility operations and software infrastructure also represent functions that either already are or likely will be enhanced by AI applications in the future. For example, machine learning may be applied to derive insights on ride demand, optimal routing and optimal physical distribution of vehicles (specifically in the micromobility context). Dynamic pricing algorithms, which have become an important element of ride-hailing economics, also build on advanced machine learning techniques. Additionally, AI will likely help support the electric charging infrastructure, providing intelligent solutions for distributing and allocating charging slots to cope with peak stress on the electricity grid.

Mobility-adjacent services are another domain with high AI impact potential. For automotive insurance, AI can be used to automatically process claims, predict call centre capacity needs, automate customer calls and detect fraudulent activity.

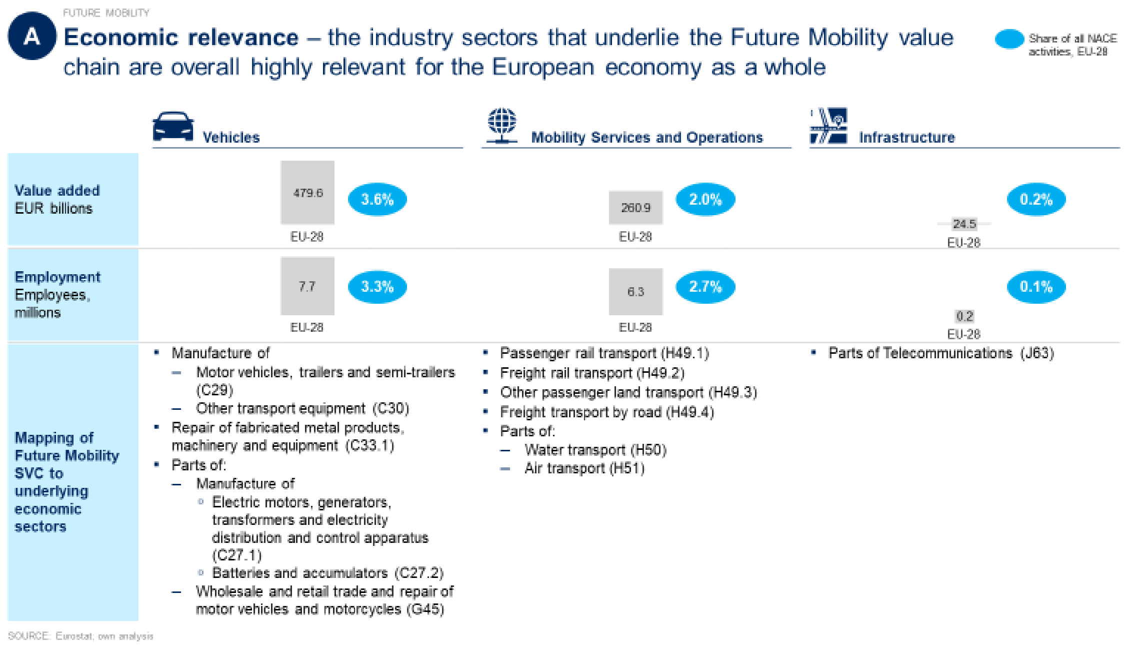
1.4 Prioritisation of the longlist of AI applications in future mobility

We followed the same prioritisation approach/logic for future mobility AI applications as we did for those in IIoT. We prioritised the list of the 23 overall future mobility AI applications in a two-step process (relevance of the respective sub-value chain and expert feedback) and assessed their impact along three dimensions (social, environmental and economic impact).

Step 1: Relevance of sub-value chains

We used the economic relevance of the respective future mobility sub-value chains as a first filter to prioritise the smart health AI applications (see Exhibit 30 for the economic relevance of the three future mobility sub-value chains). The **vehicles** sub-value chain is characterised by the highest value added; this was rated as 'highly relevant'. The **mobility and services operations** sub-value chain also has a relatively high value added and relevant employment numbers, and was accordingly rated with 'medium relevance'. The **infrastructure** sub-value chain was rated with ‘low relevance’ due to its considerably lower value added and employment impact.

EXHIBIT 30: ECONOMIC RELEVANT OF THE SUB-VALUE CHAINS IN FUTURE MOBILITY



Step 2: Expert pre-selection of AI applications

The first part of the pre-selection draws on input from the second multi-stakeholder workshop, conducted jointly with the European Commission, industry experts and the project team on 11 July 2019.

During this workshop, experts agreed that robo-delivery, smart charging and fleet management constitute use cases that could be very impactful for SMEs, because:

- Robo-delivery has derivative effects on SMEs – it could enable them to integrate their own last-mile-delivery infrastructure instead of relying on intermediaries (e.g. restaurants in food delivery)
- A smart charging infrastructure could in part serve as an adjacent line of business for traditional SMEs (e.g. gas stations, parking lot operators)
- Fleet management is locally organised (e.g. charging and distribution of e-scooters in cities) and could be championed by SMEs.

Experts also agreed that L4/L5 autonomy and driverless vehicles will fundamentally transform mobility concepts and public infrastructure. They confirmed that parking analytics constitute an interesting use case that could impact SMEs should they choose to provide and sell parking data, either to attract more business or to serve the informational needs of other players – but currently, the business case is not economically viable, and the ecosystem has to mature first.

Experts highlighted that applications related to digital customer engagement as well as up- and cross-selling are mainly relevant for large B2C companies with comprehensive data repositories and are thus less impactful for SMEs. They also noted that generative design solutions are mostly already in place where they add value.

In addition to the collection of expert feedback gained from the second multi-stakeholder workshop, a list of 16 future mobility AI applications was also included in our SME survey. We asked the SMEs to select the top three future mobility AI applications. Detailed results are included in the appendix.

Applying the filters outlined in Step 1 and Step 2 produced a shortlist of six prioritised future mobility AI applications (see Table 3). Two out of these six AI applications are part of the vehicles sub-value chain, three belong to the mobility and services operations sub-value chain and one is used within the infrastructure sub-value chain. Four AI applications are product innovations and two represent process optimisation approaches.

Steps 1 and 2 – relevance of sub-value chain and expert feedback:

TABLE 3: PRIORITISATION OF AI APPLICATIONS IN SMART HEALTH – RELEVANCE OF STRATEGIC SUB-VALUE CHAIN AND EXPERT FEEDBACK

No.	AI application	Filter 1 – strategic sub-value chain	Filter 2a – expert feedback	Filter 2b – SME survey	Result after filters 1 and 2
1	**AI-enhanced predictive maintenance**	High	Medium	Low	Out
2	**Generative design**	High	Low	Low	Out
3	**Predictive service**	High	Medium	Medium	In
4	**Upselling and rebate reduction**	High	Low	Medium	Out
5	**L4/L5 autonomous driving**	High	High	High	In
6	**Inventory management**	High	Medium	Low	Out
7	**AI-based asset quality inspection**	High	Medium	Low	Out
8	**Next-product to-buy prediction**	High	Low	*n/a*	Out
9	**Targeted advertising**	High	Low	*n/a*	Out
10	**Crash test simulation**	High	Low	*n/a*	Out
11	**Digital customer engagement**	Medium	Low	High	Out

No.	AI application	Filter 1 – strategic sub-value chain	Filter 2a – expert feedback	Filter 2b – SME survey	Result after filters 1 and 2
12	**Mobility planning and analytics**	Medium	Medium	High	In
13	**Robo-delivery**	Medium	High	Medium	In
14	**Truck platooning**	Medium	Low	Medium	Out
15	**Fleet management**	Medium	High	High	In
16	**Automotive finance**	Medium	Medium	*n/a*	Out
17	**Automotive insurance**	Medium	Medium	*n/a*	Out
18	**Parking analytics**	Medium	High	Low	Out
19	**Traffic management**	Low	High	High	In
20	**Smart charging**	Low	High	Low	Out
21	**HD mapping**	Low	Low	Low	Out
22	**Virtual training data generation**	Low	Low	*n/a*	Out
23	**Deep natural anonymisation**	Low	Low	*n/a*	Out

Step 3: Impact assessment of prioritised AI applications beyond GDP

The six prioritised AI applications in future mobility can be analysed with regard to impact that goes beyond traditional metrics related to revenue or cost. We look at their impact along the three dimensions of:

- Social impact
- Environmental impact
- Economic impact.

For all six AI applications, we identified a high social impact potential. Some of them will enhance road safety and lead to fewer traffic accidents. Autonomous driving applications will also enable more inclusive mobility (e.g. for elderly and disabled persons) at reduced costs at the same time. Moreover, robo-delivery will considerably improve health and safety for delivery drivers and fleet management applications will improve customer experience through better reliability and availability of services.

We also found that nearly all prioritised AI applications are characterised by a positive impact on our climate. Reduced pollution, energy consumption and congestion (e.g. through optimised routing and vehicle behaviour) are major positive effects of most of the prioritised AI applications.

Our economic impact assessment of the prioritised AI applications revealed several significant positive effects. These include reduced maintenance or overall costs (through *predictive services* or *traffic management*), enhanced productivity of drivers/commuters (due to *autonomous driving* applications) as well as new business opportunities (e.g. due to *robo-delivery*).

The detailed findings for the prioritised AI applications in future mobility are summarised in Table 4.

TABLE 4: EVALUATION OF PRIORITISED AI APPLICATIONS IN FUTURE MOBILITY BEYOND GDP IMPACT

No.	AI application	Social impact	Environmental impact	Economic impact	Source
3	**Predictive service**	• Enhanced road safety and fewer traffic accidents due to reduction of faulty cars in traffic	• Improved product lifecycles	• Reduced maintenance cost, because faults are repaired before car breaks down • Customer satisfaction	• Bosch, Link
5	**L4/L5 autonomous driving**	• Inclusive mobility through removal of barriers, e.g. mobility for the elderly and disabled • Inclusive mobility through reduced mileage cost, thus higher overall affordability of mobility • Enhanced road safety and fewer traffic accidents • Re-purposing of public areas and roads, as on-demand mobility may lower absolute number of cars in operation	• Reduced energy consumption of individual vehicles • Reduced congestion • Reduced pollution	• Enhanced productivity of drivers/commuters • Less fuel spending • Less maintenance spending, due to smoothness/consistency of vehicle operation	• Stanford, Link
12	**Mobility planning and analytics**	• Time savings for commuters • Cost savings for commuters, through all-in-one bookings and thus more inclusive mobility	• Reduced congestion • Reduced pollution • Higher integration/visibility of environmentally friendly transport modes	• Shorter routes • Enhanced customer satisfaction • Enhanced visibility for local operators	• Expert interviews • Door2door company website, Link

No.	AI application	Social impact	Environmental impact	Economic impact	Source
13	**Robo-delivery**	• Fast delivery times and customer satisfaction • Improved health and safety for delivery drivers, where autonomous ground vehicles act as enabler instead of replacement	• *n/a*	• Improved unit economics for last-mile delivery providers • New business opportunities for companies who traditionally relied on third-party distributors	• McKinsey, Parcel delivery: The future of last mile, Link
15	**Fleet management**	• Inclusive mobility through reduced mileage cost, thus higher overall affordability of mobility • Enhanced customer experience through improved reliability and availability of service • Faster pick-up times	• Less pollution through optimised routing and vehicle behaviour	• Higher asset utilisation • Improved unit economics	• Hitachi, Link
19	**Traffic management**	• Enhanced road safety • Time savings for commuters	• Reduced congestion • Reduced pollution	• Reduced overall spend • Shorter routes	• Telegra Europe, Link

3 SMART HEALTH

Summary of key insights

- Overall, we identified 29 relevant AI applications in smart health. Thereof, four AI applications belong to the industry sub-value chain, 16 to the health service provision sub-value chain, seven AI applications to the governance sub-value chain and two AI applications to the administration/payors sub-value chain.

- Out of these 29 smart health AI applications, 12 are product innovations and 17 are characterised as process optimisations.

- We prioritised the list of the overall 29 smart health AI applications in a two-step process (relevance of the respective sub-value chain and expert feedback) and assessed their impact along three dimensions (social impact, environmental impact and economic impact).

- After applying these filters, we arrived at a shortlist of seven prioritised smart health AI applications. Six out of these seven AI applications are part of the health service provision sub-value chain, one belongs to the governance sub-value chain. Three AI applications are product innovations and four represent process optimisation approaches.

- The impact assessment of prioritised AI applications beyond GDP revealed both a high social impact (e.g. significant contribution to the well-being/health of individuals, considerable improvement of public health) and a high economic impact potential (e.g. decreased healthcare (delivery) costs) for all seven prioritised AI applications. The environmental impact of the selected AI applications is less important and mostly indirect.

1.5 Analysis of the relevant AI applications in smart health

Based on an extended literature search, expert interviews and one multi-stakeholder workshop, we identified 29 relevant AI applications for the smart health value chain. Of course, this list of AI applications is not exhaustive, but includes relevant AI applications that are either already in use or at least in testing phase and are of relevance for at least one of the four sub-value chains in smart health.

We identified:

- Four AI applications for the industry sub-value chain,
- 16 AI applications for the health service provision sub-value chain,
- Seven AI applications for the governance sub-value chain
- Two AI applications for the administration/payors sub-value chain.

Interestingly, the highest number of AI applications was determined for the sub-value chain of health service provision, which is also by far the one with the highest economic relevance. However, we also found several application cases for AI in the governance sub-value chain, which shows that AI has the potential to improve public health.

Out of these 29 smart health AI applications, 12 are product innovations and 17 are characterised as process optimisations. Whereas all AI applications in the *industry* and most of the AI applications in the *governance* sub-value chain are process optimisations, AI leads to completely new products/services particularly in the *health service provision* sub-value chain (10 out of 16 AI applications are product innovations). For the administration/payors sub-value chain, we found one example for each innovation type. Example AI applications both for product innovations and process optimisations are presented in more detail in chapter 3.3 in the market analysis part of this report.

We provide detailed information on all of the 29 identified smart health AI applications in a table format on the following pages.

Industry

No.	AI application	Description	AI capability used	Innovation type	Source
1	**Deep learning in drug discovery**	▪ Deep learning algorithms streamline laborious and expensive drug discovery process ▪ During drug discovery and in-vitro experiments, AI can predict chemical effects on cells at different dosages using previous experiment's data ▪ *Novartis* has built a deep learning model with about 100 per cent accuracy to recognise the subtle changes that experimental compounds induce in a cell during treatment	▪ Insight generation from complex data ▪ Image recognition and video analytics	Process optimisation	▪ Novartis (2018), Link
2	**Clinical trial optimisation**	▪ Implementation of real-time monitoring and predictive modelling to ensure flawless execution of clinical trials (e.g. AI-based evaluation of trial data in real time) ▪ Prediction of adverse drug effects and drug interactions prior to clinical trials, thereby reducing aftermarket interventions ▪ Quantitative/big-data-driven trial decisions during execution (e.g. milestones for go/no-go decisions based on real-time data evaluation, cost and timeline prediction, site selection)	▪ Automated decision making ▪ Insight generation from complex data	Process optimisation	▪ MGI AI use case library
3	**Label expansion**	▪ AI-supported identification of opportunities so that more patients benefit from approved therapies (i.e. additional clinical data have shown that a drug can safely and effectively treat patient populations other than those for which it was originally intended)	▪ Automated decision making ▪ Insight generation from complex data	Process optimisation	▪ MGI AI use case library

No.	AI application	Description	AI capability used	Innovation type	Source
4	**Tracking pharma sales force performance**	▪ AI-algorithms support a faster initiation of first sales ▪ AI-supported analysis of sales performance and sales force operational planning ▪ Examples: identification of optimised cycles of sales force visits, optimisation of sales territories of individual sales force representatives	▪ Automated decision making ▪ Insight generation from complex data	Process optimisation	▪ MGI AI use case library

Health service provision

No.	AI application	Description	AI capability used	Innovation type	Source
5	**Robotic/VR-AR-supported surgery**	▪ In-surgery support through AI-based aggregation of information from comparable medical cases ▪ Example: a visual overlay inside the surgical space could indicate where critical blood vessels lie behind the current operating plane, with the AI suggesting that the surgeon steer clear of those areas ▪ *Cyber Surgery* develops a robotic system for spinal procedures. It was founded in 2017 as a spin-off from the industrial group *Egile*	▪ Image recognition and video analytics ▪ Insight generation from complex data	Product innovation	▪ Accenture (2017), Link ▪ rbr (2019), Link

No.	AI application	Description	AI capability used	Innovation type	Source
6	**Service robots in patient care**	▪ Service robots in stationary and residential patient care facilities ▪ Intelligent robo-carts measure medication and utensils inventory, automatically resupplying, autonomously navigating facility, recognising personnel and patients and automatically dispensing assigned items (beverages, food, drugs, utensils etc.) ▪ The *Fraunhofer Institute for Manufacturing Engineering and Automation (IPA)* has implemented several service robots for care facilities	▪ Robotics ▪ Automated decision making ▪ Language processing, text and audio analytics	Product innovation	▪ Fraunhofer IPA (2019), Link
7	**Virtual health agents/tele-consultation**	▪ Virtual health agents act as first point of contact for patients from remote areas ▪ Patients call or access virtual health agents and specify health problems for which the agent decides on a best approach; additionally, virtual agents can use facial recognition software to detect stress and anxiety to optimise response ▪ Other areas of applications include first point of contact in hospitals, additional support for medical personnel in mental health cases ▪ *Babylon*'s chatbot can interpret symptoms and medical questions and can provide recommendations on next steps	▪ Virtual agents, bots and avatars ▪ Automated decision making ▪ Language processing, text and audio analytics	Product innovation	▪ MGI (2017), Link

No.	AI application	Description	AI capability used	Innovation type	Source
8	**Telemonitoring**	▪ Special type of telemedicine ▪ Technology-enabled monitoring of patients outside of conventional clinical settings (e.g. at home), which may increase access to care and decrease healthcare delivery costs ▪ Evaluation of data sent from sensors, wearables, local data storage, diagnostic applications and/or healthcare providers ▪ Diagnostic application software develops treatment recommendations and intervention alerts based on the analysis of collected data ▪ Application fields include, e.g. diabetes, dementia, congestive heart failure ▪ *OpenTeleHealth* (developed as a part of a government-funded national project in Denmark) offers cloud-based remote patient monitoring	▪ Insight generation from complex data ▪ Automated decision making	Product innovation	▪ Rosner et al. (2017), Link
9	**Interconnected implants**	▪ Intelligent implants provide real-time data (e.g. interconnected pacemakers) ▪ An implant continuously transmits monitored data on blood congestion, pressure etc. enabling early detection of health deterioration ▪ The Irish medical device company *Medtronic* developed an app that enables pacemakers to communicate directly with patients' smartphones and tablets	▪ Insight generation from complex data ▪ Automated decision making	Product innovation	▪ Medtronic (2019), Link

No.	AI application	Description	AI capability used	Innovation type	Source
10	**Smart pills**	▪ AI-powered telemedicine adherence/compliance ▪ Pills that dissolve in the stomach and produce a small signal that is picked up by a sensor worn on the body, confirming that the patient has taken their medication as directed ▪ *Proteus Digital Health* released first digital cancer pill in January 2019	▪ Insight generation from complex data ▪ Automated decision making	Product innovation	▪ Mobi health news (2019), Link
11	**Chronic disease risk identification and treatment**	▪ Using data from electronic health records to develop personalised, condition-specific risk predictors that consider potential outcomes for individual patients ▪ Predictors are part of an AI algorithmic platform, with integration into clinical decision support (CDS) tools ▪ Improve chronic disease treatment by early detection and optimised treatment plans ▪ Google and some start-ups (e.g. Enlitic and jvion are active here	▪ Language processing, text and audio analytics ▪ Insight generation from complex data	Product innovation	▪ Arruda-Olson et al. (2018), Link ▪ Davenport et al. (2018), Link

No.	AI application	Description	AI capability used	Innovation type	Source
12	**Neuroscientific training**	▪ Machine learning aiding in neuro-training of body and mind ▪ Intuitive human-machine interface applies machine learning to help stroke victims retrain their minds and bodies and regain motoric and cerebral functioning ▪ Swiss start-up *Mindmaze* helps patients regain motoric functions 35 per cent faster	▪ Language processing, text and audio analytics ▪ Virtual agents, bots and avatars	Product innovation	▪ Wallstreet Daily (2015), Link
13	**Mental health screening/ treatment**	▪ Analysis of social media using an AI algorithm to pick out linguistic cues that might predict depression (prerequisite is that the patient explicitly agreed on the analysis of his or her data) ▪ Using technology to explore the way facial expressions, enunciation of words and tone and language could indicate suicide risk ▪ AI-system analysis of audio recordings of patients being treated with depression or bipolar disorders and identification of changes in behaviour for proactive mental health monitoring ▪ The *University Hospital of Frankfurt* uses an app that helps its therapists to recognise at an early stage when their patients are experiencing a depressive or manic episode	▪ Language processing, text and audio analytics ▪ Insight generation from complex data	Product innovation	▪ Accenture (2018), Link ▪ FAZ (2019), Link
14	**Personalised care for chronic and high-acuity diseases**	▪ Personalised messaging, approach and treatment to improve wellness and adherence for chronic and high-acuity diseases	▪ Insight generation from complex data ▪ Automated decision making	Product innovation	▪ MGI AI use case library

No.	AI application	Description	AI capability used	Innovation type	Source
15	**Medical imagery analysis**	▪ Computer vision-based pattern recognition in medical images (MRI, X-ray etc.) ▪ After running individual tests on the patient, the AI algorithm analyses results and looks for anomalies, comparing images to full population data and after initial diagnosis, scans images of peer patients to find similar cases that could help with the treatment decision ▪ *Signostics* is a developer of advanced ultrasound technology	▪ Image recognition and video analytics	Process optimisation	▪ MGI (2017), Link ▪ Expert interviews
16	**Patient triage at hospitals**	▪ AI-powered solutions for triage of patient cases during hospital admission using patient data, audio and video	▪ Image recognition and video analytics ▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ MGI AI use case library
17	**Big data health platform**	▪ Extraction of key health data points (e.g. from clinical data, patient-reported data points) from separate data sources via an AI-powered big data platform ▪ Enabling healthcare practitioners to optimise patient treatment and provide tailored care in real time ▪ IPCEI initiative recommends setting up a federated structure of health databases to provide a secure and reliable communication network and enable the access to and exchange of health data that exist at national or European level	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ European Commission/ IPCEI initiative ▪ Expert interviews

No.	AI application	Description	AI capability used	Innovation type	Source
18	**Capacity utilisation at hospitals**	▪ Optimised capacity utilisation in care facilities ▪ Algorithms predict patient inflow based on public and individual healthcare data (like flu spread, accident occurrence etc.) and plan staffing schedules, inventory and waiting times accordingly	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ MGI (2017), Link
19	**Patient-to-doctor routing**	▪ Identification of best-in-class doctors based on complex evaluation system ▪ AI-based matching of patients to doctors to ensure optimised treatment depending on patient needs and preferences ▪ The Berlin-based healthcare start-up *Qunomedical* offers routing to doctors for best-in-class treatments across Europe	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ Expert interviews
20	**Generation of medical reports**	▪ AI-supported generation of medical reports using intelligent decision trees (e.g. text suggestions for common disease patterns) ▪ Standardisation of workflow and provision of fully machine-readable data ▪ Better quality and greater efficiency in medical reports, alongside a quicker workflow pattern ▪ The start-up *Smart Reporting* offers an intelligent solution for structured medical reporting and clinical guidance. Integration with speech recognition helps radiologists directly in the clinical workflow to produce high-quality, policy-compliant reports	▪ Language processing, text and audio analytics ▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ Expert interviews

Governance

No.	AI application	Description	AI capability used	Innovation type	Source
21	**Seasonal vaccination prediction**	▪ AI algorithms predict risk of exposure to and infection with e.g. seasonal flu ▪ Based on public health and epidemics data and individual behaviour the algorithm predicts the infection probability and recommends vaccination to at-risk groups	▪ Insight generation from complex data ▪ Automated decision making	Product innovation	▪ Expert interviews
22	**AI-supported catastrophe risk evaluation**	▪ The use of low-orbit geospatial satellite data enables the managing of flood and coastal erosion risk, agricultural land usage and disaster relief ▪ Identification of fastest/shortest rescue routes in areas difficult to access after natural catastrophes	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ MGI AI use case library
23	**AI-supported improvement of preventative interventions**	▪ Improvement of the targeting of preventative interventions for vulnerable people ▪ Potential application fields: domestic abuse, sexual exploitation and child abuse	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ MGI AI use case library
24	**AI-supported epidemiological statistics**	▪ AI-supported forecasts of health risks and epidemics ▪ Identification of patients that are particularly at risk	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ MGI (2017), Link

No.	AI application	Description	AI capability used	Innovation type	Source
25	**Disease risks due to environmental factors**	▪ Analysis of environmental health factors (e.g. air pollution) ▪ Identification of risk groups and information of local authorities to decide about where to implement preventive-care programmes	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ MGI (2017), Link
26	**Patient flow management on city/regional level**	▪ AI-supported integrated patient flow management systems at a city or regional level to optimise overall utilisation and throughput across care/medical centres	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ Expert interviews
27	**Personalised emergency response**	▪ AI-based suggestions for personalised treatments leading to reduced risk of adverse effects in emergency services ▪ When calling emergency services, the operator can access patient records for viable information and share them with first responders who then get personalised treatment recommendations for the patient ▪ Estonia has implemented the *e-Ambulance*	▪ Insight generation from complex data	Process optimisation	▪ e-estonia (2019), Link

Administration/payors

No.	AI application	Description	AI capability used	Innovation type	Source
28	**Machine learning in patient behaviour prediction**	▪ Improved calculation of disease probabilities by applying machine learning to predict patient behaviour ▪ New business models (e.g. 'pay-for-performance') make use of AI combined with behavioural health interventions to focus on prevention, disease management and wellness – addressing unhealthy behaviours before people become patients ▪ A South African insurer, *Discovery Health,* tracks the diet and fitness activity of people it insures and offers incentives for healthy behaviours ▪ Potential to lift the profitability of life- and health insurance providers	▪ Insight generation from complex data ▪ Automated decision making	Product innovation	▪ MGI AI use case library
29	**Machine learning in payments and claim management**	▪ Optimisation of claims allocation and steering through legal intervention and best-match routing (e.g. optimise case assignment to claims handlers according to expertise/capacity or prioritise settlement of cases likely to generate legal intervention)	▪ Insight generation from complex data ▪ Automated decision making	Process optimisation	▪ MGI (2017), Link ▪ MGI AI use case library

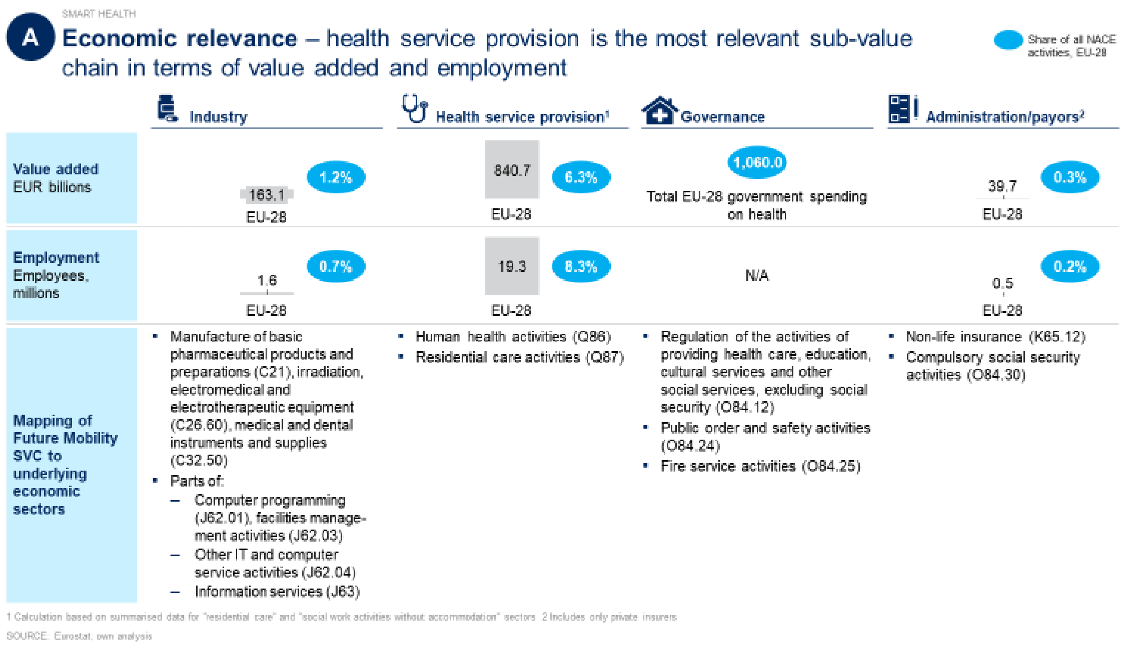
1.6 Prioritisation of the longlist of AI applications in smart health

We followed the same prioritisation approach/logic for the smart health AI applications as we did for those in IIoT and future mobility. We prioritised the list of the overall 29 smart health AI applications in a two-step process (relevance of the respective sub-value chain and expert feedback) and assessed their impact along three dimensions (social impact, environmental impact and economic impact).

Step 1: Relevance of sub-value chains

We used the economic relevance of the respective smart health sub-value chains as a first filter for the prioritisation of the smart health AI applications (see Exhibit 31 to recall the economic relevance of the four smart health sub-value chains). As *health service provision* is by far the most relevant sub-value chain, all AI applications within this sub-value chain were rated as 'highly relevant'. The *industry* sub-value chain was assessed with 'medium relevance' due to its both lower value added and employment impact. The *governance* sub-value chain was also assigned with 'medium relevance' due to its high societal relevance, but less economic/employment impact. Finally, the *administration/payors* sub-value chain was only rated with 'low relevance' due to its very low value added and employment impact.

EXHIBIT 31: ECONOMIC RELEVANCE OF THE SUB-VALUE CHAINS IN SMART HEALTH



Step 2: Expert preselection of AI applications at second multi-stakeholder workshop and via SME survey

The first part of the preselection draws on inputs from the second multi-stakeholder workshop, conducted jointly with the Commission, industry experts and the project team on 11 July 2019.

During this workshop, participants agreed that a big data health platform, medical imagery analysis and robotic surgery constitute use cases that could be very impactful, because:

- Access to relevant health data is critical for SMEs developing innovative solutions and having a central data repository could remove a major roadblock that holds these companies back.

- Both medical imagery analysis and robotic (or visually guided) surgery have significant welfare benefits: they essentially democratise the knowledge and experience of world-class doctors and bring the highest standards of care to a broader share of the population (e.g. because patients can receive complex and rare procedures in their regional hospital, rather than having to travel far away to see a specialist)

With regard to these AI applications, the group agreed that uptake among SMEs critically depends on understanding the business case behind the specific application, including the measurable financial impact. Moreover, the SME needs to understand how the AI application links to its business or organisational priorities (e.g. documenting a high standard of care in a hospital).

The group also identified additional AI applications that could be relevant, namely:

- Optimising treatment of patients with rare diseases by analysing combinations of medication already in use

- Improving the monitoring of patients (especially for chronic diseases, elderly patients or in remote areas) through wearable devices that analyse vitals and communicate with healthcare providers

Participants also evaluated 16 predefined smart health AI applications (positive vs negative impact). The detailed results are presented in the appendix.

In addition to the collection of expert feedback within the second multi-stakeholder workshop, a list of 16 smart health AI applications was also included in our SME survey. We asked the SMEs to select the top three smart health AI applications. Detailed results are also included in the appendix.

After applying the filters outlined in step 1 and step 2, one arrives at a shortlist of seven prioritised smart health AI applications (see Table 5). Six out of these seven

AI applications are part of the health service provision sub-value chain, and one belongs to the governance sub-value chain. Three AI applications are product innovations and four represent process optimisation approaches.

Steps 1 and 2 – Relevance of sub-value chain and expert feedback:

TABLE 5: PRIORITISATION OF AI APPLICATIONS IN SMART HEALTH – RELEVANCE OF STRATEGIC SUB-VALUE CHAIN AND EXPERT FEEDBACK

No.	AI application	Filter 1 – strategic sub-value chain	Filter 2a – expert feedback	Filter 2b – SME survey	Result after filters 1 and 2
1	**Deep learning in drug discovery**	Medium	Medium	Low	Out
2	**Clinical trial optimisation**	Medium	Low	*n/a*	Out
3	**Label expansion**	Medium	Low	*n/a*	Out
4	**Tracking pharma sales force performance**	Medium	Low	*n/a*	Out
5	**Robotic/VR-AR-supported surgery**	High	Medium	Low	Out
6	**Service robots in patient care**	High	Low	Medium	Out
7	**Virtual health agents/tele-consultation**	High	Low	High	Out
8	**Telemonitoring**	High	Medium	*n/a*	In
9	**Interconnected implants**	High	Low	Low	Out
10	**Smart pills**	High	Low	Medium	Out
11	**Chronic disease risk identification and treatment**	High	Medium	Low	Out

No.	AI application	Filter 1 – strategic sub-value chain	Filter 2a – expert feedback	Filter 2b – SME survey	Result after filters 1 and 2
12	**Neuroscientific training**	High	Medium	Medium	In
13	**Mental health screening/treatment**	High	Medium	Low	Out
14	**Personalised care for chronic and high-acuity diseases**	High	Medium	*n/a*	In
15	**Medical imagery analysis**	High	High	High	In
16	**Patient triage at hospitals**	High	Low	*n/a*	Out
17	**Big data health platform**	High	High	High	In
18	**Capacity utilisation at hospitals**	High	Medium	High	In
19	**Patient-to-doctor routing**	High	Low	Medium	Out
20	**Generation of medical reports**	High	Medium	Low	Out
21	**Seasonal vaccination prediction**	Medium	Low	Low	Out
22	**AI-supported catastrophe risk evaluation**	Medium	High	*n/a*	In
23	**AI-supported improvement of preventive interventions**	Medium	Medium	*n/a*	Out
24	**AI-supported epidemiological statistics**	Medium	Medium	*n/a*	Out

No.	AI application	Filter 1 – strategic sub-value chain	Filter 2a – expert feedback	Filter 2b – SME survey	Result after filters 1 and 2
25	**Disease risks due to environmental factors**	Medium	Medium	*n/a*	Out
26	**Patient flow management on city/regional level**	Medium	Low	*n/a*	Out
27	**Personalised emergency response**	Medium	Low	Low	Out
28	**Machine learning in patient behaviour prediction**	Low	*n/a*	*n/a*	Out
29	**Machine learning in payments and claim management**	Low	*n/a*	*n/a*	Out

Step 3: Impact assessment of prioritised AI applications beyond GDP

The seven prioritised AI applications in smart health can be analysed with regard to impact that goes beyond traditional metrics related to revenue or cost. Like for the previous two strategic value chains, we analysed the impact of these applications along the following three dimensions:

- Social impact
- Environmental impact
- Economic impact.

For all seven prioritised AI applications in smart health, we identified high social impact potential. They either significantly contribute to the well-being/health of individuals or even considerably improve public health. But AI applications positively affect more than just the well-being of patients; several also contribute to better working conditions for doctors and nurses. Therefore, we see high societal impact for all seven prioritised smart health AI applications.

We also found that all seven of these applications have relevant economic impact, as they help to decrease healthcare (delivery) costs, e.g. due to improved diagnostic and treatment processes or the avoidance of hospital overcapacity.

The environmental impact of the selected AI applications is less important and mostly indirect (e.g. telemonitoring helps to avoid driving long distances to a medical specialist for routine checkups). Only AI-supported catastrophe risk evaluation has a highly positive environmental impact, as data and forecasts can also be used for creating environmental protection strategies or monitoring such measures.

The detailed findings for the prioritised AI applications in smart health are summarised in Table 6.

TABLE 6: EVALUATION OF PRIORITISED AI APPLICATIONS IN SMART HEALTH BEYOND GDP IMPACT

No.	AI application	Social impact	Environmental impact	Economic impact	Source
8	**Telemonitoring**	▪ Increases access to care ▪ Rural regions with low physician density and weak infrastructure benefit the most from this	-/-	▪ Decreases healthcare delivery costs (e.g. reduces number of hospital stays)	▪ Gesundheitsindustrie BW, Telemonitoring, eine besondere Form der Telemedizin, Link
12	**Neuroscientific training**	▪ Helps stroke victims retrain their minds and bodies and regain motoric and cerebral function ▪ Enables stroke victims to recover and take part in their daily life	-/-	▪ Decreases healthcare delivery costs as patients practiced up to 15 times more therapeutic exercises compared to traditional treatment	▪ Wallstreet Daily, 12.05.2015, Virtual reality therapy wows stroke victims, Link
14	**Personalised care for chronic and high-acuity diseases**	▪ Personalised care improves patients' satisfaction as individual treatment is perceived as more effective ▪ Studies show that mHealth programmes improve patients' care experiences as well as overall population health	-/-	▪ Decreases healthcare costs (e.g. University of Chicago mHealth programme for diabetes patients led to USD 437 net cost of care decline per participant, or 8.8 per cent savings)	▪ MGI AI use case library ▪ Nundy et al. (2014), Mobile Phone Diabetes Project Led To Improved Glycemic Control And Net Savings For Chicago Plan Participants, Link

No.	AI application	Social impact	Environmental impact	Economic impact	Source
15	**Medical imagery analysis**	▪ Supports improved diagnoses, customised treatments and forecasting of the spread of diseases	-/-	▪ Decreases healthcare costs/reduces treatment costs as it allows for more accurate diagnoses, earlier identification of diseases	▪ MGI, 2017, Artificial Intelligence – the next digital frontier?, Link
17	**Big data health platform**	▪ Facilitates data access strategies (e.g. developed under the Horizon 2020 Innovative Medicines Initiative and similar initiatives) ▪ E.g. improves forecasts of public health and early detection of disease spread, supports better management of rare diseases	-/-	▪ Decreases healthcare costs (e.g. electronic patient files include all patient data and provides access to this to all doctors; therefore avoiding, e.g. double medical tests or examinations)	▪ European Commission/IPCEI initiative ▪ Expert interviews
18	**Capacity utilisation at hospitals**	▪ Avoids overcrowding of hospitals ▪ Allows for optimal patient care ▪ Significantly improves the working conditions of doctors and nurses	-/-	▪ Decreases healthcare costs significantly due to reliable prediction of patient flows (based on public and individual healthcare data) and accordingly optimised staffing schedules and inventory	▪ MGI, 2017, Artificial Intelligence - the next digital frontier?, Link ▪ Expert interviews

No.	AI application	Social impact	Environmental impact	Economic impact	Source
22	**AI-supported catastrophe risk evaluation**	▪ Enables the management of flood and coastal erosion risk, agricultural land usage and disaster relief ▪ Allows for early evacuation of risk areas and therefore saves lives ▪ Gets help to affected persons quickly through identification of the fastest/shortest rescue routes in difficult to access areas after natural disasters	▪ Low-orbit geospatial satellite data can also be used for environment protection	▪ Decreases cost of destruction/rebuilding of infrastructure	▪ MGI AI use case library

C – Analysis of the conditions for rollout of AI applications

Summary of key insights

- The major general barriers to AI adoption perceived by European SMEs include uncertain or only long-term return on investment, missing business cases, lack of digital or managerial skills and lack of access to external funding.

- Beyond these general barriers to AI adoption, SMEs see additional crucial barriers to AI adoption within their respective strategic value chains.
  - SMEs in IIoT perceive access to data to be a 'difficult topic' due to uncertainty about legal requirements (e.g. GDPR) and see the lack of common technological standards as another critical barrier.
  - SMEs in future mobility see regulatory barriers as particularly relevant to the rollout of autonomous driving, including an inconsistent legal landscape across EU Member States.
  - SMEs in smart health also rated regulatory barriers and uncertainty as particularly relevant (including the heterogenous reimbursement landscape across EU Member States) as well as access to health data and legal uncertainty regarding its use within the GDPR guidelines.

- In addition to removing these barriers, policymakers can also support the adoption and rollout of AI by fostering specific AI enablers. These include digital absorption, innovation foundation, human capital, connectedness and labour market structure and flexibility.

- Opportunities to accelerate the rollout of AI in Europe are analysed in a forward-looking SWOT analysis:
  - **Strengths.** Europe's strong industrial base, Europe's strong research landscape (including open science) and the EU's digital single market
  - **Weaknesses.** Europe's regulatory landscape in critical areas for AI rollout (e.g. fragmented/missing regulatory frameworks), insufficient digital infrastructure (e.g. 5G readiness), limited funding availability (e.g. access to venture capital), the inadequate industrialisation of research and the widespread negative sentiment towards AI

  - **Opportunities.** An increasing pool of digital talent, strong AI solution providers, expansion of network of technology centres and expansion of data platforms, e.g. industrial data platforms
  - **Threats.** Europe's widening gap in digital/AI patents, future critical skill development, significantly less investments in critical AI technologies and a lack of understanding of AI business cases by European SMEs.
- As both barriers and enablers are not AI-application specific, we have identified five high-priority policy domains to support both the development and deployment of AI in Europe: 1) adapt regulatory framework, 2) make external financing easily accessible, 3) facilitate secure and easy data access/exchange, 4) support AI skill building of managers and workforce and 5) facilitate collaboration between ecosystem stakeholders.

0 APPROACH AND METHODOLOGY

In this chapter, we analyse the conditions for the rollout of AI applications from two perspectives. Firstly (Section 1), we provide detailed information on the barriers to AI rollout in Europe that must be overcome. Taking a negative/deficiency-based perspective, we will address general barriers to AI rollout as well as specific barriers to AI applications within the prioritised strategic value chains. Our analysis builds on insights from our SME survey, discussions at our multi-stakeholder workshops and extensive desk research. Secondly (Section 2), we present enablers that can support the rollout of AI, taking with a positive/opportunity-based perspective. To this end, we draw upon previous work of the MGI, which defined five key enablers of AI adoption.

Based on this analysis of barriers and enablers, we show that the two are often tightly related: barriers often stem from or result in the insufficient presence of enablers. Thus, to successfully roll out AI applications in Europe, barriers must be removed and enablers should be strengthened. In Section 3, we therefore outline opportunities to accelerate this rollout based on a forward-looking SWOT analysis and examine additional concrete actions needed for a successful rollout.

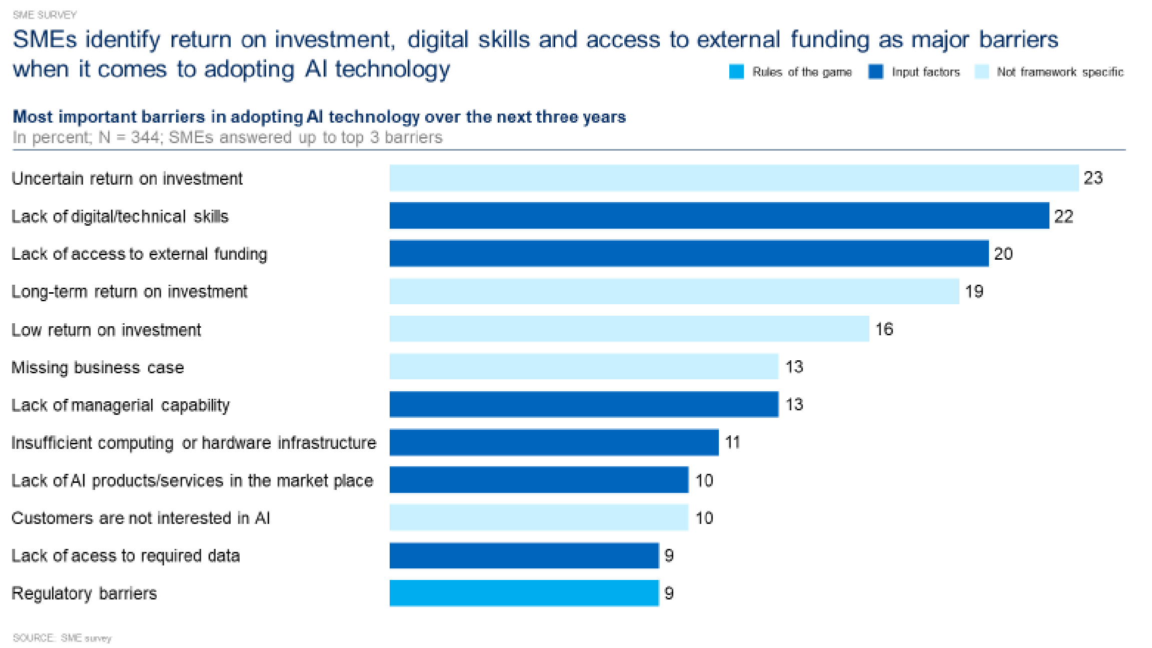
1 BARRIERS TO AI ADOPTION BY SMES

1.1 General barriers to AI adoption by SMEs

Our survey across 344 European SMEs revealed the following major barriers when it comes to adopting AI technology (see Exhibit 32):

- Uncertain/only long-term return on investment (23 per cent) as well as missing business cases (13 per cent)
- Lack of digital/managerial skills (internally and externally due to missing access to talent pools) (22 per cent/13 per cent)
- Limited access to external funding (20 per cent).

EXHIBIT 32: MOST IMPORTANT BARRIERS IN ADOPTING AI TECHNOLOGY OVER THE NEXT THREE YEARS PERCEIVED BY EUROPEAN SMES (SME SURVEY, 2018)



These findings were confirmed in our discussions with SMEs and other relevant stakeholders during the multi-stakeholder workshops. In the following, we will elaborate in more detail on the three barrier categories and also refer to additional barriers to AI adoption and rollout that were mentioned during the workshop discussions and expert interviews.

Uncertain/only long-term return on investment and missing business case

European SMEs do not invest in AI because they perceive the return on investment to be either completely uncertain or too long term. SMEs usually lack the financial resources for large upfront investments or have very limited budgets for such investments, particularly compared to large enterprises. They hesitate to invest in both the adoption of AI and in the development of AI applications. This behaviour is reinforced by a lack of understanding of the clear business cases for AI within their industry sectors. This holds particularly true for non-born-digital SMEs whose business models do not build on digital/AI, but who need to integrate AI applications into internal processes and/or products to remain competitive in future.

Lack of digital/managerial skills

The surveyed SMEs rate the lack of digital and managerial skills as a barrier to AI adoption at a similar level to uncertain returns on investment and missing business cases. European SMEs compete globally with large companies for digital professionals. Usually, they cannot offer the same incentives (e.g. wages, career perspectives) that these large companies can. In addition, this skills shortage of digital talent is even more severe in rural European areas – where a lot of SMEs are located. Finally, we see a general lack of digital professionals in Europe and a net outflow of talent to the US. Thus, the EU is facing a brain drain, induced by promising ecosystems, high salaries and the required technical infrastructure in the US. Therefore, European SMEs are at a disadvantage when trying to recruit digital talent from the labour market. They lack both the financial and human resources to extensively build digital and technical skills in-house. Even though support for re-skilling employees has been, at least partially, already put in place, some SMEs are just not aware of these support schemes and do not know how to get funding. In this regard, SMEs are critical of school systems in most EU Member States, as the education does not reflect the disruptive changes caused by AI and automation and graduates do not have the skills necessary to thrive in today's market.

Lack of access to external funding

SMEs criticise the European funding landscape for its complexity, claiming that there is insufficient transparency regarding available funding options and that the requirements to receive funding are too high. In their view, this holds even more true for getting funding for innovative, high-risk projects. Application processes for funding are perceived as too bureaucratic and even if funding is received, SMEs see the high documentation efforts as a burden. Again, SMEs lack resources to, for example, always be up-to-date on the most recent funding opportunities/sources or to meet all the bureaucratic requirements that accompany funding. Regarding different types of funding, especially for European AI start-ups, the lack of access to venture capital is criticised. Access to growth funding (funding beyond seed funding; EUR 20 million and upwards) is very difficult to receive in

Europe and is much scarcer than in the US or Asia. Finally, the more restrictive research conditions (e.g. regarding truly large-scale testing areas, data protection) and therefore limited opportunities to receive external funding in Europe (compared to in other regions like the US or Asia) are perceived as barriers to AI adoption and rollout.

Additional barriers to AI adoption and rollout

Besides these three prioritised barriers to AI adoption and rollout, SMEs and experts referred to some additional issues that hinder the rollout of AI applications in Europe. Gaps in the physical data transmission infrastructure (e.g. regarding 5G) as well as missing common technological standards (e.g. Wi-Fi vs. 5G) are perceived as significant hurdles. In addition, it was often mentioned that the European innovation ecosystem is less vibrant and connected than in the US, for example. Even though a network of digital innovation hubs has been set up across EU Member States in the past few years, SMEs (and also other stakeholders like academics/researchers and larger enterprises) lack knowledge about it. Regarding the research environment, an insufficient industrialisation of research (i.e. translation of insights to products) was also highlighted as a barrier to AI rollout. Finally, the fact that separate national research teams work in parallel without knowing about each other or without collaborating on similar/identical problems hinders an efficient rollout of AI applications. The same holds true for resources spent on solving similar/identical problems multiple times due to insufficient exchange between individual SMEs.

1.2 Specific barriers within the prioritised strategic value chains

We also identified some differences across SMEs from the three strategic value chains regarding their perception of barriers to AI adoption.

Industrial Internet of Things (IIoT)

European SMEs in IIoT rate the lack of access to external funding and a low return on investment as bigger barriers compared to SMEs in future mobility and smart health (SME survey, 2019). Uncertainty regarding the business relevance of AI applications was mentioned as another barrier to AI rollout within the IIoT value chain. Research on the application of algorithms and specific precision applications would be needed to ensure a successful rollout.

Moreover, IIoT SMEs perceive access to data as a ‘difficult topic’ due to confusion about legal requirements, e.g. regarding GDPR. They argue that high data protection requirements and cloud entry barriers hinder the easy deployment of AI. In their view, an adaptation or at least a clarification of the rules for data ownership, transmission and use is urgently needed in the EU.

Finally, IIoT SMEs also rate the lack of common technological standards (e.g. interoperability of different solutions) as a major barrier to AI rollout. This holds true not only for non-harmonised standards across EU Member States, but also across industry sectors.

Future mobility

Future mobility SMEs rated long-term returns on investment as a much bigger barrier to AI rollout compared to SMEs from the other two value chains (SME survey, 2019). This holds particularly true for AI applications in autonomous driving. It is unclear when and to what extent autonomous cars will hit the roads, and thus the whole ecosystem and digital supply chain around it are also characterised by high uncertainty regarding future returns on investment.

This also corresponds with the fact that for many AI applications, e.g. a car detecting a free parking spot, no concrete business model exists yet because it is not clear who would pay for this type of information (e.g. the OEM who offers it as an additional integrated service or vehicle drivers themselves directly through in-car app purchase).

Access to external funding and missing business cases are less relevant barriers for future mobility SMEs (SME survey, 2019). As the mobility space has seen large investments globally (McKinsey, 2019, *Race 2050 – a vision for the European automotive industry*), it is not surprising that funding is not mentioned as a big barrier.

Within the future mobility value chain, regulatory barriers in particular hinder the rollout of autonomous driving and associated AI applications. This includes safety and liability rules not adapted to concerns for autonomous vehicles, an inconsistent legal landscape across EU Member States for testing autonomous cars and general legal uncertainty relating to vulnerabilities of tech-enabled products, e.g. in case of a large-scale cyberattack. This is also reflected in the legal uncertainty regarding the outcome of driverless systems' decisions, as these are affected by multiple parties – which currently leads to ambiguity in the case of accidents. Finally, a broader set of rules relating to road access is not yet adapted to autonomous driving (e.g. driver's licenses, professional driving) and legal uncertainty persists regarding data collection, processing, sharing and utilisation.

Smart health

European SMEs active in smart health rate missing business cases and regulatory barriers as much more relevant barriers than SMEs from the other strategic value chains (SME survey, 2019). They see that safety and liability rules are not adapted to particular concerns for smart health products, which impose barriers to the rollout of smart health applications (e.g. a distinct EU-wide regulatory approval process for digital health products is missing as well as harmonised regulation regarding telemedicine across all EU Member States).

Besides this regulatory uncertainty, the very heterogenous landscape of national reimbursement systems in the EU Member States also hinders a rollout of smart health AI applications. SMEs lack the resources to build up expertise in each reimbursement system to successfully enter the national market and commercialise their products.

In general, it is very difficult, and it takes a long time to get access to large sets of health data as well as to assemble, clean, and label data to make them fit for training AI systems. However, SMEs need access to health data for their research, which is hampered by often unused or underused data that can only be accessed by individual parties, such as pharma companies or payors. This is reinforced by the fact that electronic health records are still not fully implemented in all EU Member States. This would at least make data access easier. Even if SMEs get access to data sets, legal uncertainty because of GDPR regarding data collection, processing, sharing (e.g. via cloud systems) and utilisation hamper its usage for the development of AI applications.

Interestingly, the lack of customer interest was rated as less important for smart health than for IIoT or future mobility (SME survey, 2019). This means that customers/patients see a clear need for smart health applications and are willing to use them. This fact makes it even more urgent for the aforementioned barriers to be eliminated.

2 ENABLERS OF AI ADOPTION

Barriers tend to be specific to individual firms (e.g. why a specific firm cannot adopt AI with its current business focus, skill set, industry sector etc.). At the same time, previous MGI research has identified larger themes that support and contribute to the adoption of AI. These enablers take a broader, society-level perspective and a more positive view (‘do more of the good things’). They can support a successful rollout by reducing friction for companies developing or deploying AI. Thus, policymakers can accelerate rollout not just by removing specific barriers but also by creating general conditions that are supportive for AI.[3]

AI enablers are the foundations for adoption and absorption of AI as an emerging technology. In line with previous work by the MGI (MGI, 2018, Notes from the AI frontier – Modelling the impact of AI on the world economy), we define the following five key enablers of AI adoption and elaborate on their special relevance with

[3] Additional information on the MGI AI enabler framework and the EU’s performance across these enablers can be found in the report on foresight scenarios.

regard to AI development and adoption for SMEs and within the three prioritised value chains wherever suitable:

Digital absorption

Digital absorption is defined as the degree to which corporations are using the latest (digital) technologies in each country, using this indicator as a proxy for companies' ability to absorb digitisation. As digitisation is a basic prerequisite for the successful rollout of AI, countries and companies that are already highly digitised must overcome a smaller gap to use AI than those who lag behind in the digital transformation. Therefore, support for digitisation can contribute to enabling the rollout of AI. Examples of actions in this area include dedicated funding for the digitisation of business processes, the development of digital skills both at schools/universities and within the current workforce, or the provision of necessary digital and data infrastructure (e.g. 5G networks, cloud solutions).

Digital absorption is key for both the successful development and the adoption of AI across all three strategic value chains. The provision of the necessary digital and data infrastructure is of highest importance for IIoT and future mobility, as actors in these two value chains depend on the continuous and fast exchange of large amounts of data. In smart health, training the current workforce on digital skills will have an even greater effect, as many healthcare professionals have not yet been well trained in this area and often lack digital competencies to fully leverage the potential of smart health applications. For a fast and broad rollout, smart health applications depend on healthcare professionals' ability to fully understand their potential and make extensive use of them (e.g. for process optimisation in hospitals, diagnostics and doctor-patient interactions).

As our previous analyses have shown that SMEs lag behind large companies in digital absorption capacities (particularly due to lacking digital skills and only a small share of completely digitised business processes), all actions taken to strengthen this enabler will contribute to successful AI development and absorption for SMEs. Examples of actions particularly relevant for SMEs include the targeted training of SME managers on digital skills to enable them to identify relevant business cases and the improvement of digital infrastructure in rural areas.

Innovation foundation

The innovation foundation is defined as the overall innovation capacity and industry dynamism. The focus lies on differences in companies' abilities to use the technologies and create new business models or adapt their organisational models in order to absorb technologies. Companies whose business models are either fully digital already or transitioning towards digital, will struggle less with the development or adoption of AI applications than companies that lack these competencies or adhere to a traditional business model. Policymakers can support the rollout of AI by improving the conditions for innovation or extending the support for innovation. Examples of actions could include revising intellectual property rights to better reflect particularities of digital business models, setting-up (temporary) tax incentives for innovation or fostering technological skill building.

The innovation foundation is relevant as an enabler for AI across the three prioritised value chains, and of high importance for SMEs. SMEs can be expected to especially benefit from financial support for building innovation capabilities, as they lack resources (both financial and personnel) to build these capabilities on their own. Tax incentives for innovation may be an effective lever to strengthen the innovation foundation as they make building innovation and R&D capabilities in-house more attractive for SMEs (depending on the legal setting across EU Member States, tax incentives may also be applicable to large companies). As an example, Germany has recently decided to introduce tax incentives for innovation in SMEs from 2o2o onwards.

Human capital

Human capital is a critical enabler for the absorption of new knowledge and its real-world applications. This includes both the overall quality of human capital (e.g. level of education, availability of skills such as problem-solving in the workforce) and the availability of specific talents, such as scientists, engineers or other knowledge workers. Digitisation and AI adoption rely on the workforce's ability to acquire new skill sets and the incorporation of these newly required skills into vocational training and university programmes. Thus, AI rollout could be supported by incentivising companies to invest in continuously training their current workforce, increasing universities' capacity in STEM fields or providing visa schemes for highly educated foreign IT and engineering professionals to close the current skills gap.

As touched upon in the section on digital absorption, digital skill building within the current workforce and access to digital talents are crucial for AI development and absorption. This holds true across the three strategic value chains but again represents a challenge for SMEs. They usually find it more difficult to attract talent, especially when it comes to competing with large companies for scarce digital talent. Thus, SMEs could benefit from policy actions that increase the availability of digital talent and contribute to reducing the skill gap. In training their current workforce, SMEs may benefit from a better overview of existing training opportunities, easier access to training (e.g. via central platforms), financial support for training initiatives (e.g. through education vouchers) or innovative exchange formats (e.g. exchange programs connecting SMEs leading in AI with those struggling with AI adoption).

Connectedness

Connectedness is defined as the flows of goods, services, capital, people, and data between countries. In times of increasing digitisation, data flows are becoming as relevant as physical flows, such as the exchange of manufactured goods (e.g.

ensured by the digital single market). Companies can only collaborate internationally or enter foreign markets if this connectedness is ensured (e.g. through common standards or a common digital infrastructure). SMEs in the IIoT and future mobility value chains are expected to benefit from common international data standards and digital infrastructure, since resource constraints limit their ability to develop region-specific versions of their products or services. Common international standards would thus enable SMEs to expand internationally and scale their business, making business cases for AI more attractive (from both supply and demand perspective) as the potential customer base is not restricted to a certain region (relevant both in B2B and in B2C). Moreover, connectedness in terms of human capital (i.e. workforce mobility) is relevant as well, since the rollout of AI depends on it. Examples of policy actions to foster connectedness include setting up international data standards to enable direct data exchange across companies from different countries, building digital infrastructure on a common technology basis, or simplifying the recognition of international training certifications and university degrees to support workforce mobility.

Labour-market structure and flexibility

Labour market structure and flexibility are relevant to AI adoption as they can smooth the transition to AI technologies by putting in place mechanisms such as transitional support and training for displaced workers. MGI research showed that about half of all work activities globally have the technical potential to be automated using currently demonstrated technologies – including AI. Even though scenarios show that there is enough work to ensure full employment by 2030 in advanced economies, a significant part of the workforce has to switch occupational categories (MGI, *Jobs lost – jobs gained*). The adaptation process will require in the future workforce to attain higher educational credentials and both the current and future workforce must build new skills (e.g. digital, but also social, emotional and creative skills). Ensuring appropriate structures and flexibility in the labour market can contribute to promoting the development of critical skills in the workforce while offering support to vulnerable groups during the transition towards a fully digitised society in which AI will play a significant role.

This enabler is relevant across all value chains and company sizes, although specific impacts of the described skills shifts may vary by value chain. In the foresight scenarios developed in this project, we found that the relative impact on labour (in terms of FTE) will be largest in the future mobility value chain, followed by IIoT and smart health. More details are provided in the report on foresight scenarios.

1.3 SWOT analysis of conditions for AI rollout

Based on the description of barriers and enablers of AI adoption as well as our competitive- fit analyses of the three strategic value chains in the market analysis part of this report, we evaluate the conditions for rolling out the most critical AI applications based on a forward-looking SWOT analysis from the viewpoint of European SMEs and businesses.

Strengths

Overarching

- Europe has a strong industrial base (particularly in the fields of automotive/ transport, engineering, pharmaceuticals), which is a success factor particularly in B2B settings (AI supply side).
- Europe has a strong (academic) research landscape, very well-known for its reputable universities and research institutions, the high number of researchers and the high quality of scientific publications (AI supply side).
- Europe is strongly promoting open science/collaboration (including free-of-charge publishing under all Horizon 2020 projects and plans for a European Science cloud) (both AI supply and AI demand side).
- Europe's digital single market only makes AI rollout across Europe possible (AI supply and AI demand side).
- Europe has a world-class security ecosystem and world-leading companies in security components, hardware security modules and security software, as elaborated by the Task Force on Cybersecurity (both AI supply and AI demand side).

SVC-specific

- *IIoT.* The European industrial ecosystem is a significant competitive advantage in developing IIoT applications and systems, and leading innovation. This strong ecosystem is a potential success factor for AI rollout, especially in B2B applications (both AI supply and AI demand side).
- *IIoT.* The wide range of institutionalised cooperation platforms, both at the regional and at the European level (e.g. IoT European Research Cluster (IERC), Alliance of Internet of Things Innovation (AIOTI), IoT Action Plan for Europe, etc.) is a strength to build upon (AI supply and AI demand side).
- *Future mobility.* As with the IIoT, Europe's strong industrial ecosystem, particularly in automotive and electronic equipment manufacturing (B2B applications), is a competitive strength for Europe in the global AI competition race (AI supply side).

- *Future mobility.* The EU's internal market vehicle approval framework provides a very good regulatory environment for innovation within this area (both AI supply and demand side).
- *Smart health.* Europe's thriving, competitive ecosystem comprising digital health start-ups, especially in B2B/B2G (with centres in Berlin and London), and large innovative pharmaceutical and medical companies, is a clear strength (AI supply side).

Weaknesses

Overarching

- Regulatory landscape (both AI supply and demand side):
    - The scattered national regulatory landscape in critical areas is an obstacle for AI rollout and adoption .
    - Missing regulatory frameworks slow down the development and rollout of new digital/AI applications .
    - Data regulation (particularly GDPR regarding the use of personal data, even if this data is anonymised) or at least legal uncertainty hinder access to data as well as data collection, processing, sharing and utilisation, which are key for the development of AI algorithms and applications
- Insufficient digital infrastructure (both AI supply and AI demand side):
    - Europe lags behind China regarding 5G readiness and ease of rollout (at least on par with the US).
    - Lacking platform and technology provider: Europe has essentially lost the B2C IT platform and infrastructure game (e.g. Amazon Web Services) and is unlikely to win such scale games in the future.
    - Europe has a lower readiness for AI diffusion compared to the US and China.
- Europe's funding landscape for AI (particularly for AI supply side):
    - Investments in AI are five to seven times less in Europe than in the US and China.
    - Start-ups are facing insufficient funding opportunities beyond the seed phase in Europe.
    - Funding programmes are perceived as non-transparent and overly complex.
- Research on AI in Europe is not sufficiently addressing the transfer to industrialisation of its results(i.e. translation of insights to products) and is lacking collaboration on research topics across EU Member States (AI supply side).

- The wide-spread negative sentiment towards AI constitutes the main obstacle to its uptake in Europe, weakening the position of all involved stakeholders in Europe (both AI supply and AI demand side).

SVC-specific

- *IIoT.* Regulatory uncertainty exists regarding testing rules for IIoT applications as well as the applicability of GDPR (e.g. regarding ownership of data, sharing of data) (both AI supply and AI demand side).
- *IIoT.* Europe is weak in developing IIoT platforms and lacks technology providers that drive IIoT development. Therefore, Europe depends on non-European technology providers and is not competitive here (AI supply side).
- *IIoT and future mobility.* Stakeholders in both value chains strongly rely on 5G infrastructure (e.g. for predictive maintenance or inventory applications in IIoT and autonomous driving in future mobility) and suffer from Europe's lagging position here (both AI supply and AI demand side).
- *Future mobility.* As with IIoT, regulatory uncertainty significantly weakens Europe's position. Standardisation of legal requirements for product liability and safety on the EU level and a more unified regulatory landscape for testing rules are seen as the most pressing issues (AI supply side).
- *Smart health.* The regulatory approval process for medical products currently does not address the particularities of smart health products and takes too long overall (over 12 months). This is an important challenge for start-ups that often struggle to survive this phase since at this point they are not yet able to generate income from finished products due to pending market approval (AI supply side).

Opportunities

Overarching

- The increasing pool of digital skills could push AI rollout and adoption significantly (AI supply and demand side) due to fast growth of STEM graduates as well as high number of software developers in Europe.
- Strong AI solution providers could support the EU's technological sovereignty in strategic value chains (AI supply side).
- A further expansion of networks of technology centres (e.g. digital innovation hubs, innovation clusters, fab labs, incubators, research organisations) is highly relevant for the AI rollout in Europe (both AI supply and AI demand side).
- Empowering city ecosystems and industrial clusters could support the development and promotion of AI-enabled solutions (both AI supply and AI demand side).
- Expansion of data platforms, e.g. industrial data platforms, are important to become independent from non-European solution providers, which are e.g. not

bound by the strict European cybersecurity protection standards (both AI supply and AI demand side).

SVC-specific

- *IIoT.* Applicability of IIoT across the European economy is extremely wide and in combination with Europe's strong industrial basis in this area represents a large opportunity (both AI supply and AI demand side).
- *IIoT.* EU IIoT landmark projects such as AI4EU and the Digital Innovation Hubs aim to create a dynamic European IoT ecosystem, entailing cross-sector partnerships and collaboration (both AI supply and AI demand supply).
- *Future mobility.* Expansion of the infrastructure for autonomous vehicles due to increasing investments in IoT road connectivity and Galileo's services offered free of charge are great opportunities for all involved stakeholders (AI supply and AI demand side).
- *Future mobility.* The EU's C-Roads Platform and the European Commission's Single Platform for Cooperative, Connected, Automated and Autonomous Mobility (CCAM) represent a good foundation for the further expansion of a strong future mobility ecosystem (both AI supply and AI demand side).
- *Future mobility.* Public and political support for sustainability and shifting mobility preferences and trends in Europe may serve as catalysts for the development of AI applications as well as the increasing acceptance and deployment of AI-based solutions within this value chain (both AI supply and AI demand side).
- *Smart health.* Europe has a strong commitment to ethics in healthcare. If the advantages and promises of AI-based health solutions are clearly communicated and patients build trust in smart health solutions, we could see a significant improvement of the people's well-being in Europe. This may reinforce the opportunities and rollout of smart health solutions (particularly relevant for AI supply side).

Threats

Overarching

- Europe is facing a widening gap in patents in digital, AI, quantum computing and big data compared to US and China (AI supply side).
- Europe could fall behind in the future skill development (in a global competition).
    - Availability of critical digital/managerial skills in rural areas is critical as we see concentration of highly skilled digital talent in metropolitan areas, but SMEs are often located outside of these areas (both AI supply and AI demand side).

    - Inclusion of digital skills in curricula of training and studies is slow apart from STEM fields (e.g. health care professions) (AI supply and AI demand side).
- Significantly less (future) investment in critical AI technologies and AI applications are taking place in Europe than in the US or China (AI supply side).
- A lack of understanding of business cases for AI by European SMEs (particularly in IIoT and future mobility) hinder/slow down a rollout of AI applications (both AI supply and AI demand side).

SVC-specific

- *IIoT and future mobility.* If regulatory uncertainty on liability issues in IIoT applications, such as predictive maintenance and autonomous driving, are not solved in the near future, future success of these SVCs could be at risk as stakeholders lack a clear perspective on successful business cases (particularly AI supply side).
- *Future mobility.* As innovation in automotive is driven from outside the OEMs, it is crucial for the European automotive industry that SMEs are incentivised to innovate and enabled to master the technology change, including the adoption of AI. If this fails, Europe's leading position in the automotive industry will not continue in the future (AI supply side)
- *Smart health.* The new medical product regulation (MPR), which will come into force in spring 2020, is expected to increase requirements for market access of smart health products and could therefore slow down market development in this area (AI supply side).
- *Smart health.* Currently, only 10 EU Member States have successfully implemented electronic health records, even though the electronic availability of data and opportunities to share digital health data across healthcare stakeholders are key for successful implementation of AI-based smart health solutions (demand side). If Europe fails to develop a common standard for electronic health records, AI adoption in the smart health value chain could be at risk. This is likely to affect smart health start-ups as they would incur higher costs for adapting their products to different standards across EU Member States (AI supply side).
- *Smart health.* Current health reimbursement systems across Europe are highly fragmented and not responsive enough to innovative products. For example, digital health products are treated as medical devices, i.e. that their reimbursement is tied to the time and workload of clinicians rather than their role in improving patient outcomes (both AI supply and AI demand side).

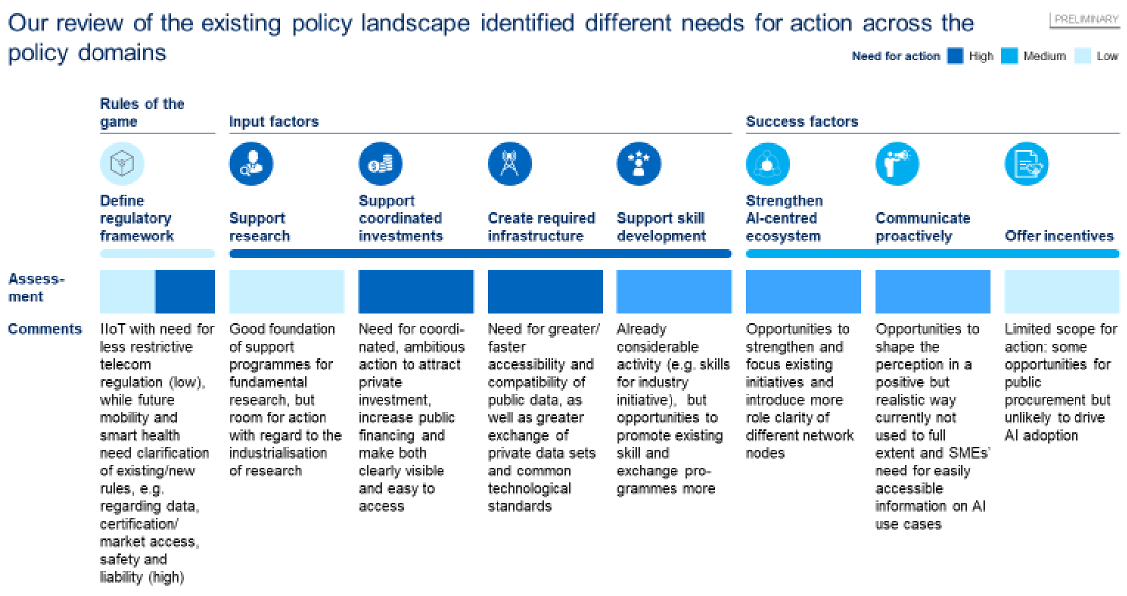
1.4 Steps/actions needed to improve conditions for AI rollout

The multi-dimensional analysis of the conditions for AI rollout (barriers, enablers, SWOT) as well as the output from our multi-stakeholder workshops on the policy baseline, gaps and opportunities showed that the conditions for a successful rollout of AI applications in Europe are not limited to a very specific or single AI application, but that these hold true for the majority of identified and prioritised AI applications across all three strategic value chains. Barriers and enablers are not AI application specific: all identified AI applications face similar problems or require similar support for a successful rollout.

Thus, we have identified five high-priority policy domains that will support both the development and the deployment of AI applications – regardless of their concrete underlying AI technology, addressed technological/business problem or their mapping to one of the strategic value chains. These five policy domains are (see Exhibit 33):

- A – Adapt regulatory framework
- B – Make external financing easily accessible
- C – Facilitate secure and easy data access/exchange
- D – Support AI skill building of managers and workforce
- E – Facilitate collaboration between ecosystem stakeholders

EXHIBIT 33: PRIORITISED POLICY DOMAINS TO SUPPORT THE DEVELOPMENT AND DEPLOYMENT OF AI APPLICATIONS



Source: European Commission policy documents (see policy baseline report for detailed list of sources); project team analysis

A *complementary proactive communication strategy* can accelerate the success of potential actions in these five policy domains. The objectives of communication are (1) to disseminate clear and accessible information about the benefits of AI, (2) to proactively address any existing concerns and fears regarding the proliferation of AI and to provide information on ongoing efforts to mitigate associated risks, thus increasing social acceptance and building trust, as well as (3) to motivate businesses, national policy decision makers and other relevant stakeholders to take action regarding the development and deployment of AI among European SMEs.

We will elaborate in detail on what action in these five domains could look like in the final summary of validated and prioritised policy opportunities (second part of the policy report). However, we will end this report by exemplifying concrete actions within these five domains to support the rollout of one specific AI application. For this purpose, we select one of the prioritised AI applications in the future mobility value chain: **autonomous driving** (see Box 3).

Box 3: Example actions across the five policy domains to support the rollout of the autonomous driving AI application

A– Adapt regulatory framework

- Develop a clear safety and liability regulatory framework taking into consideration the particularities of autonomous driving
- Define clear regulations regarding the use of anonymised personal data for mobility applications

B – Make external financing easily accessible:

- Set up specific funding programmes only for SMEs in automotive manufacturing or supply that either develop AI solutions for autonomous driving (AI supply side) or for SMEs that need to adapt their business model/develop technical skills to deploy AI (AI demand side) in their products or services
- Prioritise the increase of/access to VC funding specifically for SMEs developing autonomous driving applications (hardware and software)
- Provide transparency on financing opportunities for SMEs active in autonomous driving, both on supply and demand side (e.g. via a digital platform)

C – Facilitate secure and easy data access/exchange:

- Prioritise the development of common data standards (particularly relevant for autonomous driving)
- Prioritise the rollout of 5G in regions with high numbers of SMEs active in automotive manufacturing and supply, as well as along major traffic routes
- Establish data sharing platforms

D – Support AI skill building of managers and workforce

- Support EU Member States on adaptation of vocational and university curricula of engineering programmes to ensure that the required digital and technical skills for autonomous driving applications are included
- Develop new specific study programmes on autonomous driving in collaboration with EU Member States
- Develop professional training programmes that particularly address managers of SMEs active in autonomous driving (e.g. with focus on the impact of their current business model, data safety regulation or relevance of technological change)

E – Facilitate collaboration between ecosystem stakeholders:

- Set up and support innovation hubs, networking event series or digital networks that match AI solution providers and potential users, while specifically addressing the needs of SMEs active in autonomous driving
- Intensify collaboration with industry associations, innovation networks and research institutions active in autonomous driving and provide a platform for exchange with the European Commission to these stakeholders
- Support city ecosystems to pilot and adopt new mobility solutions
- Promote best practices

Complementary proactive communication strategy

- Develop and implement specific communication campaigns that address particular concerns about autonomous driving by the general public, e.g. road safety in general, response in case of large-scale cyberattacks or accident liability

- Take part as European Commission or Directorates-General in car fairs for consumers to learn about the positive aspects of autonomous driving in direct exchange

Appendix

I. BIBLIOGRAPHY

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II. CONTRIBUTING EXPERTS

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Möller	Timo	Future Mobility
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Rutter	Kristin-Anne	Smart Health
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III. DESCRIPTION OF AI TECHNOLOGIES

■ *Natural language processing* (NLP) (including text analytics and semantic technology) refers to software or computers that have the ability to interpret the ‘meaning’ of human-produced sentences and take action as a result. For example, a service like Google Translate uses NLP to translate relatively accurately from one language to another

■ *Natural language generation (NLG)* refers to software or computers that can generate language (text or speech) that sounds like it was generated by a human. For example, some companies are using it to produce automated reports and business intelligence insights that look human-produced.

■ *Speech recognition* refers to software or computers that can transcribe and transform human speech into text or instructions. For example, mobile phones that recognise spoken commands, such as ‘Call home’, use this technology.

■ *Image recognition and video processing* refers to software or computers that have the ability to recognise and analyse pictures of natural objects. This could be either in the form of still pictures or video. For example, electric passport gates at airports use image recognition to verify the identity of people entering the country.

■ *Machine learning and deep learning* refer to software or computers that have the ability to learn without being explicitly programmed. They use algorithms to pars data enabling computers to learn from it and then make a determination or prediction about something. For example, on-line retailers and e-commerce sites use machine learning to constantly improve their recommendations to users based on users' actions online.

■ *Virtual agents or artificial conversational entities* refer to computer programmes that conduct conversations with human users, either via speech or text. For example, some on-line retailers and banks deploy 'chat bots' to deal with basic customer queries, without having human employees involved.

■ *Robotics (including swarm intelligence)* refer to machines that can perform tasks as humans, including carrying out complex actions automatically and adapting these actions to the feedback they receive through sensors from their environment. For example, some production lines use 'robotic hands' that can 'see' objects' location, detect the mechanical flexibility of the object being handled (through 'touch') and adapt their 'grip' accordingly. Autonomous vehicles, such as the Mars rover, Curiosity, are also a type of intelligent robot.

■ *Robotics process automation* refers to scripts and other methods to automate human action to support efficient business processes. Currently used where it's too expensive or inefficient for humans to execute a task or a process. E.g. in processing invoices through the system where a number of manual interventions is required, it can almost completely eliminate human intervention from the process.

IV. SME SURVEY – RATING OF AI APPLICATIONS

Strategic value chain	**AI application**	**# mentioned**
IIoT	AI-based In-process quality inspection	36
	AI-based inventory forecasting	29
	Smart cloud for industrial IoT data	26
	AI-based design suggestions	25
	AI-based procurement expenditure savings	24
	AI-based human machine collaboration	24
	Parts tracking	24
	AI-enhanced predictive maintenance	23
	Production lot optimisation	23
	AI-based asset quality inspection	22
	Focussed product development	22
	R&D effectiveness	21
	AI-enabled yield enhancements	20

	Optimised sourcing	15
	Remote monitoring	10
	Optimised labour deployment	6
Future mobility	Digital customer engagement	41
	Autonomous driving	38
	Mobility planning and analytics	36
	Fleet management	33
	Traffic management	26
	Truck platooning	22
	Robo delivery	21
	Predictive service	20
	Upselling and rebate reduction	20
	AI-enhanced predictive maintenance	19
	Generative design	15
	Inventory management	15
	AI based asset quality inspection	11
	Parking analytics	10
	Smart charging	10
	HD mapping	9
Smart health	Medical imagery analysis	50
	Virtual health agents	27
	Capacity utilisation	25
	Big data health platform	25
	Patient-to-doctor routing	23
	Neuroscientific training	21
	Smart pills	20
	Service robots in patient care	20
	Seasonal vaccination prediction	18
	Personalised emergency response	18
	Deep learning in drug discovery	17
	Generation of medical reports	17
	Mental health screening/treatment	16
	Interconnected implants	14
	Chronic disease risk identification	11
	Robotic surgery	8

V. PRIORITISATION LOGIC ACROSS FILTER 1, 2A AND 2B

- Applications were rated as ‘*in*’ in case of the following evaluation results: minimum 2x *high* (remaining filter could be rated *low* or *medium*) or in case of 1x *high* and 2x *medium*

- All other combinations of evaluation results were rated as '*out*' (e.g. 1x *high*, 1x *low*, 1x *medium*)

VI. SME SURVEY – BARRIERS TO AI ADOPTION BY SMES DIFFERENTIATED BY STRATEGIC VALUE CHAIN

EXHIBIT 34: BARRIERS TO AI ADOPTION – RESULTS FOR IIOT SMES

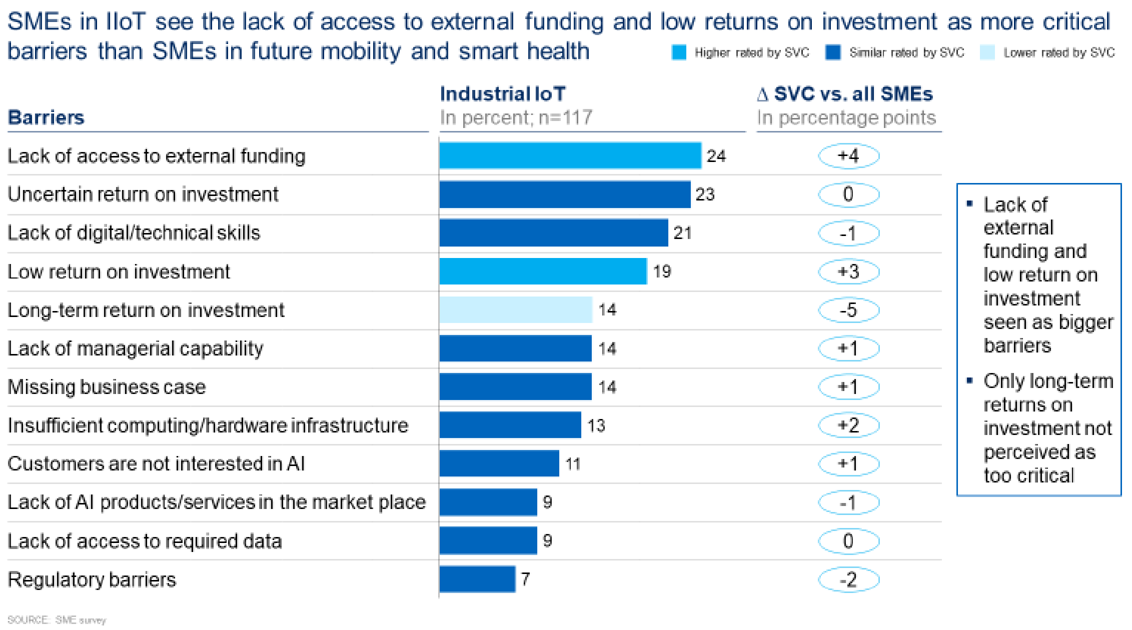
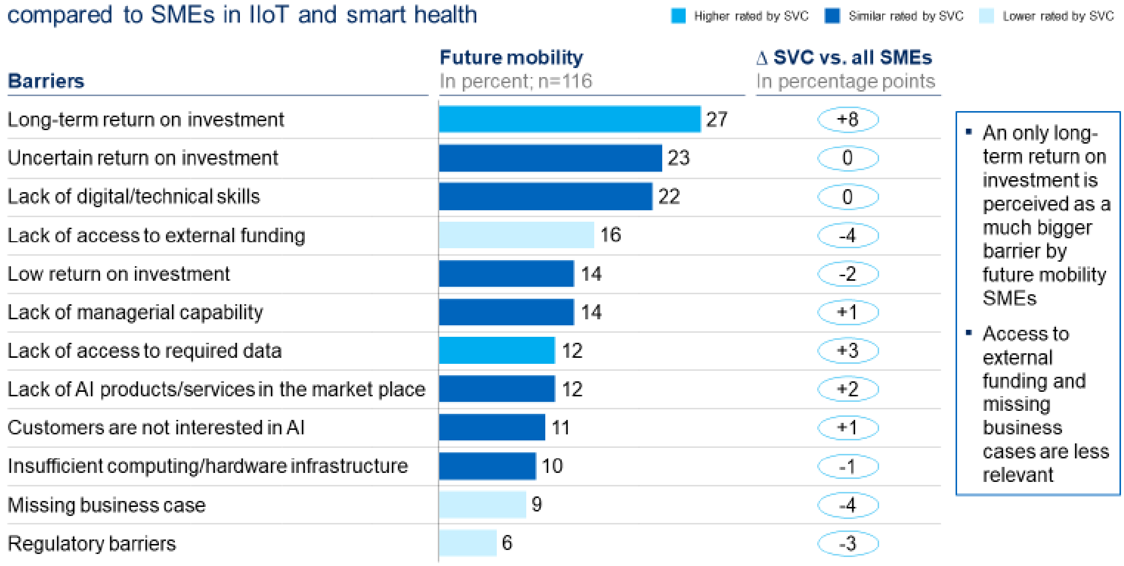


EXHIBIT 35: BARRIERS TO AI ADOPTION – RESULTS FOR FUTURE MOBILITY SMES

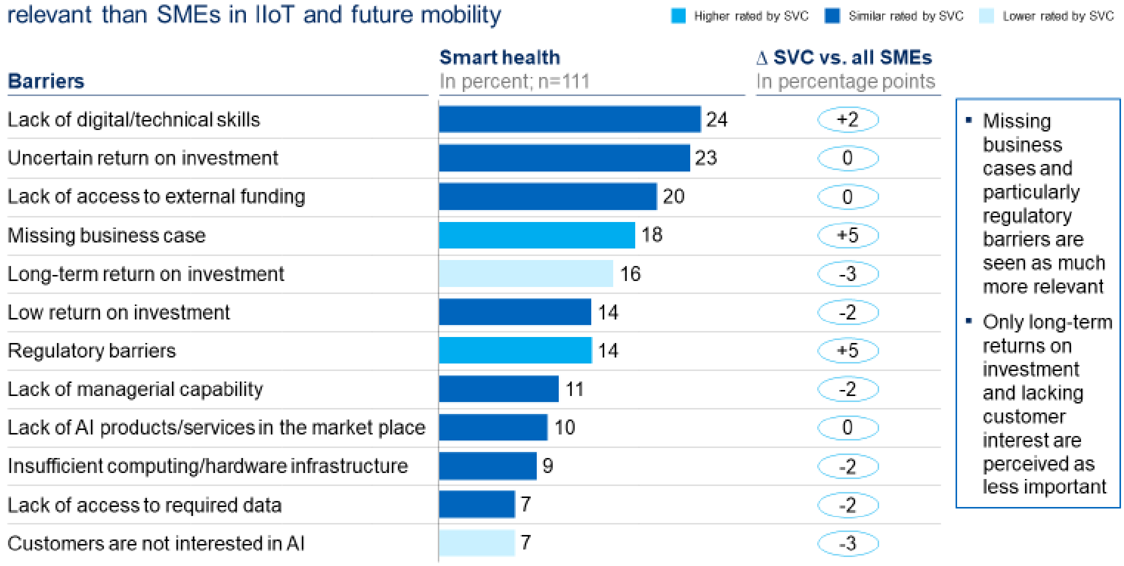
SMEs in future mobility see only long-term returns on investment as a much more relevant barrier compared to SMEs in IIoT and smart health



SOURCE: SME survey

EXHIBIT 3618: BARRIERS TO AI ADOPTION – RESULTS FOR SMART HEALTH SMES

SMEs in smart health perceive missing business cases and particularly regulatory barriers as more relevant than SMEs in IIoT and future mobility



SOURCE: SME survey

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