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EMERGING AI AND DATA DRIVEN BUSINESS MODELS IN EUROPE

A report of the Cross-KIC Activity "Innovation Impact Artificial Intelligence"

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Abbreviation	
AI	Artificial Intelligence
AIAaaS	AI Application-as-a-Service
AIIaaS	AI Infrastructure-as-a-Service
DRT	Demand Responsive Transport
DG	Data governance
EIT	European Institute of Innovation and Technology
XKIC	Cross Knowledge Innovation Communities
MaaS	Mobility-as-a-Service
PoC	Proof of Concept

LIST OF TABLES

1. EXECUTIVE SUMMARY

With its capability of driving productivity and economic development, Artificial Intelligence (AI) is already having a huge impact on our everyday lives in recent years. The European Institute of Innovation and Technology (EIT), a body of the European Union, is well positioned with its vast network and broad thematic coverage to help Europe make the most of Artificial Intelligence's potential and keep up with the AI technological race.

The EIT Innovation Communities (KICs) EIT Climate-KIC, EIT Digital, EIT InnoEnergy, EIT Health, EIT Manufacturing, and EIT Urban Mobility have joined forces in a cross-KIC activity to foster collaboration in, education about, and uptake of Artificial Intelligence by European enterprises and society. In 2020, the main focus of the joints activities was taking stock of the state of AI in the KICs innovation, education, and business creation ecosystems. As part of that, EIT Urban Mobility led this study by focusing on existing AI technology business models and applications across urban mobility, climate, manufacturing and healthcare sectors in EU[1]. We engaged over 60 individuals from EIT AI partners and captured their perspectives on the practices of AI technologies. The survey included the sections of barriers and risks for AI adoption, methodological approaches to AI algorithm development, and business models for AI deployment. Building upon the survey results, we also conducted a systematic secondary research of AI landscape, business approach and practices in EU. The report segmented AI applications with the main focus on the value creation of AI technologies in the existing and established sectors.

In summary, this report contains the results of the surveys and desk research study including:

- Mapping AI landscape across Europe focusing on the area of national initiatives, regulatory framework and ethical guidelines
- Conducted a XKIC survey with EIT AI partners and received over 60 valid responses
- Consolidation of various AI business models in Europe
- Consolidation of EIT AI partners' perspective on AI benefit realisation
- Systematic mapping of AI applications across health, manufacturing, urban mobility, and climate in Europe

We recommend the creation of a backend database capturing evolving EU AI applications with proven business models. By systematically segmenting the existing AI solutions across verticals, the database would strengthen EIT's leading position in helping EU advance AI development and deployment in 2021. The database would also be used as the backbone for an online platform presenting EU successful cases of AI applications. The live platform would aim to streamline knowledge, experience, and expertise in AI deployment, connect, share and encourage an open innovation environment with policy leaders, industrial experts, and innovator communities. To achieve such goals, EIT is recommended to work more closely with its ecosystem partners to build data sharing culture, to facilitate wider collaboration, and to demonstrate European leadership in building AI-driven businesses locally, regionally and internationally.

EIT Urban Mobility, EIT Climate-KIC, EIT Digital, EIT Health and EIT Manufacturing are co-funded by the EIT, a body of the European Union.

[1] AI in Energy is an area to examine for next year's report.

2. OVERVIEW OF EU LEADERSHIP IN AI

AI is already transforming business, and this trend is only set to continue. The power of AI is understood by business leaders regardless of company size: from companies with annual revenue over €8 billion to as low at €200 million, with remarkable consensus across business size and sectors. A Forbes Insights survey in 2018 showed that, among 300-plus executives, 95% believe that AI will play an important role in their responsibilities in the near future[2].

The US, China, and Europe are main leading competitors in AI development. China is closely following the top leader, the US, and aims to lead by 2030. For the EU, the focus might be more on finding the ways to embracing the opportunities offered by AI in a way that is human-centred, ethical, secure, and true to its fundamental values[3].

Europe has technological and industrial strengths with a high-quality digital infrastructure and a regulatory framework based on its fundamental values to become a global leader in innovation and its applications as set out in the European data strategy. On that basis, the whole of European society and economy will benefit from its AI ecosystem for its citizens, businesses and public services (Table 1).

2.1. AI LANDSCAPE IN EU

Europe is home to 1,600 early-stage AI software companies. AI entrepreneurship is becoming mainstream. Today, one in 12 put AI at the heart of their value proposition. Among the main European players in AI, the UK, Germany and France progress fast from strategic frameworks to AI practices[5]. French AI start-ups became the most European funded, expected to reach €1.14 billion in 2019[6]. At city-level, the top 10 AI start-up hubs within the EU are London, Berlin, Paris, Madrid, Stockholm, Amsterdam, Copenhagen, Barcelona, and Dublin7. According to European Commission, the top 5 industries AI companies operate in are FinTech, HealthTech, MadTech (marketing, advertising and technology), business intelligence, and automotive[8]. Collectively, European AI start-ups raised €6.7 billion in 2020, almost doubling the figure in 2017.

As one of the most important applications of data economy, AI drives Europe's current and future sustainable economic growth and societal wellbeing by value creation from data. Largely AI companies in the EU focus on B2B, which represents 76% of the business compared to 24% for B2C (business-to-consumer)[9]. Moving from consumer focused, centralised cloud based to industrialised and distributed edge cloud architecture, future AI practices will continue to strengthen EU's leading position in digitised B2B industry and building the next edge-cloud ecosystem (Table 2).

2.2. NATIONAL AI INITIATIVES OF EUROPEAN COUNTRIES

Being in a global AI race, the world's largest economies have all made announcements about their nation state AI strategies. For example, US claims the Top Spot in Global AI Investment whereas China has not been shy about its intent to become a world leader in AI by 2030.

European nations have been also active in AI, for example, the French government intends to spend $1.85 billion over the next five years to support the AI ecosystem including the creation of large public datasets. However, the risks facing European countries are that they could fall into subsidising talent for the global AI giants and accelerate the wealth

Target Groups	Benefits examples
For citizens	Improved health care, fewer breakdowns of household machinery, safer and cleaner transport systems, better public services.
For business development	A new generation of products and services in areas where Europe is particularly strong (machinery, transport, cybersecurity, farming, the green and circular economy, healthcare and high value added sectors like fashion and tourism).
For services of public interest	Reducing the costs of providing services (transport, education, energy and waste management); Improving the sustainability of products and equipping law enforcement authorities with appropriate tools to ensure the security of citizens, with proper safeguards to respect their rights and freedoms.

Table 1. The benefits of AI ecosystem to European society and economy[4]

	Current Practice	Future Practice
Data Source	Related to consumers	From industry, business and the public sector.
Data Storage and Processing	On central cloud-based infrastructure	On a variety of systems, notably on computing devices working at the edge of the network.
Status of Development	A relatively weak position in consumer platforms	A strong position in digitised industry and business-to-business applications.

Table 2. Comparison of current and future data management practice in in Europe[10]

of other sovereign nations[11]. Also, whether strict regulations on data privacy and ethical AI slow down European countries' AI innovation are debated. The recurring work has highlighted the need for coordinated actions at EU level – given data, privacy and services are being offered across the single market.

Germany launched its AI strategy (December 2018)

Aim: To become a leading centre for AI by pursuing speedy and comprehensive transfer of research findings into applications.

AI Strategy: To meet with infrastructure requirements, provide enhanced access to data, skills development, and security to prevent misuse and ethical dimensions. e.g., Ethical guidelines for self-driving cars (BMVI, 2017) [12].

France announced its AI strategy (March 2018)

Aim: To allocate €1.5 billion of public funding to AI by 2022 to help France become an AI research and innovation leader[13].

AI Strategy: Calls for investment in public research and education and build world- class research hubs linked to industry through public-private partnerships. "Upgrade" existing industries. Starting from applications in health, environment, transport and defence, the French AI initiative aims to use AI to renew existing industries. It proposes to prioritise access to data by creating "data commons" between private and public actors; adapt copyright law to facilitate data mining; and open public sector data to industry partners[14].

Spain launched National R&D and Innovation Plan (2017-2020).

Aim: To invest €90 million in digital society and language technology between 2016 and 2021.The investment will focus on areas related to infrastructure, public administration, industry, and lighthouse projects.

AI Strategy: To focus on four core areas: (1) talent, (2) science, (3) industry, and (4) social challenges, alongside several strategic actions such as digital society, language technology, and Industry 4.0.

Poland published a draft of national AI strategy (Ministry of Digitization, 2019)

Aim: To encourage the growth and innovation of the knowledge-based economy by supporting AI science and research developments and to prepare citizens for the digital transformation by improving their competences.

AI Strategy: to account for the protection of human dignity and to ensure conditions for fair competition. The Polish strategy is providing strategic guidance and policy initiatives to develop a holistic AI ecosystem to meet the following objectives: 1) reforming the educational system in AI-related fields; 2) encouraging growth and innovation of AI companies; 3) increasing national and international partnerships in AI;

Finland announced Finland's Age of Artificial Intelligence (October 2019)

Aim: To develop a safe and democratic society with AI; to use AI to provide the best public services in the world; and for AI to bring new prosperity, growth and productivity to citizens.

AI Strategy: A roadmap for the country to leverage its educated population, advanced digitalisation and public sector data resources. The strategy foresees building international links in research and investment and encouraging private investments[16,17].

Italy published "AI at the Service of Citizens" (March 2018)

Aim: To leverage AI technologies to serve people and business and increase public- service efficiency and user satisfaction. To address challenges to implement AI in public services related to ethics, technology, data availability and impact measurement.

AI Strategy: Along the process of achieving the objectives Italy highlights the importance of accounting for the protection of human dignity and ensuring conditions for fair competition.

Summing above,

- German's objective is to become a leading centre for AI by pursuing speedy and comprehensive transfer of research findings into applications.

- France focus on become an AI research and innovation leader to help use AI to renew existing industries.
- Spain draw attention on digital society and language technology.
- Italy to leverage AI technologies to serve people and business and increase public-service efficiency and user satisfaction.

There are also both commonalities and differences between EU countries in terms of governmental initiatives and funding, ethical guidelines, source of investments. For example,

- Ethical dimension and human dignity for AI development are addressed by most EU countries.
- The majority of EU countries recommend distributed but cooperative AI clusters as key next steps.
- Infrastructure and industry update are called by a number of EU countries, while there are differences in the focus on industry sectors.
- Education and talent are recognised as core competences for AI by most EU countries.
- Most countries view data as the key to develop AI and are working on suitable data solutions.
- There are differences in public acceptance, usage, and uptake of ICT technologies across European countries.
- Academia across Europe actively counteracts fragmentation between different AI-related disciplines and uses opportunities to cross-pollinate with industry and government.

Country	AI Policy Document	AI Objective	AI Strategy18,19,20,21	Top Influenti al AI Companies22,23,24
EU	European Commission's White Paper on Artificial Intelligence – A European Approach to Excellence and Trust (2020) European Commission's policies for shaping Europe's digital future: Advancing in digital science and infrastructures Responsible Research and Innovation in ICT-related parts of H2020 Information & Communication Technologies in Horizon 2020	Promote the uptake of AI Address the risks associated with certain uses of AI	Work with member states Focus on the efforts of the research and innovation community Strong focus on skills to fill competence shortages Focus on SMEs Partnership with the private sector Promote the adoption of AI by the public sector Secure access to data and computing infrastructures Exercise global leadership in building alliances	The 7bridges Replai Horavisi on Quortex Bubo.AI
Germany	The Federal Government's Artificial Intelligence Strategy (2018).	Make Germany and Europe global leaders on the development and use of AI. technologies and secure Germany's competitiveness in the future. Safeguard the responsible development and use of AI which serves the good of society. Integrate AI in society in ethical, legal, cultural and institutional terms in the context of a broad societal dialogue and active political measures.	Strengthen research in Germany to driver innovation. Innovation competitions and European innovation clusters. Transfer to business, strengthen the Mittelstand. Foster the founding of new businesses and lead them to success World of work and labour market: shaping structural change. Strengthen vocational training and attracting skilled labour/experts. Use AI for tasks reserved for the state and administrative tasks Make data available and facilitate its use Adapt the regulatory framework National and international networking Engage in dialogue with society and continuing the development of the framework for policy action	DeepSpi AskBrian SpeechTe xt. AIdelphai SPRK.global

Table 3: Illustration of AI policies, objectives and strategies of European countries.

Country	AI Policy Document	AI Objective	AI Strategy[18,19,20,21]	Top Influential AI Companies[22,23,24]
France	For a Meaningful Artificial Intelligence Towards a French and European Strategy prepared by French deputy Cédric Villani (2018)	Improve the AI education and training ecosystem to develop and attract the best AI talent Establish an open data policy for the implementation of AI applications and pooling assets together Develop an ethical framework for a transparent and fair use of AI applications	Build a data-focused economic policy Promote agile and enabling research Assess the effects of AI on the future of work and the labour market, and experiment adequate policy responses Artificial intelligence working for a more ecological economy Ethical considerations of AI Inclusive and diverse AI.	Quortex Ubble.ai ExJewel Zama Lingua Custodia
Spain	RDI Strategy in Artificial Intelligence (2019)	Establish a series of priorities and policy recommendations to create an appropriate ecosystem for development and application of AI-technologies..	Developing a framework for the development of solid IA RDI system and the analysis of its socio-economic impact Identifying key priority areas in which research and innovation in AI should be maximized. Facilitate the transfer of knowledge and its return to societ.y Foster the development of education and competences in the field of A.I Establish a digital data ecosystem and enhance the available digital infrastructures. Analyse and develop an ethical framework from an RDI perspective.	Unicsoft Koukio Solutions Arus Defence Serendee pia Research Bismart
Poland	Artificial Intelligence Development Policy in Poland for 2019-2027 (2019)	Encourage growth and innovation of the knowledge-based economy by supporting AI science and research developments and prepare citizens for the digital transformation by improving their competences Account for the protection of human dignity and ensure conditions for fair competition.	Reform the educational system and provide lifelong learning opportunities in AI-related fields Encourage growth and innovation of AI companies through dedicated support in AI research, including the provision of sufficient financial resources Increase national and international partnerships in AI Create a data ecosystem with trustworthy and high-quality data and increased data exchange mechanisms Reinforce the digital infrastructure, regulatory framework and test environments to foster the development of AI innovations Release more concrete investment plans that could be earmarked to foster AI development	Neoteric Intellias Netguru STX Next Miquido

2.3. AI REGULATORY FRAMEWORK AND ETHICAL GUIDELINES IN EU

All 28 Member States of European Commission plus Norway have signed the Digital Day Declaration 'Declaration of Cooperation on AI'. In the Declaration, Member States agree to work together towards a comprehensive and integrated European approach on AI and, where needed, review and modernise national policies to ensure that the opportunities arising from AI are seized and challenges addressed. The Declaration aims to build a framework for cooperation on areas ranging from AI's impact on the labour market, sustainability and trustworthiness to ethics and funding.

Importantly, the Declaration demonstrates a clear concern for the ethical issues arising out of current and future AI-system's development and deployment. The Declaration commits its signatories to ensuring that 'humans remain at the centre of AI development, and to prevent the harmful creation and use of AI applications. Table 3 outlines the EU's overarching regulatory framework and ethics guidelines on AI[25] , which further complement the EU's AI strategy, and demonstrate the EU's intention to be a leader in 'ethical AI'.

Country	AI Policy Document	AI Objective	AI Strategy[18,19,20,21]	Top Influential AI Companies[22,23,24]
Finland	Finland's Age of Artificial Intelligence (2018) Work in the Age of Artificial Intelligence (2018) Leading the way into the Age of Artificial Intelligence (2019) Ethical information policy in an age of artificial intelligence (2018)	Increase the competitiveness of business and industry Provide high-quality public services and improve the efficiency of the public sec-tor Ensure a well-functioning society and wellbeing for its citizens.	Support education and training in AI with particular attention devoted to the working-age population targeting vocational training and lifelong learning opportunities Close the gap of available skills and the needs of the labour market Encourage research and innovation in AI Highlight various support instruments and reform to foster collaborations in AI Improve the international attractiveness of Finland for foreign AI talents and start-ups Monitor and disseminate the use and understanding of AI to a larger population Promote the good management and the effective utilization of information by a reform of legislative or regulatory framework Gain understanding on ethical principles and to ensure that Finland's AI development is human-oriented and based on trust Facilitating the construction and use of data resources in all sectors.	Claned The Curious AI Company Kirontec h WordDiv e Valossa
Italy	National Strategy on Artificial Intelligence (2019a) Proposals for an Italian strategy for AI Artificial intelligence at the service of citizens	Improve AI-related skills and competences at all education levels and create lifelong learning and reskill opportunities for the labour force Foster AI research and innovation to enhance the competitiveness of the entrepreneurial ecosystem Establish a regulatory and ethical framework to ensure a sustainable and trustworthy AI Support (international) networks and partnerships Develop a data infrastructure to fuel AI developments Improve public services through wider adoption and use of AI applications	Strengthen the provision of AI competences at all education levels. Reinforce the available public funding and encourage public- private venture capital support to increase the competitiveness of the AI industry and the use of AI application in the public sectors with priority given to manufacturing industries, food, energy, healthcare, transport, smart cities, culture and tourism, and public administration. Encourage the centres of excellence to build up a network for research and development which will work in close relationship with the industrial community Increase the international attractiveness of Italy in the field of AI.. Disseminate and uptake AI through promotion campaigns via broadcasting and multimedia, targeting the population as whole. Ensure the design of AI systems is based on principles of transparency, reciprocity and reliability, the Italian government emphasizes the need to establish a regulatory and ethical framework for AI Harness the potential of the data economy by improving the interoperability and accessibility of public administration data through API interfaces. Develop a digital and telecommunication infrastructure by developing a competitive European computing ecosystem and connectivity.	BID Company Radicalbi t Soft-in SRL CrowdM Italy DOING

Regulations & Guidelines	Description
Declaration of Cooperation on AI (Published on 10th April 2018)	The signatories of this declaration commit to a regular assessment of the achievements and progress made on the matters agreed above and on the adoption of the appropriate measures in order to adequately react to the emerging evolution of AI and the opportunities and challenges related.
Communication on AI (Published on 25th April 2018)	The European Union (EU) should have a coordinated approach to make the most of the opportunities offered by AI and to address the new challenges that it brings. The EU can lead the way in developing and using AI for good and for all, building on its values and its strengths.
Communication on AI (Published on 25th April 2018)	The European Union (EU) should have a coordinated approach to make the most of the opportunities offered by AI and to address the new challenges that it brings. The EU can lead the way in developing and using AI for good and for all, building on its values and its strengths.
Coordinated Plan on the Development and Use of Artificial Intelligence Made in Europe (Published on 7th December 2018)	Member States and the Union should attempt to align bilateral outreach efforts related to AI between individual Member States and third countries and pool their efforts pushing for a responsible development of AI at the global level. The Union needs to speak with one voice to third countries and the world at-large on this topic. In synergy with activities of the Member States, the EU should also seek alliances with stakeholders —tech companies, academia and other parties—to engage in a multi-stakeholder alliance at the global level for responsible AI.
High-Level Expert Group on AI (Established on 14th June 2018)	Advise the Commission on next steps addressing AI-related mid to long-term challenges and opportunities. Support the Commission on further engagement and outreach mechanisms. Propose to the Commission AI ethics guidelines.
European AI Alliance (Established on 14th June 2018)	Create a platform for cross-sectorial and open discussions on AI in Europe.
Artificial Intelligence, Robotics and 'Autonomous Systems' (Published on 9th March 2018)	Among others, the statement suggests ideas for a set of ethical guidelines and democratic prerequisites. They centre around data protection and privacy, sustainability, rule of law and accountability, security, safety, bodily and mental integrity and democracy.
Draft Ethics Guidelines for Trustworthy AI (Draft published on 18th December 2018)	On the whole, AI's benefits outweigh its risks, we must ensure to follow the road that maximizes the benefits of AI while minimising its risks. A human-centric approach to AI is needed, forcing us to keep in mind that the development and use of AI should not be seen as a means in itself, but as having the goal to increase human well-being. Trustworthy AI will be our north star, since human beings will only be able to confidently and fully reap the benefits of AI if they can trust the technology.
Opinion on AI: Artificial intelligence – The consequences of artificial intelligence on the (digital) single market, production, consumption, employment and society (Published on 31st August 2017)	The EESC published recommendations concerning the following 11 areas in which AI may create societal challenges: "ethics; safety; privacy; transparency and accountability; work; education and skills; (in)equality and inclusiveness; law and regulations; governance and democracy; warfare; superintelligence.
General Data Protection Regulation (Came into force on 25th May 2018)	Objective: strengthen EU citizens' control over their data and protect them from data and privacy breaches.

Table 4: EU's overarching regulatory framework and ethics guidelines on AI.

2.4. European advantages in AI development

Europe has a very strong academic landscape concerning AI and AI-related research. Academia across Europe actively counteracts fragmentation between different AI-related disciplines and uses opportunities to cross-pollinate with industry and government.

For instance, Europe has academic strengths in quantum computing as well as leading industrial position in quantum simulators and programming environments for quantum computing. Recent advances in quantum computing will generate exponential increases in processing capacity. European initiatives that aim to increase the availability of quantum testing and experimentation facilities will help apply these new quantum solutions to a number of industrial and academic sectors. Europe is also a global leader in low-power electronics, key for the next generation of specialised processors for AI. Europe leads in neuromorphic solutions that are ideally suited to automating industrial processes (industry 4.0) and transport modes. They can improve energy efficiency by several orders of magnitude.[26] In parallel, Europe continues to lead progress in the algorithmic foundations of AI, building on its own scientific excellence, such as machine learning and deep learning (characterised by limited interoperability, the need for a large volume of data to train the models and learn through correlations) and symbolic approaches (where rules are created through human intervention).

Advanced research in key areas is fundamental to the success of AI technology development in Europe. For some areas of research, this might require access to infrastructure – namely, compute power – and data with good quality. Investment in research and collaboration across industry sectors can facilitate this. Articulating new areas for AI research would

Organisation	Description
European Molecular Biology Laboratory (EMBL)	EMBL is an intergovernmental organisation comprised of more than 80 research groups operating across six locations in Europe. It works to "promote molecular biology across Europe, and to create a center of excellence for Europe's leading young molecular biologists" through access to research funding, infrastructure and facilities, training, and technology transfer activities. For AI research collaborations, EMBL may offer lessons in: ▪ Enabling access to infrastructure. ▪ Storage of datasets. ▪ Facilitating collaborations across multiple sites; and ▪ Offering training schemes for early career researchers.
Mila	Mila is a partnership between the Université de Montréal, McGill University, École Polytechnique de Montréal and HEC Montréal. It seeks to advance the science of deep learning, and understanding of its socio-economic implications, while supporting technology transfer activities that foster local economic growth.
Cyber Valley	Cyber Valley is a research network consisting of the Max Planck Institute for Intelligent Systems, the University of Tübingen, the University of Stuttgart, and industry partners from: Amazon, BMW Group, IAV GmbH, Daimler AG, Porsche AG, Robert Bosch GmbH and ZF Friedrichshafen AG. Supported by the State of Baden- Württemberg, Cyber Valley seeks to coordinate research activities in AI across these partners, establishing new research groups and professorships in machine learning, robotics, and computer vision, and training up to 100 doctoral students.
PRAIRIE	The Paris Artificial Intelligence Research Institute (PRAIRIE) is an industry-academia collaboration aiming to boost the contribution of Paris-based AI labs to international research.

Table 5: Examples of research collaboration from cross-disciplines.

inspire a new generation of AI applications, with the support from ethical AI policies, regulations, and proactive sharing of AI benefits across European societies [27] . The below provides examples of industry-academic research collaboration to foster AI technology development.

Europe has tremendous strengths in AI: its universities are home to leading researchers, the world's largest technology companies have set up significant bases throughout Europe, and many countries support a vibrant start-up environment. Across Europe, national governments are seeking to capitalise on the opportunities presented by these technologies by developing national strategies aimed at boosting economic growth and improving societal wellbeing. There are new opportunities for collaborations – across nations, and between industry and academia – to translate the potential of AI into benefits for people across Europe.

Section Footnotes:

[1] AI in Energy is an area to examine for next year's report.

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3. AI BUSINESS MODEL

3.1. AI BUSINESS MODEL

AI technology is the catalyst of business model innovation that disrupts industries and companies. AI transforms how businesses create and capture value, triggering business and technology innovation in the era of user-oriented digital economy[28,29,30]. According to Gartner Research (2018), AI-derived business value will reach up to $3.9 trillion by 2022.

There are numerous valuable use cases that AI can address across organisations. In the form of vertical industrial and enterprise solutions, AI can offer substantial value such as enhancing customer services, driving productivity, reducing cost and lowering prices, improving product and service offerings.

AI companies can be categorised based on the level of their business replying on AI as[31]:

- AI application provider – companies whose product simply could not function without AI at its core, whether they serve consumers or enterprises.
- AI infrastructure provider – Companies providing AI tools and infrastructure (software & hardware to all companies)
- AI adopter – companies using AI as part of a broader product or technology stack.

Revenue Model [32]

(1) AI Application-as-a-Service

For most AI application providers that develop sectoral solutions to tackle specific industrial and enterprise business requirements, they normally generate revenue through commoditisation of AI software. A lot of those AI application providers are start-ups. They run their business models based on an Application-as-a-service (AaaS) licensing model, by developing applications for specific use-cases for their clients. For organisations (AI adopters) that decide to partner with AI technology start-ups to co-develop tailored-made solutions, a revenue-sharing or data sharing model could be adopted by both companies to meet a common interest. Both the AI technology provider and adopter can agree to build a proof of concept (PoC) and if it works, both parties share the benefits in the form of revenue or data proprietary[33]. Implementing AI Application-as-a-Service, AI technology providers charge their customers with monthly running cost as well as operational support/training fees (i.e. annual subscription fee). They could also run a fee per study pricing model along with a perpetual licence and annual maintenance contract with their customers. AI Application as-a service is a variation of the Software-as-a-Service (SaaS) model that would accentuate the role of sectorally competent AI companies. However, different from SaaS that normally is sold on a per-user bases, AIAaaS are priced by transaction or completed computation. The more work AI does, the more you pay for AI.

(2) AI Infrastructure-as-a-Service

For organisations that are unwilling to build their own AI solutions or can't afford for budget reasons, they could tailor AI technology services provided directly from a third-party vendor and use them nearly immediately. In such case, the AI technology firms provide AI Infrastructure-as-a-Service by offering computational services such as infrastructure and pre- trained algorithms. They charge the usage of AI technologies based on API calls.

AI Infrastructure-as-a-Service is a model which extends and strengthens the existing business model that has gone through multiple "branding" stages from Outsourcing to Shared Services, to As-a-Service to Cloud – but remains constant. Generally, this model is based on moving from a company developing, maintaining, and operating their own technology services to a model where technology direction and operations is handed over to an external multinational company. For example, IBM Watson provides AI services including Sentiment Analysis, NLP and Entity Recognition. Primarily, this model has its benefits in reducing capital, operational and staffing costs while its drawbacks are overt dependency on a limited number of external contractors with a risk of "lock in" and challenges in service quality and change management. For AI adopters this would mean that their existing business models would be strengthened, and a few key multinationals may be able to consolidate their positions. These IT multinationals often do not have explicit knowledge of each sector but depend on "back-to- back" contracts with AI technology start-ups with a higher level of sectoral competence. This business model would maintain a distance between the AI business users and the AI designers with a high contract "handling costs" and

limited legal liability. Large multinationals can both assume the risks inherent in adopting a new technology and distance themselves from legal liability in ways which smaller companies would be challenged to match.

Cost Structure

Building AI-based solutions, despite being affordable, is far from being cheap. Companies needs to take several unavoidable costs into account in addition to hardware for computing power. The expenditure for developing AI solutions could include cost of business consulting, feasibility studies, data scientist, minimum viable product, implementation, maintenance and continuous learning.

It is worth noting that until an AI system goes through enough training data and is exposed to several use cases, it is unlikely for AI to perform any better than conventional software. Depending on the business issue, once the solution is fully operational and after the improvement of its learning curve, the added value of AI solutions will become more obvious. Thus, it is hard for AI start-ups to use freemium models. AI requires more time than traditional solutions and it is very challenging for an AI product to be profitable at first launch[34].

Discussion

For AI Infrastructure-as-a-Service model, Europe needs to ask if we want to strength the existing dominance of key multinationals as we move AI adoption forward.

- The financial benefits incurred in this model may well be exported to non-European countries
- The key role of intermediaries weakens the potential of European AI start-ups and unicorns
- The model creates additional links and distance between user and designers

For AI Application-as-a-Service model, AI solution providers would expand the B2B model in which the role of large multinationals would be lessened within the model. While large multinationals may provide the computing capacity needed, they would neither be the primary developer of AI applications, nor front for European AI innovators to our own EU companies. This A-a-a-S model would create closer alignment and communication between AI adopters and AI providers. New network value would be created, and emerging AI consulting services would be closer to their own sectors. Financial value would be maintained within Europe and upscaling of AI start-ups is attainable. This appears as an optimal solution. However, for "application-as-a-service" marketplace to develop in Europe there are some key issues that have to be addressed.

3.2. METHODOLOGY

To explore how AI technology firms (including both providers and adopters) within the EIT XKIC partnership programme currently execute their business models, we conducted a survey EIT cross-KIC "Impact AI" - Survey on the usage of data, algorithms and the application of artificial intelligence in June-August 2020. The survey invites XKIC partners including firms/institutes affiliated with EIT Climate, Manufacturing, Urban Mobility and Healthcare. Focused group meetings with EIT AI technology partners from both academia and industry were also held to complement the understanding of the survey.

Our survey covers the areas of both data management for AI development as well as AI business model and applications in Europe. The survey is structured into the sections below:

- Data Governance, Data Privacy, Data Platforms,
- AI Methodologies and Capabilities
- Deploying and Driving Value of AI Technologies

Model	Description	Examples
AI Applications as a Service	Develop applications for specific use-cases defined by their clients and provides ready to go AI applications that can interact with other systems. A general trend of AI company's business model, since the deployment process is relatively fast, with a proven ROI. This business model exists in both B2B and B2C. AI solutions are priced by transaction completed computation, which means the more work AI does, the more you pay for AI.	AI-based applications and their business models in climate, manufacturing, urban mobility, and health sectors are illustrated in the report in Section 6, 7, 8, 9
AI Infrastructure / Systems as a Service	Provide computational services like the infrastructure and pre-trained algorithms. It is generally based on API calls. Because of intensive and costly deployments process, this model is mostly adopted by leading AI global companies. Companies' revenue comes from the development of a tailored-made solution and monthly running costs as well as operational support/training.	IBM Watson is offered as a service, other companies and developers can access through API in order to develop their own applications, e.g. Satisfi which uses Watson to help customers navigate retails space.

Table 6: AI business Model.

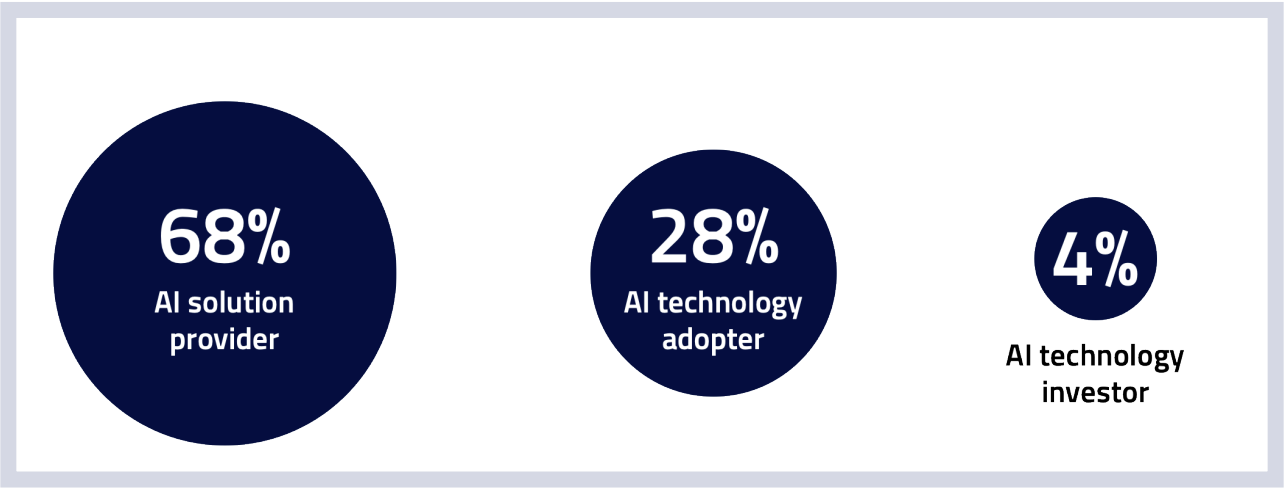

Figure 1. Most responders are AI providers.

- Costs, Barriers, and Risks of Adopting AI
- Collaboration to Improve AI Adoption

The participants were asked to provide their point of view on the overall management of the availability, usability, integrity and security of the data, the practices which ensure that the data shared by customers is only used for its intended purpose, the platform concept that an integrated technology solution that allows data to be governed, accessed, and delivered to users, data applications, or other technologies for strategic business purposes. The participants also responded with important perspectives about where AI technologies are in terms of generating revenue and reducing cost for client organisations.

By the end of August, we received 64 valid responses, among which 68% are AI solution provider, 28% are AI technology adopter and 4% are AI technology investor (Figure 1).

3.3. SURVEY FINDINGS

AI technology development

Based on our survey result, industrial partner collaboration and in-house development are the two main approaches to developing AI algorithm among the EIT XKIC AI partners.

Over 50% of AI developers rely on external partners to develop AI solutions, helping them with scaling up, testing and design.

AI technology deployment

Reported by EY35 (2019), European companies are quite evenly split across deploying AI as a top-down process (35%), as a bottom up (29%), or as a combination of the two (28%). However, most advanced companies are adopting more top-down than bottom- up approaches. AI is mostly often deployed as a combination of business pull and technology push, with 45%

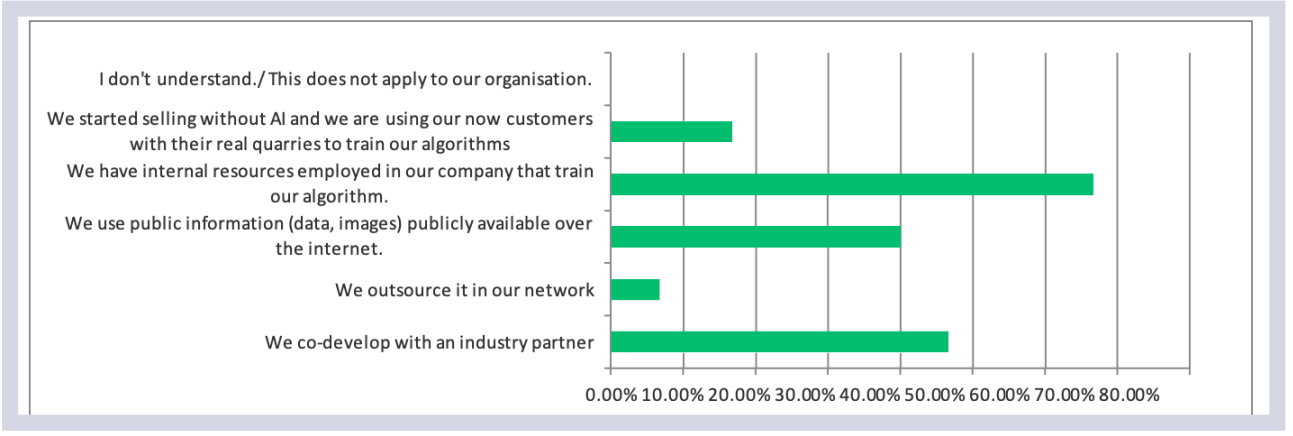

Figure 2: AI algorithm development approaches

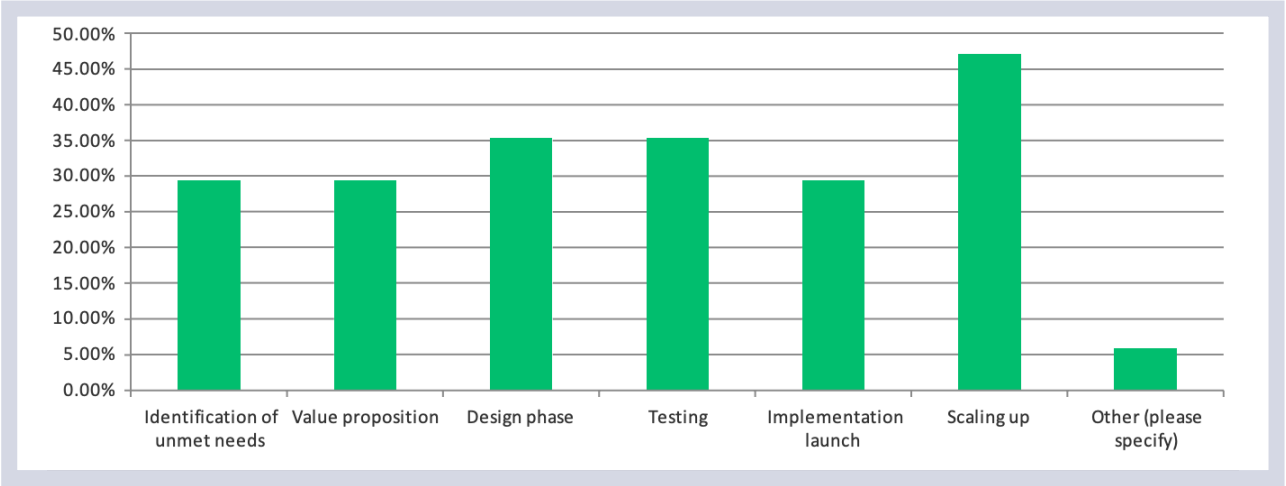

Figure 3: 50% of AI developers rely on external partners to develop AI solution.

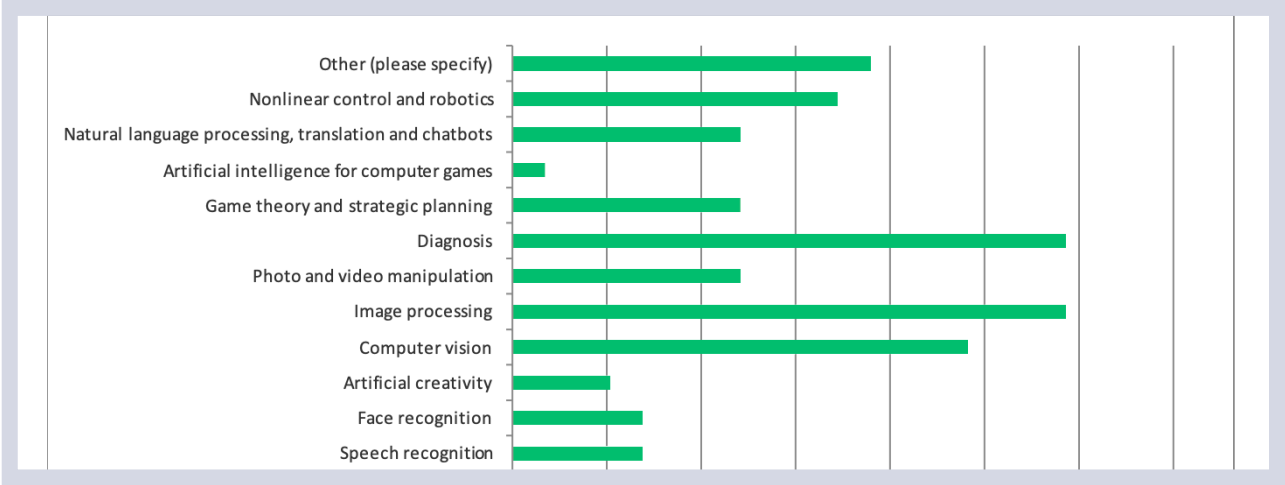

Figure 4: Deployment of different AI solutions among XKIC AI partners .

compare to 24% and 23% respectively. This resonates well with one of the most consistent inputs from the executives on the most sought-after AI profiles.

According to our respondents, the most widely deployed AI solutions are image processing, computer vision and diagnosis.

When asked about the main AI market in the next 5 years, AI solution developers feel that the market for their solutions would be mainly in Europe, then North America and Asia, with Europe being the biggest estimated market growth.

AI impact on revenue generation & cost reduction

AI has a positive impact on the way the IT sector works, with the potential to change business models from every part of a value chain. AI can effectively be used to create expert systems that will exhibit intelligent behaviour, provide solutions to complicated problems, and further help to develop stimulations equivalent to human intelligence within machines.

More than 60% of responders in our survey have yet to feel that AI solution deployment would lead to revenue generation in business functions (Figure 5). However, for those 40% that have experienced the impact of revenue generation, supply-chain management was the most benefited business department in revenue growth as a result of AI deployment. The second mostly benefitted function is manufacturing, whereas 30% of AI partners felt that AI could help with revenue increase by 6-10%.

Similarly, about 54% of responders felt that AI solution had not been making impact on cost reduction. For those responders who did notice the impact, they recommended that the most benefited business functions in terms of cost reduction are manufacturing, product and service development, and supply-chain development.

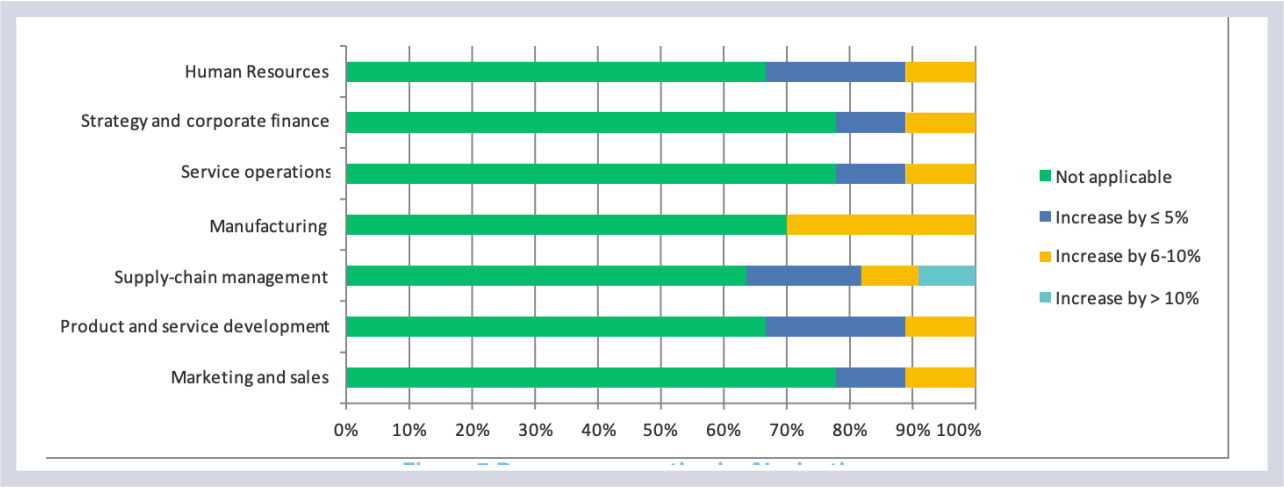

Figure 5: Revenue generation by AI adoption.

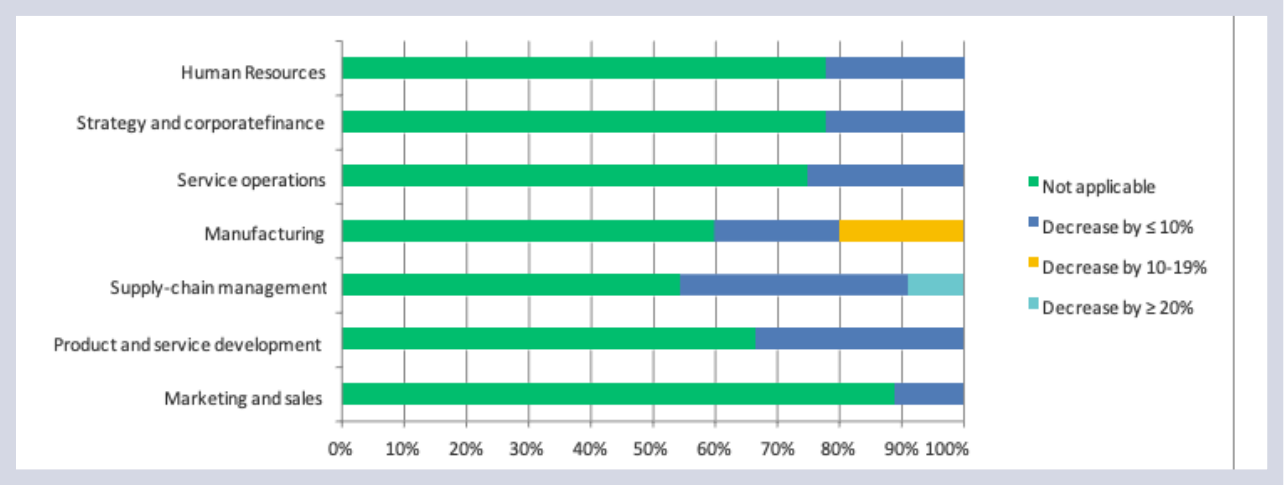

Figure 6: Cost reduction by AI adoption.

AI benefits across companies' value chains

Companies work to overcome the challenges associated with building AI into their businesses because the benefits are too great to ignore. The well recognised business benefits corporate leaders see from AI include:

- **Engage customers**[36]

AI can help to improve marketing and advertising & identification of new customers. AI can make the CRM a self-updating, auto-correcting system and much more efficient.

Machine learning can analyse your prospects data and predict who will buy[37]. AI can also improve customer services. AI answers queries quickly and are available 24/7, and can analyse customer call data, classify interactions based on positive or negative outcomes and analyse patterns to provide a script with the most effective phrases[38].

- **Enable employees**[39]

AI could enable talent acquisition by automating recruitment[40] (avoiding human bias), on-boarding (Q&A), performance evaluation (analysing data), and effectively dealing with routine tasks. It can relieve employees from routine tasks and improve employee productivity. It is estimates that at least 20-30% of current tasks can be done without human intervention. A substantial number of companies are currently in the process of training chatbots to transform the way information is acquired[41].

- **Transform products & services (R&D)** [42]

On top of an expected high prevalence of AI within IT departments, AI is commonly used within R&D functions. Employees in R&D are often engineers who tend to have a good understanding and appreciation of AI; the R&D function is often already wired AI technologies in the future[43].

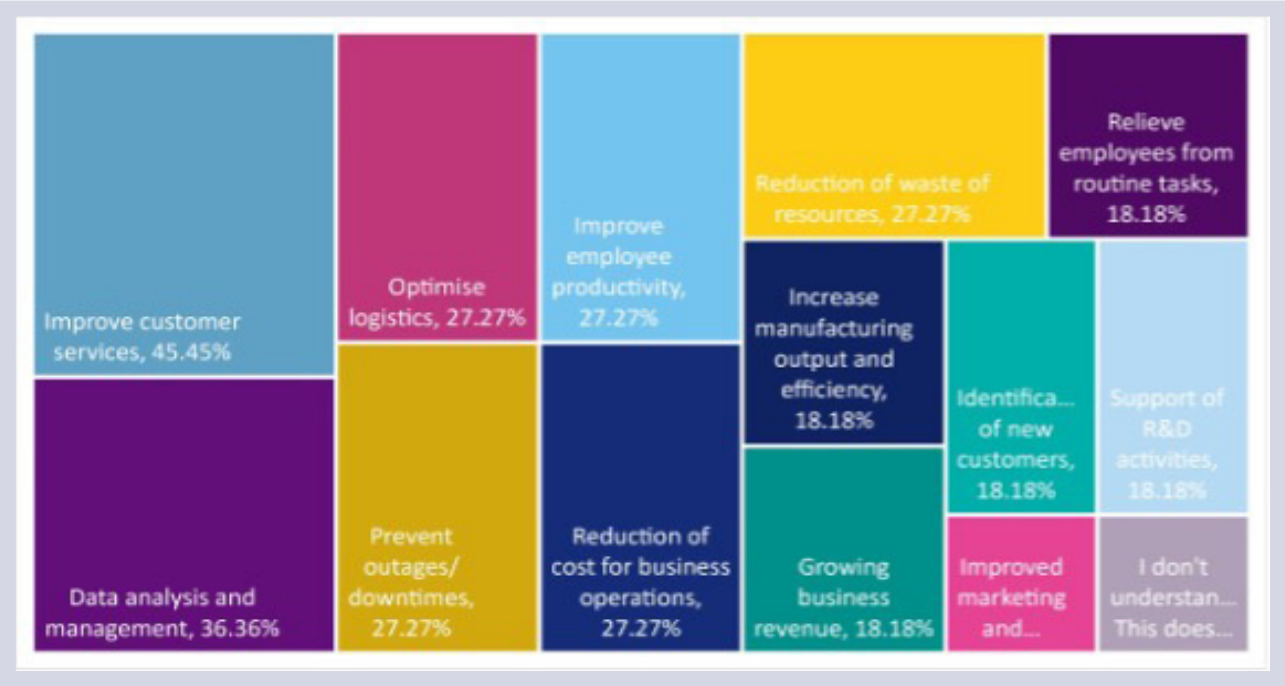

Figure 7 :XKIC AI adopters' view of AI benefits.

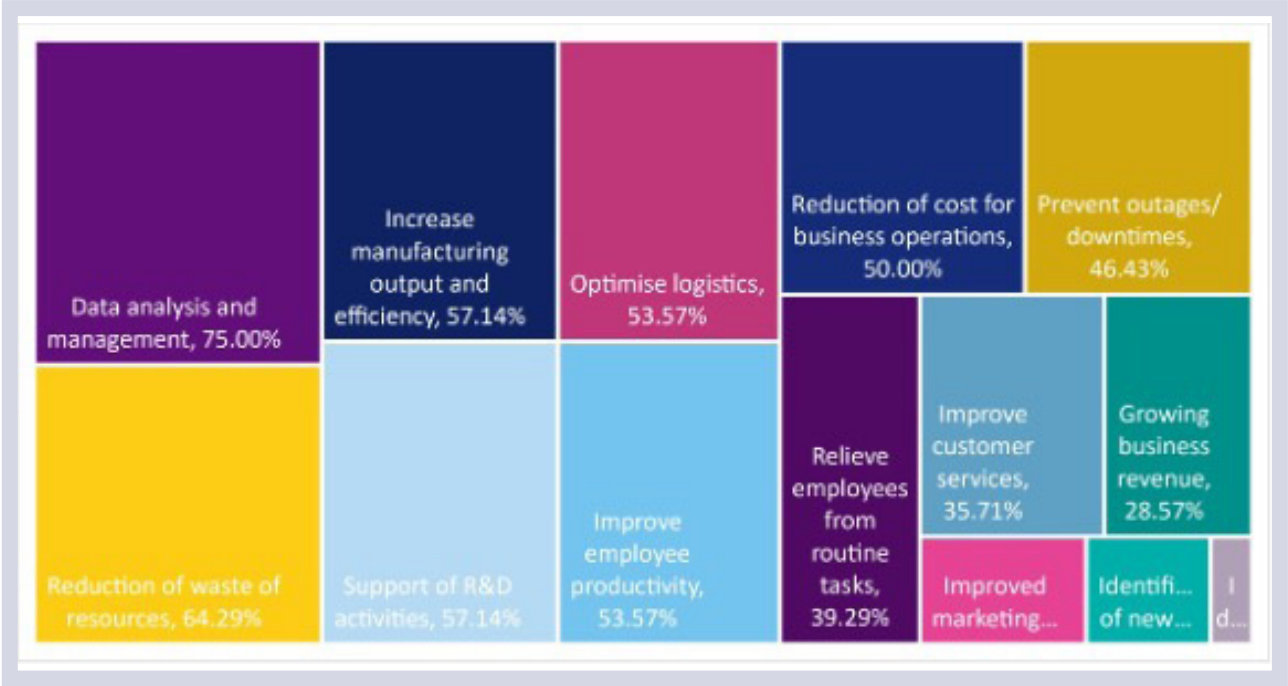

Figure 8 :XKIC AI adopters' view of AI benefits.

- **Improving Security**

Public as well as private organisations store tons of customer, strategic, and other forms of data which need to be secured at all time. AI can provide the necessary security and help to create a layered security system which enables a high-security layer within these systems. AI can make computers and networks safer by filtering out malware, spam and phishing emails even before a human opens them. According to our survey, the XKIC AI adopters expect AI's impact to vary mainly from "improve customer service"to "data analysis and management" Compared to AI adopters' view, the XKIC AI providers believe that the main AI benefits go towards data analysis and management and reductions of waste of resources.

- Figure 9: Barriers for deploying AI solutions.

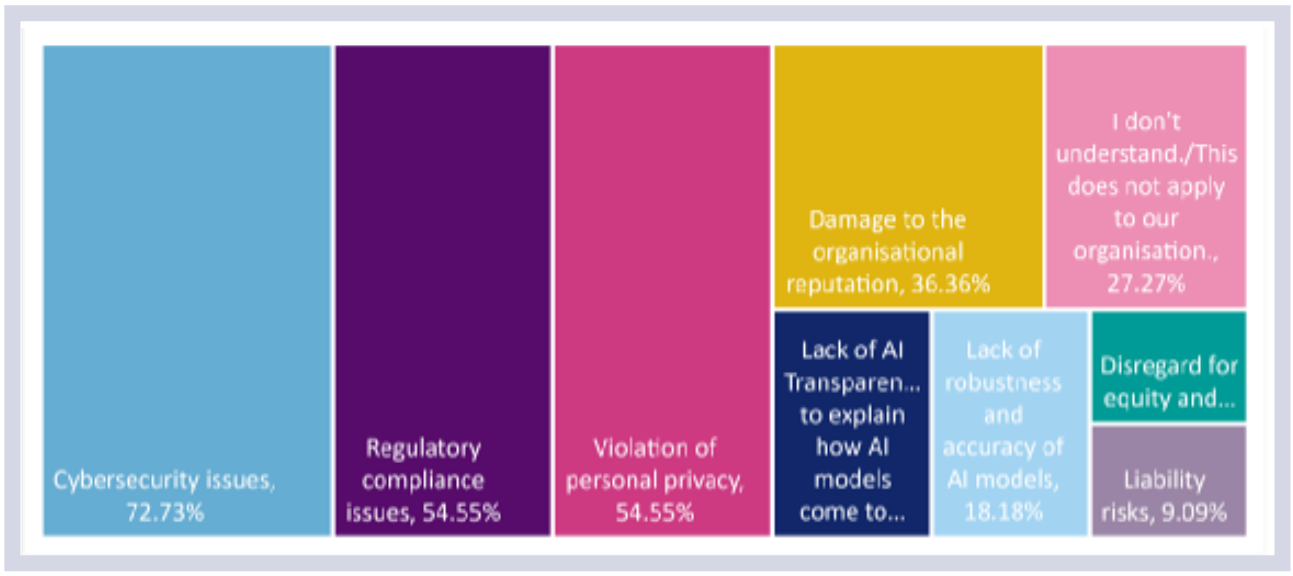

Figure 10: Risks for adopting AI solutions.

error; AI can help optimise the host server to improve customer service and enhance operations[45] to save money through decreased downtime.

Barriers and risks for AI adoption

Although promising in realising wide benefits across business functions and industrial sectors, significant challenges pose to AI adoption. Barriers and risks at both economic (need of funds, impact on employment and performances) and organisational (changing working practices, cultural barriers, need of new skills, data integration, etc.) levels need to be mitigated when developing and deploying AI solutions[46, 47].

For the XKIC AI partners, our survey suggested that the biggest barriers in deploying AI solutions are lack of technical feasibility, lack of data availability & quality, and budget constraints. Cybersecurity, compliance, personal privacy are raised as three top risks for XKIC AI partners.

Data barrier

AI relies on vast amount of data and on the algorithms to make predictions and help mangers make decisions. Data governance (DG) is the overall management of the availability, usability, integrity and security of the data used in organisations. DG is still a challenge for many organisations, due to lack of inter-operability and standardisation. Data storage, data quality, data

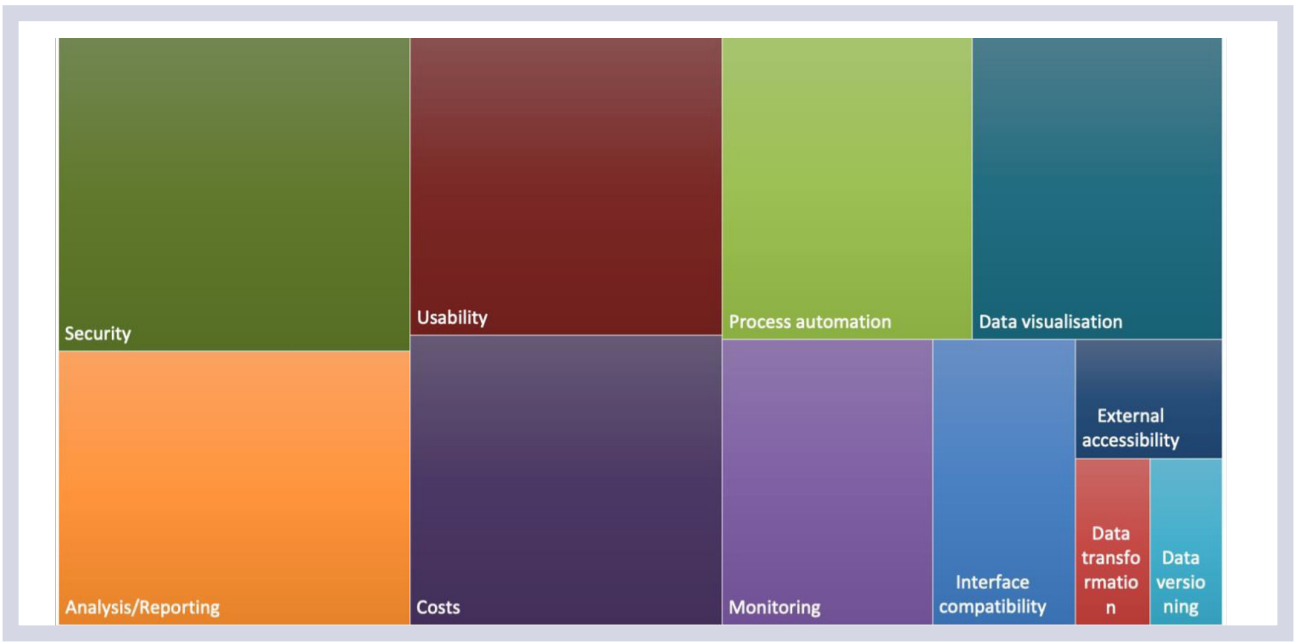

Figure 11: Desired features of a data platform.

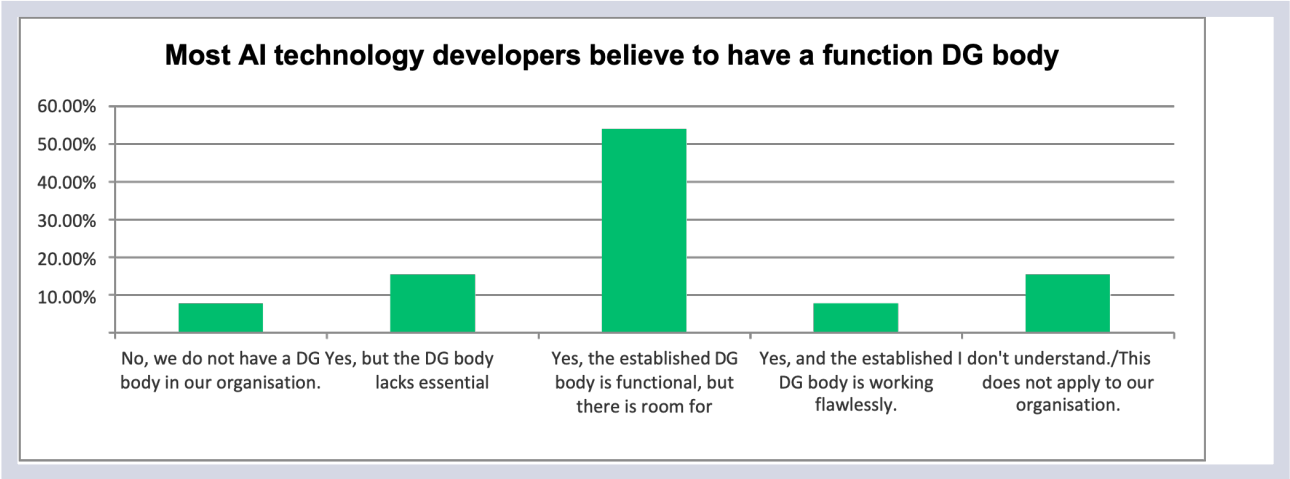

Figure 12: XKIC AI developers' perspective on their own data governance body.

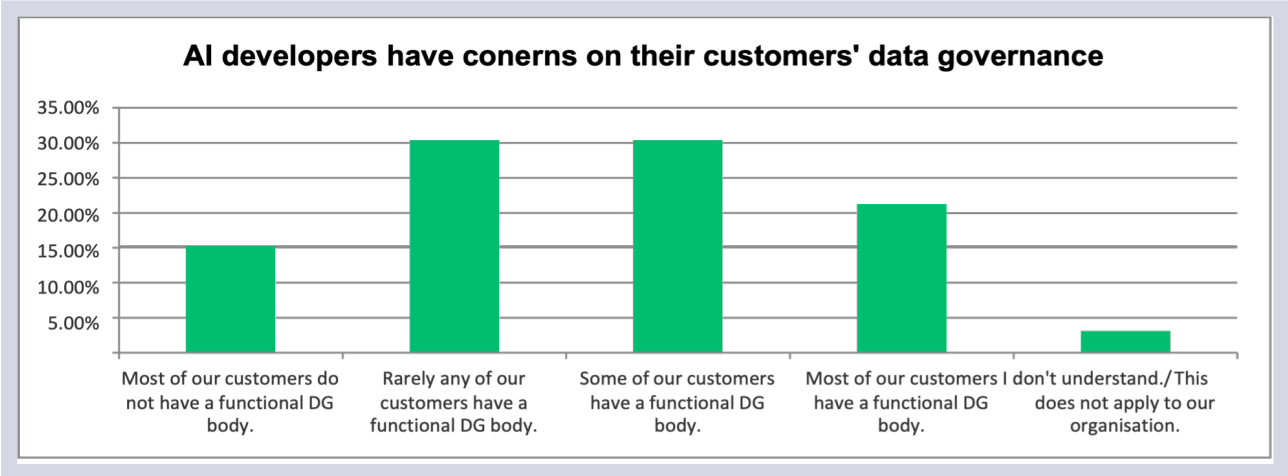

Figure 13: XXKIC AI developers' perspective on their own data security.

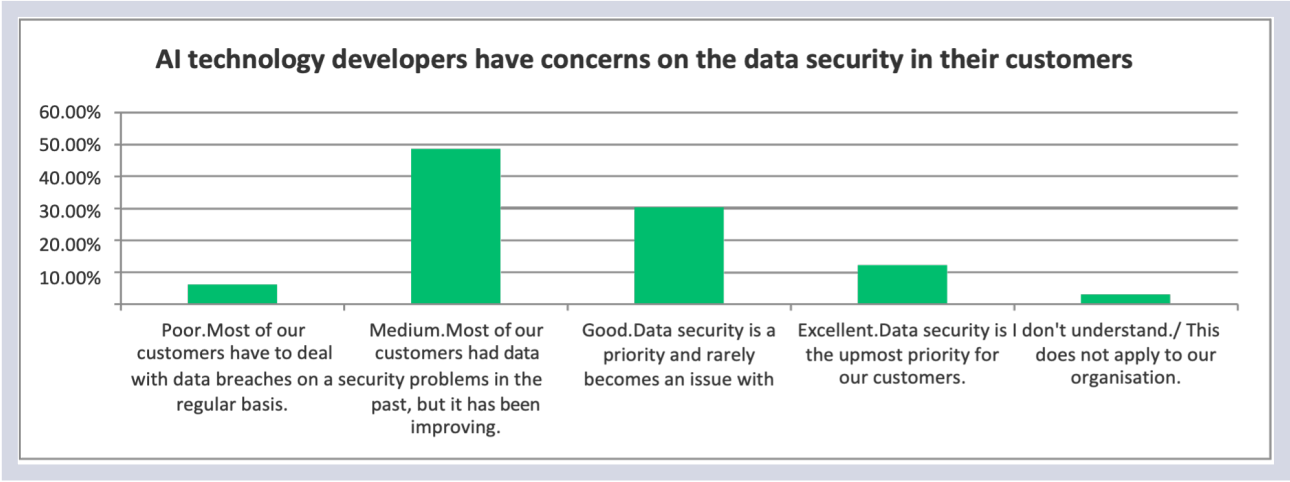

Figure 14: XKIC AI developers' perspective on their own data security..

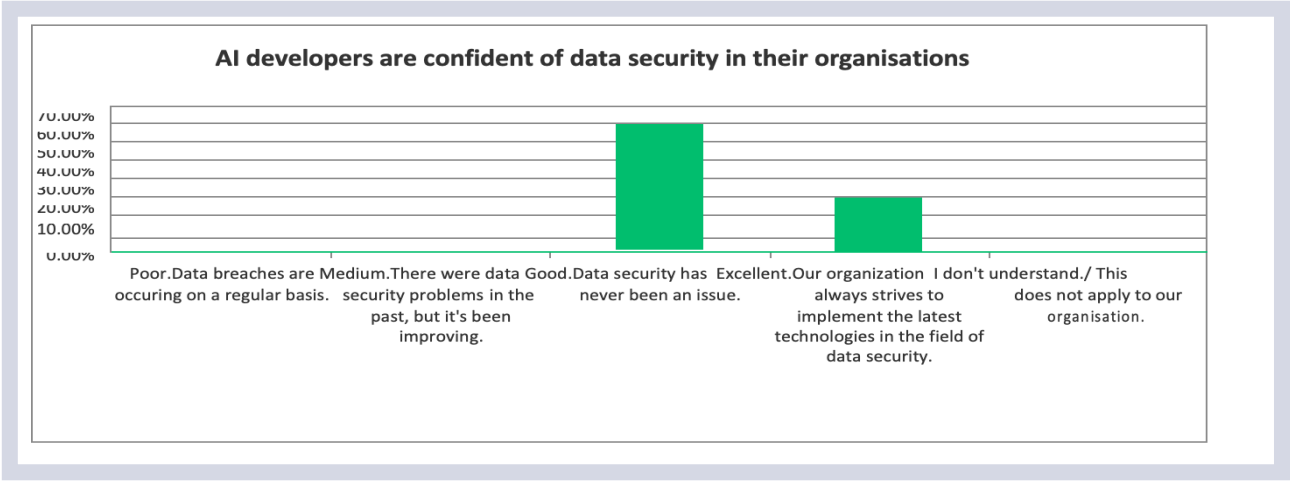

Figure 15: XKIC AI developers' concern on their customers' data security.

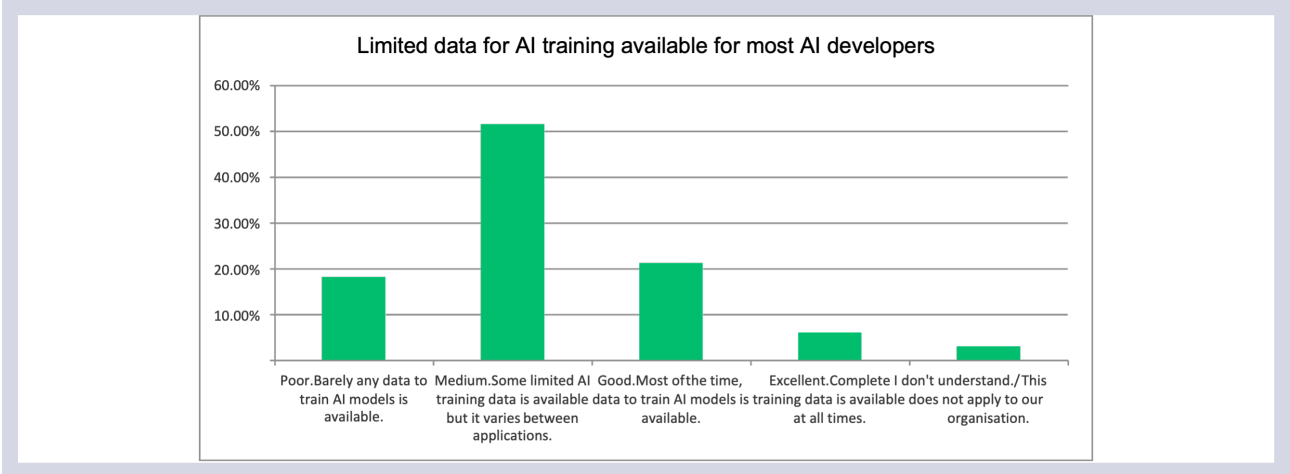

Figure 16: Data availability from XKIC AI developers' perspective.

Figure 17: Data quality from XKIC AI technology developers' perspective.

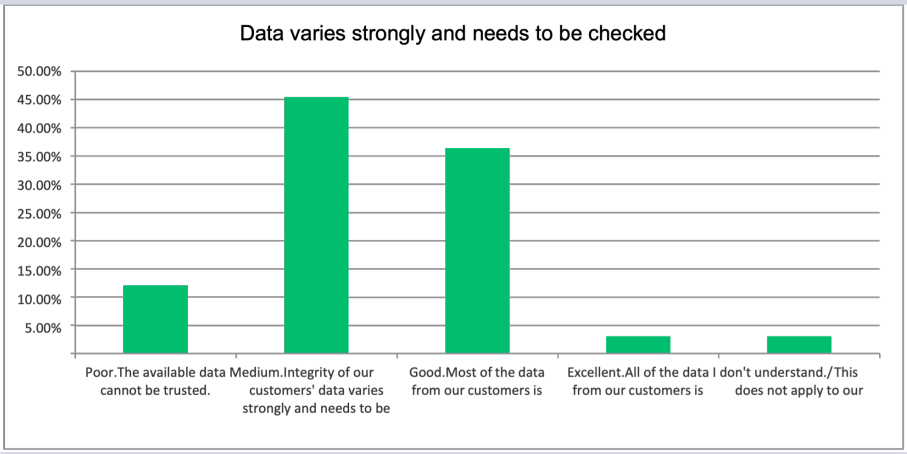

Figure 18: Data integrity from XKIC AI developers' perspective.

processors and algorithms need to be well governed, especially when sensitive data are used to make decision that may affect the data owner.

For data governance, our survey result shows that more than half of AI technology developers see them having a functional DG body, with room for improvement. Contrastingly, they felt less confidence in their customers' data governance, with 75% of them not seeing their customers having a functional DG body.

Similarly, in the aspect of data security, the XKIC AI developers provided confident feedback about their own practices, but much less positivity toward their customers' data security practice. As such, our responders highlighted the need for further development of related data regulations would help to enhance the mutual trust between AI providers and their customers.

In addition to data security, data availability, quality and integrity are important to AI organisations. From XKIC AI developer's perspective, all of the three aspects need to be improved. Our survey suggested that limited data for AI training was available for most AI developers. The data was mostly with fairly good quality but still required additional processing. Also most XKIC AI developers had experienced varying data integrity from their customers thus lots of time and energy have been devoted to review, clean and re- structure datasets before any AI work could get started.

Cost barrier

Cost remains a key concern for XKIC AI adopters. According to the survey, most costly activities are due to immature AI tech, consulting cost, software licence fee, software configuration and customisation.

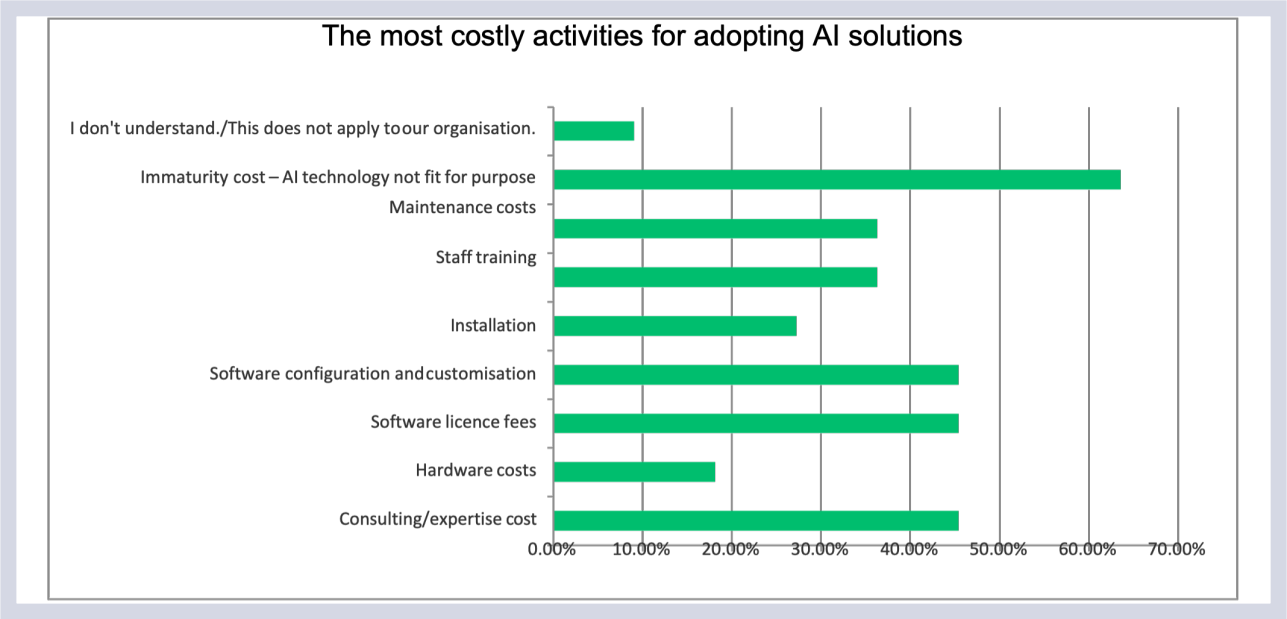

Figure 19: The costliest activities for adopting AI solutions

Cultural barrier

AI will bring a change to workplaces and jobs. Some jobs will go and others will be created. Change is not something everyone can easily get comfortable with in the business world, and this culture of resistance is a barrier for AI adoption. Disruption and expense need to be overcome in order to see the overall gains.

Political, legal, and social ramifications

So far, AI is still at risk for being biased by the humans that build it. If there is bias in the data sets the AI is trained from, that bias will affect AI action. AI's ability to monitor the global information systems from surveillance data, cameras, and mining social network communication has great potential for good and for bad. If governments and business institutions don't spend time now formulating rules, regulations, and responsibilities, there could be significant negative ramifications as AI continues to mature.

The current approach to AI strategy is overly narrow and the trend of AI application and adoption still does not respond adequately to rapidly evolving intelligence capabilities. Also, businesses often may foster an environment of mistrust and animosity towards each other within respective industries and nations. This is perhaps a reason that prevents a common approach to data collection and information access. Moreover, many countries lack the necessary digital data infrastructure. The lack of digital infrastructure, in turn, discourages data opportunities and innovations, making it challenging to address business data and information needs adequately. All of these have restricted the development of AI business[48,49].

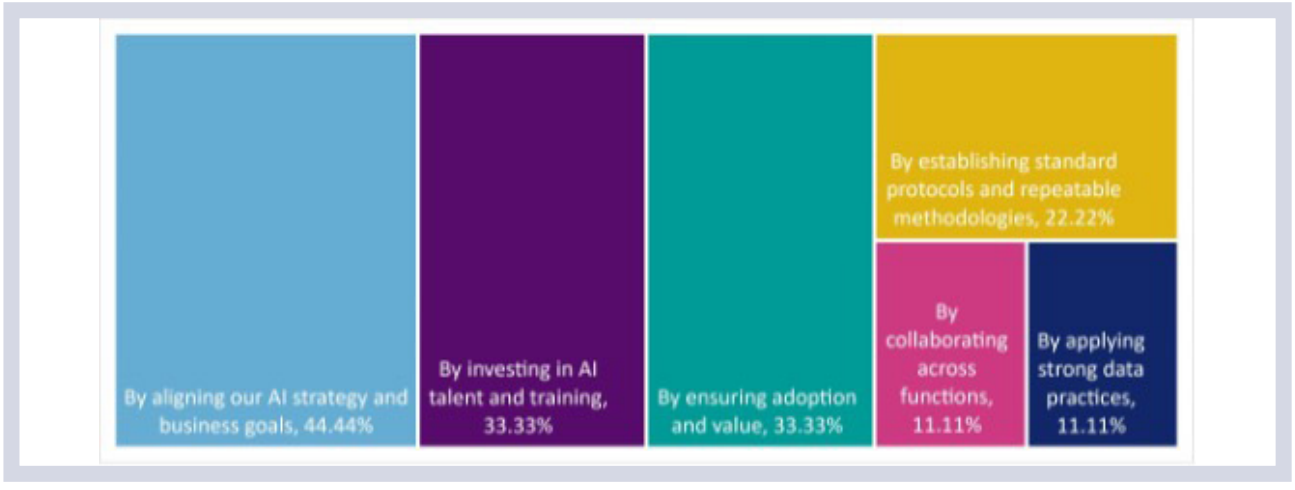

Figure 20: Approaches that XKIC AI adopters took to drive AI value..

Figure 21: Approaches that XKIC AI providers help their customers to drive AI value.

Value driver of AI solutions

To be successful in the age of AI, companies demand new competencies, including the vision to embrace AI and a shift in mindset; data sets to train and deploy AI algorithms; the ability to diligence AI partners effectively; the ability to manage workflow changes; the ability to manage challenges of organisational design and culture.

To fully drive value and positive impact of AI solutions, AI providers and AI adopters take different approaches. Inherently, AI providers and AI adopters have totally opposite priorities. On the organisational level, the top three approaches for XKIC AI adopters are "alignment between AI strategy and business goals", "investment in AI talent and training" and "ensuring adoption and value'" Differently, the top three approaches that XKIC providers took to supporting their customers for AI adoption include "improving their data practices", "helping them with establish standard protocols and methodologies" and "supporting collaboration across functions".

Section Footnotes:

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4. AI APPLICATIONS IN THE CLIMATE SECTOR

As average temperatures rise, climate science finds that acute hazards such as heat waves and floods grow in frequency and severity, and chronic hazards, such as drought and rising sea levels, intensify. In 2016, the number of weather and disaster events was tripled compared with 1980. In 2100, almost 50 percent of species may face extinction[50]. The affected physiological, human-made, or ecological systems may break down and we may suffer from a variety of hazards, such as flooding, forest fires, hurricanes, and heat. The EU parliament declared a global climate and environmental emergency on 28th November 2019. To address climate change, they focus on developing renewable energy sources, developing higher capacity batteries to store energy and power electric vehicles and researching on truly transformational energy sources. AI will be a powerful tool in reducing greenhouse gas emissions and helping society adapt to a changing climate[51].

4.1.AI'S IMPACT ON CLIMATE

AI is an enabling technology that has a critical role to play in reducing the carbon footprint of energy generation, transportation, food production, industrial manufacturing, and our homes, offices and cities. Predictive AI is even helping to improve how oil and gas companies locate the most resource-rich drilling grounds. For the wind and solar power industries, AI is enabling greater energy yield through advanced weather forecasting and analysis. The paper "Tackling Climate Change with Machine Learning" listed 13 areas where machine learning can be deployed[52], and this covers all aspects of people's life: Electricity systems, transportation, buildings and cities, industry, farms & forests, carbon dioxide removal, climate prediction, societal impacts, solar geoengineering, individual action, collective decisions, education and finance. The World Economic Forum in 2017 also advocates to focus technology development on five areas of our society to address climate change[53]: Power and electricity generation; Transportation; Food and its supply chain, manufacturing and Buildings and cities.

Power and electricity generation

A sustained and increased focus on modern renewables such as wind and solar power is critical as power and electricity generation account for 25% of all greenhouse emissions[54]. In the future, utilities need better ways of predicting how much energy is needed, in real time and the long term. AI algorithms can forecast energy demand, but they could be improved by taking into account of finer local weather and climate patterns or household behaviour. For instance, wind companies can produce more electricity per rotation by incorporating real time weather and operational data, which can be achieved by AI. In a smart grid, AI is increasingly used to manage the intermittency of renewable energy so that more can be incorporated into the grid. The table below lists potential opportunities of AI. AI innovations are projected to save oil and gas companies as much as €41 billion in production costs annually[55].

AI Contributions	Subfields	
Enabling low-carbon electricity	Variable sources	Forecasting supply and demand
		Improving scheduling and flexible demand
		Accelerating materials science
		Additional applications
	Controllable sources	Managing existing technologies
		Accelerating fusion science
Reducing current-system impacts		Reducing life-cycle fossil fuel emissions
		Reducing system waste
		Modelling emissions
Ensuring global impact		Improving clean energy access
		Approaching low-data settings

Table 7: Selected opportunities to reduce GHG emissions from electricity systems using AI[56]

AI Contributions	Subfields
Reducing transport activity	Analysing data Remote sensing Forecasting Freight consolidation Alternatives to transport
Improving vehicle efficiency	Designing for efficiency Detecting loading inefficiency 3D printing Autonomous vehicles
Alternative fuels	Research and development
Electrical vehicles	Charging patterns Charge scheduling Congestion management Vehicle-to-grid Algorithms Battery energy management Battery R&D
Modal shift (shifting to lower-carbon options, like rail)	Consumer choices Coordinating modes Bike share rebalancing Predictive maintenance Enforcing regulation

Table 8: Selected strategies to mitigate GHG emissions from transportation using AI[57]

Transportation

Transportation represents 23% of global related carbon dioxide emissions. AI plays a significant role in transforming this sector, and some opportunities of AI are listed in the table below. AI's applications in transportation are also included in Chapter 6.

Optimise traffic management

AI is being used to measure and optimise traffic flows in cities. Just reducing the number of cars stopping at red lights by optimizing flows through better timing of traffic signals can have material impact on carbon emissions. In India, McKinsey & Co reports that smart rubbish bins are being trailed that means that rubbish trucks do not pick up if the bins are not 75% full.

In Pittsburgh, an AI system incorporating sensors and cameras that monitors traffic flow adjusts traffic lights when needed. The systems are functioning at 50 intersections with plans for 150 more and have already reduced travel time by 25 percent and idling by more than 40 percent. Less idling means fewer greenhouse gas emissions.

In China, IBM's Green Horizon project is using an AI system that can forecast air pollution, track pollution sources and produce potential strategies to deal with it. It can determine if, for example, it would be more effective to restrict the number of drivers or close certain power plants in order to reduce pollution in a particular area.

Empower autonomous and electric vehicles

It has been estimated that smart automated driving systems could see a 15% reduction in fuel consumption over human operators. AI will be vital in the widespread transition to autonomous connected electric vehicles (EVs), which will ultimately transform short-haul mobility while reducing greenhouse gas emissions and delivering cleaner air. EV charging will become more affordable via demand-response software programs enabled by big data. Clean, smart, connected and increasingly autonomous and shared short-haul transport will combine AI with other Fourth Industrial Revolution technologies, notably the Internet-of-Things, drones and advanced materials[58].

Improve efficiency of logistics

AI can improve efficiency of logistics and supply chain by better matching supply and demand. AI is increasingly being used to understand demand levels across complex and increasingly international supply chains. Shipping goods around the world is a complex and often a highly inefficient process that involves the interplay of different shipment sizes, different types of transportation, and a changing web of origins and destinations.

AI could help to find ways to bundle together as many shipments as possible, minimise total number of trips, optimise trade and shipping routes, and lower emissions of shipment transportation59. It can also minimise inefficiencies and carbon emissions in the supply chains of the food, fashion, and consumer goods industries. Better predictions of supply and demand would reduce production and transportation waste, while targeted recommendations for low-carbon products could encourage more environmental friendly consumption[60].

Otto, a German e-commerce company, predicts with 90% accuracy what products will be sold within 30 days. Schneider Electric reduced transportation needs significantly with an AI model to predict the best way to acquire raw materials and send their products to 240 global manufacturing facilities and 110 distribution centres.

Food and its supply chain

Food and its supply chain represent 25% of global emissions. The agricultural production needs to be increased as much as 70% to feed all its inhabitants as the earth's population is expected to reach 10 billion people by 2050. AI is a helpful tool from predicting food de-mand to reducing food waste to helping developing world farmers diagnose with precision agriculture.

Precision agriculture

Different from traditional farming that treats all fields homogeneously applying one flat rate of agrochemicals at the whole field[61], AI enables precision agriculture that enables waste and reduces carbon emission while improving crop yield[62]. AI helps to apply variable rates of inputs (irrigation water, fertilisers, pesticides, etc.) according to the actual needs of different areas in the field.

BioSense[63] aims to develop low cost, easy to use precision farming solutions that can be applied anywhere regardless of the size, type and age of agricultural machinery used by the farmers and make IT an important tool to drive small farms towards sustainability. To this end, a free web-based and android-based digital platform named "AgroSense" was developed to support farmers in decision making and field management.

Manufacturing

Manufacturing in industry represent 30% of global related carbon dioxide emissions. Technologies are being developed to help manufacturers become more productive and reduce use of power and toxic emissions, which can be helpful to improve manufacturing efficiency and to discover new materials. AI impacts on manufacturing sector are included in more detail in Chapter 5.

Buildings and cities

Buildings and cities represent 20% of global emissions. Leading European cities and companies pledged to slash carbon emissions from their buildings to net zero. Helsinki, Finland and Valladolid, Spain have signed the World Green Building Council's (WorldGBC) Net Zero Carbon Buildings Commitment (the Commitment), alongside property sector leaders Buro-Happold, Carbon Credentials, Deerns, Grimshaw Architects, Grosvenor Group, Newsec Finland and Ylva[64]. Many AI applications in smart city sector are being developed and has become a trend. For example, AI control system can improve energy efficiency by incorporating data from smart meters and the Internet-of-Things to forecast energy demand and reduce a building's energy consumption by taking weather forecasts, building occupancy, and other environmental conditions into account to adjust the heating, cooling, ventilation, and lighting needs in an indoor space[65].

AI driven consumer applications are offered to help measure and predict the level of carbon footprint. Using gaming mechanics, people can start to compare sustainability footprint with others. Consumers could receive tailored interventions to promote their enrolment in energy saving programs

AI Contributions	Subfields
Optimising buildings	Modelling building energy Smart buildings
Urban planning	Modelling energy use across buildings Gathering infrastructure data
The future of cities	Data for smart cities Low-emissions infrastructure

Table 9: Selected strategies to mitigate GHG emissions from smart city using AI[66]

Examples of European AI applications

- **Qucit**[67]

Qucit is a French start-up that uses AI to make cities more efficient. Qucit aims to quantify and analyse urban activities with AI algorithms in order to reduce pollution and optimise transportation and resource management. transportation and resource management.

- **Cargonexx**[68]

Cargonexx is the first digital freight forwarder to use AI to reduce empty runs, which in turn leads to better prices, higher quality and less CO_2 emissions. The company is aiming to build the largest B2B trucking network in Europe. Last year, the company won Europe's best Deep tech scaleups award in the EIT Digital Challenge 2018.

Build better climate models

Precise modelling of climate change is increasingly important, and AI can be helpful in building better climate models by:

- Building better predictions of extreme weather events such as hurricanes and unlock new insights from the myriads of climate data that is collected[69.]
- Reconstructing past climate conditions using data collected from things like ice cores, climate downscaling.
- Using large-scale models to predict weather on a hyper-local level.
- Using large-scale models to predict socio-economic impacts of weather and climate.
- Improving the accuracy of climate change projections. AI is helping to determine which models are more reliable by giving added weight to those whose predictions eventually prove to be more accurate, and less weight to those performing poorly.
- Using computer vision technologies such as object recognition to supercharge the analysis of visual climate data.
- Accountability for environmental pollution - AI is being used to automatically analyse data from IoT sensors and remote sensing data to identify pollutants such as ground- level ozone, particle pollution, carbon monoxide, sulphur dioxide and nitrogen dioxide. It will provide not only a more accurate and transparent picture of pollution but it will help drive accountability.

Examples of AI applications

- **Monteleoni**

The project Monteleoni works on using machine learning algorithms to combine the predictions of approximately 30 climate models used by the Intergovernmental Panel on Climate Change. Better predictions can help officials make informed climate policy, allow governments to prepare for change, and potentially uncover areas that could reverse some effects of climate change[70].

- **Google & the Mila institute**

AI and deep learning can be a good fit for data-rich climate science projects that typically provide datasets of necessary depth and variety. The research is led by Google, the Mila institute, and the German Aerospace Centre. The resulting models can, for example, evaluate energy consumption levels in buildings and electric vehicles more accurately, making it easier to discover trends and predict future consumption.

- **Facebook**

Other examples of deep data analysis in climate change-related research is Facebook's AI-based population density map for the majority of Africa and the application of DCNNs for detecting extreme weather events like tropical cyclones, atmospheric rivers and weather fronts[71].

- **MILA, Microsoft and ConscientAI**

Researchers from Montreal Institute for Learning Algorithms (MILA), Microsoft and ConscientAI Labs use GANs, a type of AI, to simulate what homes are likely to look like after being damaged by rising sea levels and more intense storms. In this way, they make the effects of climate change more realistic for more people.

- **Appsilon**

With climate change affecting wildlife all around the planet, conservationists need reliable solutions for tracking populations of endangered species without disturbing them. Appsilon's animal recognition project is addressing this challenge with an AI model capable of recognizing specific kinds of animals in images.

- **Ocean Data Alliance**

The Ocean Data Alliance is working with machine learning to provide data from satellites and ocean exploration so that decision-makers can monitor shipping, ocean mining, fishing, coral bleaching or the outbreak of a marine disease. With almost real time data, decision-makers and authorities will be able to respond to problems more quickly. Artificial intelligence

Risks	Examples
Performance	Early-warning systems for natural disasters such as flooding are trained using historical data on weather patterns. However, if there is a lack of understanding of factors driving model predictions due to poor explainability, there is a significant risk of false alarms or false negatives, particularly in situations that are not represented in the data used to train the AI model.
Security	Hackers could access automated warning systems, distributed energy grids or connected autonomous transport platforms, and cause regional disruptions. Appropriate governance will be required to ensure human and earth-friendly AI and prevent misuse. Misuse of AI could also occur when systems fall into the wrong hands. For example, poachers could profit from AI-enabled endangered-animal tracking tools meant for conservation efforts.
Control	Smart-energy optimisation across buildings and infrastructure will create interactions between energy-use decisions within each building and at the regional level. Each building would operate individually, assessing overall demand patterns to determine low-cost energy-use approaches. Depending on circumstances, individual building decisions will interact with regional ones, potentially altering demand in ways that could crash regional energy systems.
Economic	Increased productivity from automation, plus rising consumption from improved personalisation, product design and AI-informed marketing, could increase resource use, waste and demand for energy.
Social	Autonomous trucks and cars, along with energy-efficient Internet-of-Things manufacturing, offer considerable environmental benefits but could also lead to a considerable loss of employment. (Goldman Sachs estimates that the US alone will lose an estimated 300,000 jobs per year when AV saturation peaks). Regional economic decline and widening social inequality and unrest could also follow in manufacturing towns or along truck routes.
Ethical risks	Autonomous emergency food- and disaster-relief delivery systems that are trained using reinforcement learning or historical demand patterns will route supplies to specific regions during natural disasters. This could create ethical dilemmas relating to accountability for delivery dysfunctions, priority- setting and results. [73]

Table 10: Risks of AI implementation in climate sector.

can also help predict the spread of invasive species, follow marine litter, monitor ocean currents, keep track of dead zones and measure pollution levels.

- **Nature Conservancy & Microsoft**

The Nature Conservancy is partnering with Microsoft on using AI to map ocean wealth. Evaluating the economic value of ocean ecosystem services—such as seafood harvesting, carbon storage, tourism and more—will make better conservation and planning decisions possible.

The data will be used to build models that consider food security, job creation and fishing yields to show the value of ecosystem services under differing conditions. This can help decision-makers determine the most important areas for fish productivity and conservation efforts, as well as the trade-offs of potential decisions. The project already has maps and models for Micronesia, the Caribbean, Florida, and is expanding to Australia, Haiti, and Jamaica.

- **Cervest**[72]

Cervest leverages AI to analyze billions of data points and forecast how changes in the climate will impact the future of entire countries down to individual landscapes, to allow businesses, governments, and land managers to adapt to climatic and extreme events.

4.2. RISKS OF AI IMPLEMENTATION

Apart from the benefits that AI offers for building a sustainable planet for future generations, it also poses risks and negative impact on individuals, organisations, society, and the earth. We illustrate the main risks brought by AI and examples of the risks in Table 7.

AI relies on more compute. When its carbon footprint increases, significant consequences follow. A recent study from University of Massachusetts estimated the carbon footprint of training a large natural language processing model produced 300,000 kilograms of carbon dioxide emissions (Strubell et al., 2019)[74]. That's roughly the equivalent of 125 round trip flights from NYC to Beijing. The rebound effects ofmore efficient technical infrastructures need to be understood and steps need to be taken ensure AI not to lead to an increase in fossil fuel consumption[75]

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5. AI APPLICATIONS IN THE MANUFACTURING SECTOR

It is estimated that by 2035, AI-powered technologies could increase labour productivity by up to 40%[76], and will add an additional 3.8 trillion dollars GVA in 2035 to the manufacturing sector[77]. This chapter discusses how AI impacts on manufacturing sector.

5.1. PRODUCT

Quality checks

Machines equipped with cameras are much more sensitive than human naked eyes to detect even the smallest defects and flaws. AI services with very high-resolution cameras can flag errors instantly and make response automatically, which is very helpful for factories that create complex products, such as microchips and circuit boards.

Generative design

AI helps with generative design, which is a process that involves a program generating a number of outputs to meet specified criteria. Designers or engineers input design goals and parameters such as materials, manufacturing methods, and cost constraints into generative design software to explore design alternatives. The solution utilises machine learning techniques to learn from each iteration what works and what doesn't.

5.2. OPERATIONS / LOGISTICS

Predictive maintenance

Products can fail in a variety of ways, irrespective of the visual inspection. With vast amounts of data on how products are

Rolls Royce & Microsoft Azure	Rolls Royce is not only a luxury automaker but also provides maintenance services for the airlines that utilise its products. Owing to this, the company, which works with a lot of aircraft, receives a lot of data. The company has deployed Microsoft Cortana Intelligence Suite and Azure to analyse this chunk of data. The solutions can perform data modelling at scale and identify and flag anomalies. The process helps the clients to plan ahead.
Siemens	German company Siemens has retrofitted its gas turbines with hundreds of sensors that transmit data to an AI-enabled data processing solution, which adjusts fuel valves to maintain the minimum possible emission level.
BMW Group	Currently within its operations the BMW Group is using AI to analyse component images from its production line for real time identification of deviations from the standard product quality.[78]
Thales SA Intelligent maintenance	Thales SA Intelligent maintenance. Thales SA, a leading supplier of electronic systems to aerospace and defence companies, is currently collecting historic and current data relating to part failures. That data is then utilised by AI algorithms to predict potential problems in the future in order to make proactive maintenance decisions for customers.[79]

Table 11: European examples of AI applications in manufacturing quality checks.

Carlsberg Product enhancement	Implementing a "Beer Fingerprinting" project, Carlsberg is developing sensors that have the capability to differentiate between different flavours of beer. Carlsberg processes the data via AI and uses the information to develop new beers as well as enhance the quality of existing beers.[80]
Dassault Systèmes	Dassault Systèmes' 3DEXPERIENCE® platform offers sophisticated technologies and solutions for multi-disciplinary design, modelling, simulation, optimisation, execution, data acquisition, analysis and reporting in a guided operations management environment. By combining science-based virtual experiences and real-world operations, 3DEXPERIENCE twins enable companies to better understand and make decisions that deliver on the sustainable purpose. The 3DEXPERIENCE platform is the only product innovation platform that is both a system of operations (to run a business) and a business model (to transform a business). As an operational system, the platform connects people and processes across the product life cycle, from design ideation to modelling, optimising, simulation, manufacturing, market delivery and societal reception. As a business model, the 3DEXPERIENCE platform transforms relationships and roles across the value network, removing intermediaries between sellers and buyers, purchasers and subcontractors, service providers and customers.[81]

Table 12: European examples of AI application in manufacturing generative design.

Deutsche Bahn	The German railway operator, leverages data from railway switches to predict failures, thus decreasing unexpected delays at scale.
Skymind	Skymind provides AI platform that enables data scientists and IT teams to quickly prototype, deploy, maintain, and retrain machine learning workflows that accelerate time to value. Skymind bridges the gap between data science, DevOps and the big data stack. It is an ML platform that directs engineers and data scientists through the complete workflow of building and deploying machine learning models for enterprise applications on JVM infrastructure. It can be installed on any environment: cloud, on-premises, bare- metal, or hybrid systems.[82]
SAP SE	SAP SE has developed an AI-based on-premise analytics solution known as 'SAP HANA," which is an in-memory data platform that delivers business intelligence, accelerates business processes, and simplifies the factory automation environment. The company also offers "SAP Leonardo," a cutting-edge solution that integrates IoT, machine learning, and analytics. SAP's AI portfolio allows manufacturers to adopt new capabilities and business models rapidly.[83]
Schneider Electric	Schneider Electric created a predictive IoT analytics solution based on Microsoft Azure Machine Learning service and Azure IoT Edge to improve worker safety, reduce costs, and achieve sustainability goals. Schneider Electric data scientists use data from the oil field to build the models that predict when and where maintenance is needed. Data scientists use automated machine learning capabilities to intelligently select the optimal machine learning models and automatically tune machine model hyper-parameters to save time and improve efficiency. When the company deployed the Azure Machine Learning service-based solution, it helped operators increase efficiency by 10 to 20% in just two days.[84]

Table 13: European examples of AI applications in predictive maintenance.

tested and how they perform, with sensors and advanced analytics embedded technologies in manufacturing equipment, AI can accurately anticipate when industrial machines will fail, as well as determine the most probable cause of failure, and define the best course of maintenance in a given situation. AI predictive maintenance AI predictive maintenance is already used by a number of manufacturers, including LG and Siemens.

Supply chain communication and price forecasts

Manufacturers collect vast amount of data related to operations, processes, and other matters – and the data combined with advanced analytics can provide valuable insights to improve businesses. Supply chain management, risk management, predictions on sales volume, product quality maintenance, prediction of recall issues. By analysing data, AI enabled system provides accurate price recommendations. The aforementioned data can also be used to communicate with the links in the supply chain, to get real-time updates and requests.

Robotics

AI-powered robots can do much more than the conventional robots, such as interpret CAD models, which eliminates the need to program their movements and processes.

Digital twins

A digital twin is a virtual representation of a factory, pro-

Continental	Continental has built software to predict the optimal points for tire changes on its fleet. The underlying model predicts the overall running mileage and compares it to the baseline, to generate actions. By that, Continental is reducing its stock of tires, also improving safety on the road.
Danone Group	Danone Group is a French multinational food-products manufacturer who is using a machine learning system to improve its demand forecast accuracy today. They're using machine learning to improve planning coordination across marketing, sales, account management, supply chain, and finance, leading to more accurate forecasts. Using machine learning, Danone can meet demand from product promotions and achieve its target service levels for channel or store-level inventories. The system led to a 20% reduction in forecast error, a 30% reduction in lost sales, a 30% reduction in product obsolescence, and a 50% reduction in-demand planners' workload.[85]
Ocado Group	Ocado Technology is developing world-class systems and solutions in the areas of automation, robotics, artificial intelligence, machine learning, simulation, big data and more. Ocado Technology is the proud creator of the Ocado Smart Platform (OSP) - the unique end-to-end e-commerce, fulfilment, and logistics platform which allows our customers across the world to do online grocery scalability, sustainably, and profitably.[86]
SynQ, Swisslog	Synchronized Intelligence and is a modular, service-oriented software platform for warehouse management and material flow orchestration. SynQ gives you the precise functionality you need to optimise your warehouse operations. It literally embeds intelligence in the operation and synchronizes the performance of your automated and manual warehouse equipment in the best possible way. It encompasses warehouse management (WMS), material flow (MFC/WCS), and automation control systems (ACS) functionality, along with an array of business intelligence tools to boost your warehouse performance.[87]

Table 14: European examples of AI applications in supply chain communication.

Siemens	In 2017, Siemens developed a two-armed robot that can manufacture products without being programmed.
ABB	ABB is investing $150M to build an "advanced, automated and flexible" robotics factory in Shanghai. In this plant, ABB will manufacture robots using robots. According to ABB, these robots will have autonomous and collaborative elements. The robots' autonomy is built with the use of AI and digital twin
Swisslog's CarryPick system	CarryPick is an innovative automated storage and picking system designed for multi-channel intralogistics. A swarm of mobile vehicles (KMP600), developed by Swisslog and KUKA, navigates via a grid to deliver mobile racks to workstations for picking and reducing the travel path for workers. The workstations are safe and configurable to your requirements. They also reduce the picking error rate thanks to pick-by-light and pick pointer. Users benefit from an intuitive workstation interface making it easy to use and ensuring smooth processes.[88]

Table 15: European examples of AI applications in robotics.

Siemens NX	Simulation plays a large role in the development of medical devices, saving development costs by optimizing performance and reliability, reducing benchtop tests and clinical trials, and accelerating the regulatory approval process. Digital evidence generation is the process of using simulation (the Digital Twin) to establish product performance—an effort supported by FDA and regulatory agencies worldwide.[90]
GE Digital's	GE Digital's ADMS, GIS, and AEMS technologies help grid operators create a Network Digital Twin, which provides a connected view of the end-to-end network of assets, based on real operational data. It includes as-is, to-be, and real-time views of the network and enables all departments to contribute and consume data that help deliver better outcomes. Network Digital Twin can help operators create virtual models to better operate, analyse and optimise how the grid responds to the impact of increasingly extreme weather, aging infrastructure, and the growing use of renewable on the grid.[91]

Table 16. European examples of AI applications in digital twins.

duct, or service. Paired with advancements in AI, digital twin is increasingly valuable in transforming industrial operations, creating additional business value. It produces an evolving profile of an asset or process in a plant, captures insights on performance across its lifecycle[89].

5.3.COMMERCIAL

AI solutions can analyse the behaviours of customers to identify patterns and predict future outcomes. Observing customer behaviour allows companies to better answer their needs.

5.4. ENVIRONMENTAL IMPACT

AI can help to transform manufacturing by reducing, or even reversing, its environmental impact. AI helps to improve manufacturing efficiency. For example, many global manufacturers are using predictive AI modelling to make turbine combustion more efficient, reduce errors and energy wastage on the production line, and improve production efficiency with advanced robotics. AI also helps to discover new materials. The process of discovering new materials is typically slow and imprecise. AI can accelerate things by finding, designing, and evaluating new chemical structures with the desired properties.[93] AI can support developing new eco-friendly materials and help optimise energy efficiency – Google already uses AI to do that in its data centres.

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KONE	Finnish elevator and escalator manufacturer KONE is using its "24/7 Connected Services" to monitor how its products are used and to provide this information to its clients. This allows them not only to predict defects, but to show clients how their products are being used in practice.
Dragonfly	Dragonfly focuses on providing AI solutions that analyse customer attention in stores. Through two separate AI systems, Dragonfly helps businesses determine which features are recognised by customers first. In turn, they can deliver more effective marketing and promotional campaigns. Dragonfly focuses on serving customers in industries such as the government, agencies, and the developer landscape. Though the company is still in its initial stages, it's gained a lot of attention from brands that want to learn more about how clients interact with their stores, products, and physical environments. [92]

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6. AI APPLICATIONS IN THE MOBILITY SECTOR

The development of new technologies and more accurate sensors (GPS, gyroscopes, accelerometers, ambient light sensors, humidity sensors and others) are necessary to supply the human driver[94]. The new sensors will provide the availability of data and connectivity in transport, fundamental aspects for the development of intelligent traffic prediction systems, route calculation and shared UPS, which will transform transport as we know it today.

From helping cars, trains, ships and aeroplanes to function autonomously, to making traffic flows smoother, it is already applied in numerous transport fields. Beyond making our lives easier, it can help to make all transport modes safer, cleaner, smarter and more efficient. AI-led autonomous transport could for instance help to reduce the human errors that are involved in many traffic accidents.

These forces are now driving innovation in the mobility sector, highlighted by changes in how mobility is delivered, such as through the rise of on-demand services, vehicle and ride sharing and the introduction of new modes, such as active transport. The future of mobility needs to be designed around the consumer – the traveller. Businesses and service providers that have already done this have seen rapid growth and successful integration into the mobility services landscape[95].

6.1. AI IN MOBILITY SERVICES

AI has been well deployed in helping with mobility services, ranging from automating cars, trains, ships and aeroplanes to helping safer, cleaner, smarter and more efficient transportation environment.

There are different models offering integrated solutions to place-based mobility challenges. Two prominent examples are: Mobility-as-a-Service and Demand Responsive Transport.

Mobility-as-a-Service (MaaS)

The core aim of MaaS is to deliver a service that can provide a reasonable alternative to personal vehicle use within a city, which provide a holistic urban transportation system that handles every aspect of the user journey from travel planning and information, payments and the journey itself.

Demand Responsive Transport (DRT)

DRT systems are characterised by flexibility in routes, scheduling and vehicles. It is typically applicable in contexts where regular fixed route and infrastructure services would not be financially viable. DRT has the potential to alleviate the reliance on personal vehicle transportation that is common in rural and regional areas, providing a wide array of localised benefits including congestion, liveability, loneliness and isolation.

Table 15 illustrates key functions of AI applications in transportation that begin to be commercialised or undergoing research trials[96].

AI Technology Functions	Use Case Examples
Nonlinear prediction (Prediction of the behaviour of systems in which inputs and outputs are non-linear)	Traffic demand modelling or modelling transportation infrastructure health as a function of traffic, construction and weathering.
Control Functions	Signal control of traffic at road intersections, ramp metering on freeways, dynamic route guidance, positive train control on railroads
Pattern recognition	Automatic incident detection, image processing for traffic data collection and for identifying cracks in pavements or bridge structures and transportation equipment diagnosis.
Clustering	Identifying specific classes of drivers based on driver behaviour, for example.
Planning	AI-based decision support systems for transportation planning as discussed in the sections below.
Decision making	Deciding whether to build a new road, how much money should be allocated to maintenance and rehabilitation activities and which road segments or bridges to maintain, and whether to divert traffic to an alternative route in an incident situation.
Optimisation	Designing an optimal transit network for a given community, developing an optimal work plan for maintaining and rehabilitating a pavement network, and developing an optimal timing plan for a group of traffic signals.

Table 18: Functions of AI applications in mobility services.

German Autolabs	Berlin-based start-up German Autolabs use AI to enhance the comfort and safety with which drivers can operate the messaging, navigation and entertainment functions of their vehicle.
FiveAI	FiveAI is using the power of autonomy to transform Europe's cities. Based in the UK, the company is developing a fully autonomous shared transport service through AI. The service will enable communities to access mobility in minutes, on demand, and will complement existing public transport, cycling and walking in cities.

Table 19: European examples of AI applications in autonomous vehicles

6.2. AI APPLICATIONS — AUTOMATIC PASSENGER TRANSPORTATION

Self-driving cars

By 2020, it is projected to have 10 million self-driving cars on the road. Companies like Tesla, Mercedes, BMW have released, or are set to release autonomous cars[22]. A majority of companies are running their pilot projects, striving to make self-driving vehicles flawless and safe for passengers. As this technology evolves, self-driving vehicles will gain mass confidence and become mainstream in the consumer realm[97].

- **Automated valet parking**

Through communication of the parking garage with the vehicle, cameras and sensors in the garage can help depict free parking spots, while the car can autonomously navigate and park itself in the designated parking spot[98].

- **Driver assistance systems**

Vehicle assistance systems run with AI models can support drivers by taking over tasks such as adjusting the car's speed to that of surrounding cars, detecting obstacles, steering or braking (Level 2 Autonomy).

The in-vehicle infotainment systems with AI are able to be controlled via simple voice commands and hand gestures [99]. The autonomous car will be transformed from a transportation device to a moving information or entertainment centre. The connected car will have insights, not only about its environment but also about its passengers. It will be fully aware of the explicitly stated or implicitly identified preferences of the passengers and will combine this knowledge with the 'understanding of the situation' associated with the trip, in order to promote relevant content[100].

- **Driver monitoring**

AI software not only is able to identify individual drivers – adjusting vehicle settings to their preferences (seat position, temperature, mirrors, etc.), but also able to monitor the driver's capacity to operate their vehicle, by measuring eye openness, head position, and other indicators of alertness. If necessary, the system warns the driver to regain focus, or take a break. In case of accident, posture management allows the best possible deployment or air-bags to reduce injury[32].

Driverless buses

AI is poised to disrupt public transport. Using sensors, cameras, GPS technology, and AI, these buses are capable of carrying passengers to their destination. Driverless buses can be seen in the streets of Europe. The world's first driverless bus was introduced in the French city of Lyon back in 2016. In 2018, Stockholm introduced driverless buses which could travel at 20 mph[101]. Small scale autonomous bus trials have been initiated all over the world in recent times most prominently in

Sensible4[106]	Sensible 4, located in the Helsinki area, Finland, designed GACHA, the World's first self-driving shuttle bus for all weather conditions in cooperation with MUJI. GACHA was made for everyday use for people around the world. It offers smart, safe and sustainable on-demand transportation all year round.
Applied Autonomy[107]	Applied Autonomy delivers knowledge, solutions, and services for sustainable autonomous transportation. The company offers services for piloting and testing of autonomous vehicles and develops the necessary control centre systems for implementation and operation of autonomous traffic. The company has set up operations for Europe's first on-demand bus service using a self-driving bus in Trondheim.

Table 20: European examples of AI applications in driverless buses

NEVS	Founded in 2012 in Sweden, NEVS design premium electric vehicles and mobility experiences that are simple, engaging and distinctive, but that also shape a brighter, cleaner future for all. They build on their strong heritage of Saab cars. Through the partnership with the Autonomous Vehicle start-up AutoX, the companies hope todeploy the first large scale Ro otaxi pilots in Europe by the end of 2020[109].

Table 21: European examples of AI applications in autonomous taxis.

eVTOL vehicle (Lilium)	Lillium's all-electric, vertical take-off air taxi transported 5 passengers and flew autonomously using AI. Thereby, it aims to offer autonomous on-demand air travel in urban areas in the future.
Volocopter	Volocopter is building the world's first sustainable and scalable urban air mobility business to bring affordable air taxi services to megacities worldwide. With the VoloCity, the company is developing the first fully electric "eVTOL" aircraft in certification to safely and quietly transport passengers within cities. Volocopter leads and cooperates with partners in infrastructure, operations, and air traffic management to build the ecosystem necessary to "Bring Urban Air Mobility to Life'" In 2011, Volocopter performed the first-ever manned flight of a purely electric multicopter and has since showcased numerous public flights with its full-scale aircraft. The most notable have been the public test flights at Singapore's Marina Bay in October 2019 and the world's first autonomous eVTOL flight in Dubai 2017. Volocopter is also developing products for the logistics and precision agriculture space with their VoloDrone. Founded in 2011 by Stephan Wolf and Alexander Zosel, Volocopter has 150 employees in offices in Bruchsal, Munich, and Singapore. The company is managed by CEO Florian Reuter, CTO Dr. Arnaud Coville, CFO Rene Griemens, and CCO Christian Bauer, and has raised a total of 122 million euro in equity. Volocopter's investors include Daimler, Geely, DB Schenker, Intel Capital, Team Europe, btov, Micron, Mitsui Sumitomo Insurance Group, TransLink Capital (Japan Airlines and Sompo Japan Insurance), MS&AD Ventures, and Manta Ray Ventures.

Table 22: European examples of AI applications in flying drones taxis.

Finland[102], Singapore[103] and China[104].

The global non-uniformity in built-up structures,city infrastructures, road surfaces, weather patterns, traffic patterns etc. make AI applications in autonomous trucks for on-time delivery of people and packages, highly environment specific[105].

Autonomous taxis

Autonomous taxis have already started operating in Tokyo. However, for safety reasons, as of now, the driver sits in the car to take control of the taxi during an emergency situation. Autonomous taxi aims to reduce cost for taxi services and can be helpful in increasing the public transportation modes in remote areas[108].

Flying drone taxis

Pilotless helicopters present a unique solution to combat the carbon emissions, eliminate traffic congestion, and reduce the need for expensive infrastructure construction plans. Drone taxis will help people reach their destination much sooner, minimising commute time. Companies like Amazon are thinking about staring drone delivery for its customers, Boeing is also working on developing flying taxi of project[110]. The recent demonstration of an autonomous aerial vehicle in China,

Daimler Trucks	In 2014, Daimler Trucks presented the Mercedes-Benz Future Truck 2025, the world's first automated truck. Unlike systems that only work within a specific speed range, Daimler Active Drive Assist Systems gives the driver access to semi-automated driving at all speeds for the first time in a series production truck. Active Drive Assist builds on previously lane-keeping and proximity control systems—it brakes if the truck gets too close to a vehicle driving in front and accelerates again until a set speed is reached. It also actively keeps the vehicle in the lane. If the vehicle is leaving its lane unintentionally, Active Drive Assist System intervenes and independently steers the vehicle back into its lane.
Einride	In Sweden, Einride AB has created vehicles in the name of Einride pods. The pods are electric trucks remotely controlled by drivers and are made without a driver's cab. The company recently announced its intention to hire it's first remote autonomous truck operator, making truck driving an entirely new role. They assert the operator will be responsible for remote control driving of the Einride Pod, and training will incorporate safety and security protocols, basic remote driving instruction, and an extensive understanding of the technology behind the system. Multiple vehicles can be operated by one operator, monitoring them when in autonomous mode and taking active control of a vehicle for unforeseen or more complicated manoeuvres, such as parking at a loading dock.
DAF Trucks, Daimler Trucks, Iveco, MAN Truck & Bus, Scania and Volvo Group Iveco	As part of the world's first cross-border initiative with smart trucks, six 'platoons' of semi-automated trucks have completed their journeys from various European cities, reaching their final destination of the Port of Rotterdam on 6 April, 2016[112].

Table 23. European examples of AI applications in autonomous trucks.

Yara International	The vessel YARA Birkeland will be the world's first fully electric and autonomous container ship, with zero emissions. KONGSBERG is responsible for development and delivery of all key enabling technologies including the sensors and integration required for remote and autonomous ship operations, in addition to the electric drive, battery and propulsion control systems.
KONGSBERG	The UK's Automated Ships Ltd (an M Subs Ltd subsidiary) and Norway's Kongsberg Maritime have signed a Memorandum of Understanding to build the world's first unmanned and fully autonomous ship for offshore operations. In January 2017, Automated Ships Ltd contracted the 'Hrönn', which was designed and built in Norway in cooperation with KONGSBERG. Sea trials took place in Norway's newly designated automated vessel test bed in the Trondheim fjord.

Table 24: European examples of AI applications in autonomous ships.

where 17 passengers experienced smart air mobility for the first time, is a great indicator of similar future applications.

6.3. AI APPLICATIONS — "ROBOTIZATION" OF LOGISTICS

Autonomous trucks [111]

- **Unmanned last-mile delivery vehicles**

Unmanned ground vehicles can use AI to autonomously deliver packages from distribution centres to the end customer. The last mile delivery robot can help take over the last step in the delivery process. Costs and time can be saved, and road security increased by autonomous trucks.

- **Route optimisation**

Neural networks help logistics companies in planning trips optimally, so that the number of empty runs is minimised. This helps to save time, money and CO_2 emissions and increases the productivity of the trucks.

- **Platooning of trucks**

A number of trucks create a convoy on the highway using a vehicle-to-vehicle communication, sensors to detect the surroundings and autonomous driving functions. Thereby, costs can be saved due to lower gas consumption and road safety can be increased.

Cargo transportation — Crewless Ships & Railway

Railway systems can be optimised by using sensors that are placed on the switches of the rails and collect real-time data. The data is analysed by an AI, which helps to predict possible failures of railways and decrease costs and system downtimes.

AI is used to create crewless cargo ships for safely transporting cargo. Rolls Royce has partnered with Google to create autonomous ships. The idea is to replace the jobs of 20 plus crew members and let the ship take care of all the tasks. These ships will have sensors that will track ship engine performance. Loading and unloading of the cargo will also be done without a human workforce. The technology will make shipments faster, and ships will not get lost in bad weather[113].

Predictive planning

AI can be used to predict the demands of goods. Thereby, supply chains and truck allocation can be optimised, and costs can be saved by avoiding an over or under-supply of goods and adjusting inventories to the demand.

Be-Mobile	Founded in 2006 by CEO Jan Cools, Be-Mobile started collecting Floating Car Data to aggregate into real-time traffic information for automotive, navigation, TV, radio, apps and more. Today, Be-Mobile has become an all-round specialised smart mobility company offering a solution for every player in the mobility industry – from logistics companies, tolling operators, OEMs and government agencies to port authorities and parking operators.
Siemens Mobility	In Hagen, Germany, Siemens is using artificial intelligence to optimise traffic light control and reduce the waiting time at an intersection. Simulations suggest it can decrease waiting times at lights by up to 47% compared to a traditional pre-timed signal plan[118].
Mobile apps	AI-powered real-time traffic updates through services such as Google Maps or Waze. By using location data collected from users' smartphones, these apps are able to predict and analyse traffic conditions in your local area so as to better inform your travel plans.

Table 25: European examples of AI applications in traffic prediction.

Kavalir	Ljubljana's electric-powered vehicles referred to as Kavalirs ("Gentle Helpers") are a free city centre public transport option friendly both to people and the environment. Kavalirs, mainly intended for the transport of the elderly, mobility-impaired people, and visitors, run around the pedestrianized historical city centre at a speed slow enough to allow you to hail them anywhere on the street. Telephone ordering is also an option.[120]
Tele-Bus on-demand transport	The municipality of Niepołomice (near Krakow, Poland) wanted to make its public transport routes more efficient and convenient for users, whilst also driving down costs and emissions by reducing the number of unnecessary journeys. Their solution was the Tele-Bus system, an on-demand bus service, with no regular routes or timetable, operating within three districts with low population densities. Users can request a journey between any two of the 77 stops in the coverage area, up to 30 minutes before required departure. The main user groups are commuting workers, students and elderly people, and despite some initial opposition to cancellation of traditional bus services, the DRT system now has an average of more than 3,500 users per month, growing from around 300 when the system was launched in 2007, thanks to ongoing communications efforts and a focus on good service.[121]

Table 26: European examples of AI applications in on-demand transport.

6.4. AI APPLICATIONS — TRAFFIC MANAGEMENT OPERATIONS

Traffic management on the ground[114]

AI can plot a trajectory that will 'beat' the traffic by avoiding congestion where it is most likely to occur. AI can be applied to freshly emerging traffic incidents, providing the driver with the best options to avoid not just unexpected traffic jams, but also the alternative routes most likely to clog up by displaced traffic. AI can optimise logistics using historical and real-time data, do smarter route planning by considering historical and real-time data on road condition, weather, traffic, wait time, maintenance stops, and more[115].

- **Forecast traffic and optimise logistics**

AI's processing, control and optimisation capabilities could be applied to traffic management and decision-making systems to enhance and streamline traffic management and make our roads smarter. For example, smart traffic light systems can manage the traffic more efficiently which can save a lot of money.

Also, AI can process complex data and suggest the best route to the drivers[116]. Using data analytics in logistics provides a data-driven view on routes and driver behaviour, upgrades the transportation planning process, saves resources, and increases safety[117].

- **On-demand bus services**

On-demand bus services operate under flexible schedule and routes and aim to provide on delivering the door-to-door convenience of taxis at a fraction of its costs along with the efficiency of the bus model. There are many attempts and trails are happening around the world to improve the conventional bus service efficiency, and to provide convenient service to users[119].

- **Vehicle tracking on transport networks**

An Automatic Vehicle Location (AVL) system has been introduced to improve operational efficiency of public transport, manage operational control and enhance overall quality of public transport services. This system is able to extract data to track transportation units in real time by using GPS signals, detect problems to inform vehicles on any changes and manage alternative routes. It also provides information to passengers via mobile Apps[32].

- **Shared Mobility**

Shared mobility is benefited by the AI technology to improve the customer experience and streamline businesses. With the help of Floating Car Data (FCD) procedures, car-sharing providers can analyse data to detect movement patterns and predict demands. Deployment of the cars can thereby be optimised, and utilization of cars can be increased. In addition, the Uber has introduced route-based pricing, which uses AI to predict how much riders are willing to pay based on the parameters such as destination, time of day and location. Moreover, the Uber operators are using AI to identify the fraudulent drivers and prevent fraudulent activities. The future of shared mobility

Cagliari's AVL	AVL based GPS system implemented in Cagliari city in Italy. The AVL control centre receives real time data for the location of buses every 30s these data are used for three purposes: ▪ Enhance the reliability of buses' services; ▪ Prioritise movement of buses at traffic signals; ▪ Provide information to passengers about the schedule of the bus near bus stops

Table 27: European examples of AI applications in vehicle tracking.

Frankfurt Airport	German airport operator Fraport has started using a new predictive runway arrival time technology at Frankfurt Airport to improve the estimated arrivals and departures for the 1,500 flights that take off and land at one of Europe's busiest airports. Developed by FlightAware using its Firehose application, the new predictive runway technology provides estimated landing times based on statistical analysis of the trajectories and time stamps of the hundreds of thousands of flights managed by the company's web-based flight tracking platform. Using a proprietary data processing application, the predictive aircraft landing time technology uses machine learning models to predict when a flight will actually touchdown on one of Frankfurt's runways.[125]

Table 28 European examples of AI applications in air traffic management.

L'olivier Shift	L'olivier – assurance auto, an auto insurer and French subsidiary of the English group Admiral, a European leader in automobile insurance, is joining InsurTech Shift Technology to fight against car insurance fraud. L'olivier's professional teams are already working closely with Shift's data scientists in numerous workshops: it is the combination of the insurer's expertise and Shift's data processing capacity that makes the Force model unique. As well as the insurer's data (claims data, contracts, survey reports, among others), Shift recovers and analyzes external information such as meteorological data, satellite images or even web data. These data increase the appraisal abilities of the AI model, thanks to the creation and balancing of new variables, allowing potential fraud to be reported in a very precise manner. [127]

Table 29: European examples of AI applications in car insurance.

is even pictured with driverless cars, which uses AI and sensor technologies[33].

Traffic management in the air[122]

Aviation AI has been acknowledged to manage the flight journey more effectively, such as intelligent maintenance and flight route optimisation [123].

- **Fuel planning and optimisation**

AI helps airlines to save money and decrease CO_2 emissions due to optimised fuelling of airplanes. Based on route distance, weather conditions, aircraft types, altitudes, and further data, it predicts the optimal amount of fuel needed for a flight.

- **Prediction of flight movements**

AI can be used to predict flight movements and provide benefits, such as, increasing safety when an airplane is landing, helping the pilot to avoid deviating from the pre-determined route, minimising fuel cost, and enhancing air control management.

AI can process real-time airplane data, historical records, and also the weather information. On-the-spot computation will help in the revelation of hidden patterns, which can help the air transport industry glean useful insights on other possibilities that can cause flight delays and cancellations. This data can also be forwarded to passengers to help them plan schedule accordingly[124].

- **Predictive maintenance (airplanes)**

Airlines can decrease delays and flight cancellations and increase safety significantly by using predictive maintenance for their airplane fleet. Increase safety of the plane by checking the engine on-board using the Probabilistic neural network (PNN). Detect aviation turbulence more accurately.

6.5. AI APPLICATIONS — INSURTECH[126]

Car insurance companies will be significantly impacted with the development of autonomous cars. The transition to the new era requires new processes, new insurance products, legal adaptation and new models to estimate risk. In the case of an accident, the connected car will be able to signal the local authorities for help, and also automatically report its state, the conditions under which the accident happened, and all the parameters needed. This will enable involved parties, including insurance companies, to minimise the effort required to analyse the incident, coordinate the activities and conclude on responsibilities and claims.

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7. AI APPLICATIONS IN THE HEALTHCARE SECTOR

From hospital care to clinical research, drug development and insurance, AI applications are revolutionising how the health sector works to reduce spending and improve patient outcomes[128]. The total public and private sector investment in healthcare AI is stunning. The global market is expected to reach €5.37 billion by 2021. Accenture predicts that the top AI applications may result in annual savings of €122 billion by 2026. These benefits will accrue incrementally, from automated operations, precision surgery, and preventive intervention, but within a decade they will fundamentally reshape the healthcare landscape.

EIT health report shows that since 2010, $8.5 billion of VC funding has been invested in the 50 best-funded AI companies in healthcare[129]. McKinsey looked at where AI is currently being used in healthcare business operations, finding the greatest adoption rates in areas.

7.1. AI HEALTHCARE IN EUROPE

EU public healthcare systems hold a treasure trove of healthcare information at the population level that, if linked, could provide distinctive advantages in speeding up AI adoption and impact in healthcare. Private investment in Europe is increasing fast, albeit from a smaller base than the US. On another note, EU countries have significant research strengths, with established digital and innovation clusters and collaborations at the regional and pan-European level and, as we saw AI-related healthcare research and trials are on a par with the US[132].

Despite great interest in AI among the survey group, 44 percent of the healthcare professionals have yet to experience deployment or development of AI solutions in their organisation.

European healthcare sector faces a significant workforce gap that is only expected to widen. The World Health Organisation estimates overall demand for healthcare workers to rise to 18.2 million across Europe by 2030 and, as an example, states that the current supply of 8.6 million nurses, midwives and healthcare assistants across Europe will not meet current or projected future need. The impact on the workforce will be much more than jobs lost or gained – the work itself will change. The final effect on the workforce will be the introduction of new professionals. Multiple roles will emerge at the i ntersection of medical and data-science expertise.

7.2. AI IMPACT IN HEALTHCARE

Start-up executives put more emphasis on consumer-facing solutions, such as self-care, prevention and wellness, or

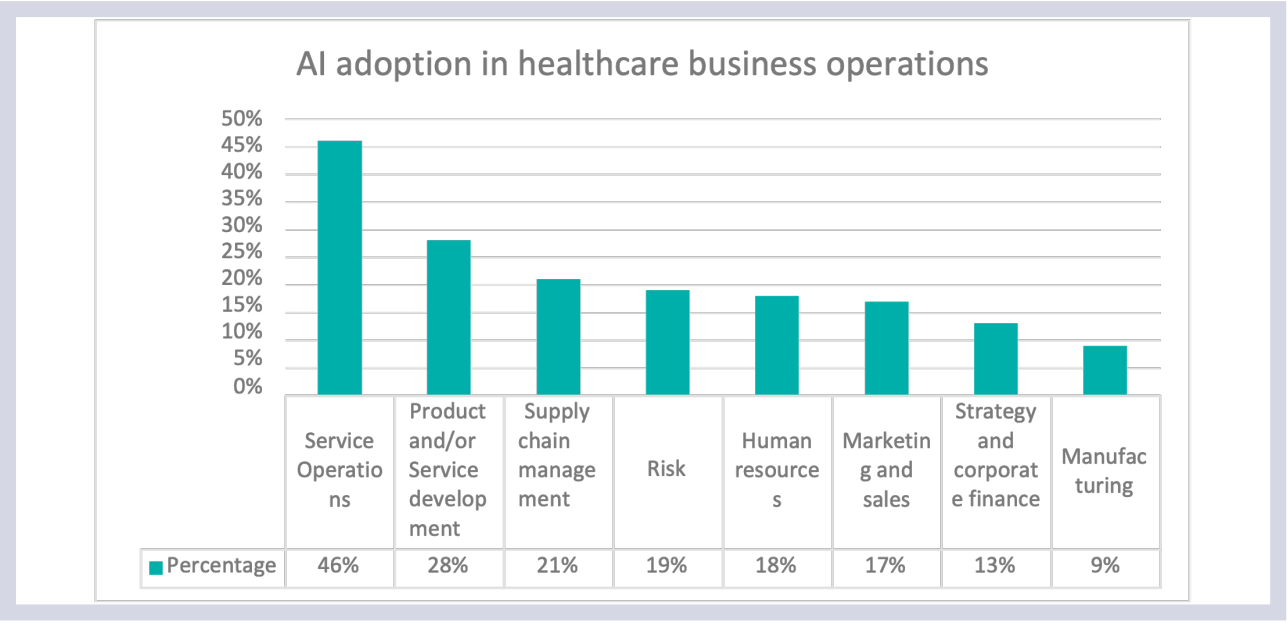

Figure 22: AI adoption in healthcare business operations[130].

Figure 23: Top AI applications in healthcare[131]..

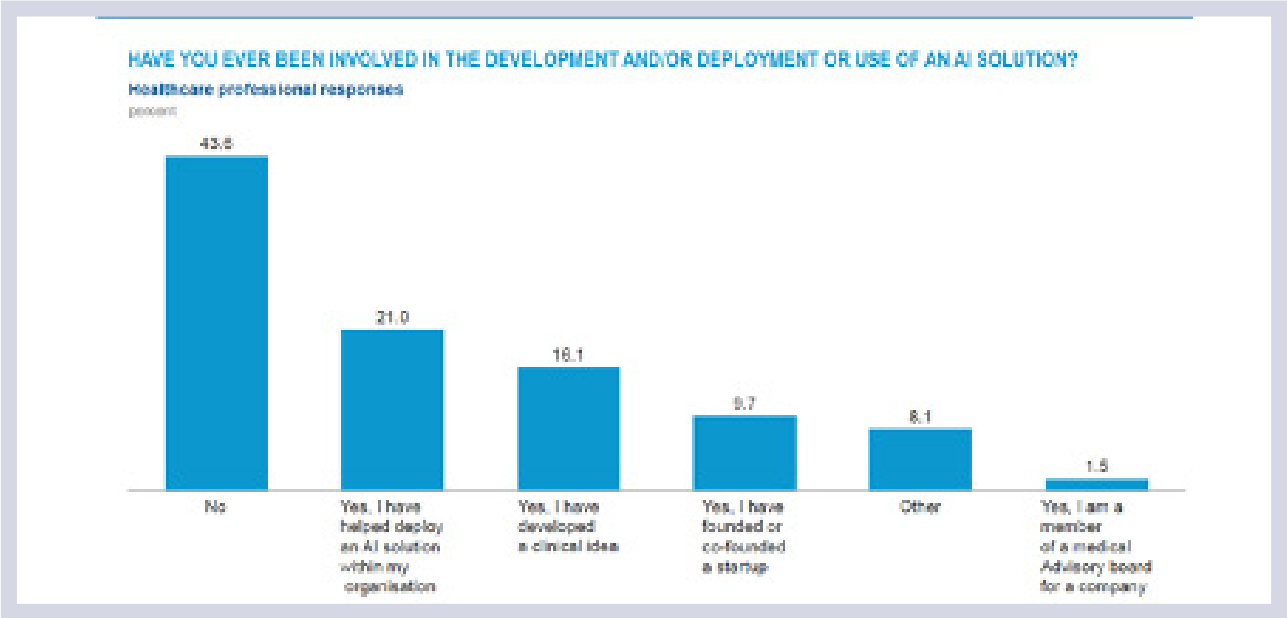

Figure 24: AI solutions' deployment in healthcare organisation[133]

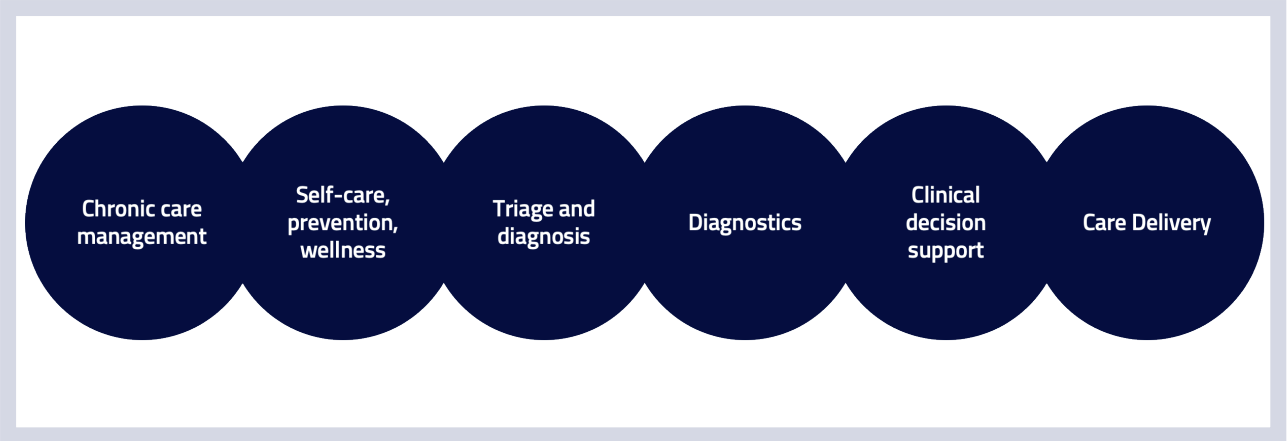

Figure 25: Top AI applications in healthcare[131]..

AliveCor	AliveCor developed KardiaMobile, a personal ECG device that can monitor heart rhythm and instantly detect and flag atrial fibrillation, bradycardia or tachycardia to clinical teams. KardiaMobile is available in 35 countries (13 in Europe) and has been used to record more than 50 million ECGs to date. Devices can be used by patients, nurses or caregivers in situations when a full 12-lead ECG is not required or feasible. As such, they could serve as mobile devices in home-care settings for the monitoring of patients with atrial fibrillation, bradycardia or tachycardia and help reduce a substantial rise across Europe of disabling strokes
Chronolife	Chronolife, an artificial intelligence company specialising in digital health has secured Class IIa medical certification from the European Union for its medical- grade smart T-shirt, KeeSense™. The multi-sensor wearable device continuously monitors electrocardiography (ECG), thoracic respiration, abdominal respiration, skin temperature, thoracic impedance, and physical activity, enabling healthcare practitioners to remotely track vital clinical data about their patients. The platform's receipt of a medical Conformité Européenne (CE) mark allows KeeSense™ to be marketed in the European Economic Area as a wearable medical device for healthcare purposes including remote monitoring of patients with chronic diseases and support for diagnostics[136].
BeWell Innovations	BeWell Innovations is a Belgian digital health and Medtech company, founded in 2010. BeWell commercializes a self-developed GDPR compliant digital patient tracking platform for data acquisition including a kiosk interface for patient self- testing, telemonitoring and a dashboard to stay focused on the patients that require action. BeWell offers hospital-based physicians (health care professionals) a patient platform that assists them to empower people with chronic conditions to live better and healthier lives. Every chronic condition can be managed with the integrated extensive library of carepaths. The products generate data for boosting artificial intelligence and allowing better health outcomes.

Table 30: European examples of AI applications in remote patient monitoring

triage and diagnosis. This partly reflects a consumer orientation and a focus on empowering individuals to take more care of themselves, but also reflects an expectation of faster adoption and the potential to scale AI through this route. AI adoption in these solutions improves population-health management, operations and strengthens innovation.

Self-care, prevention and wellness

- **Enabling remote patient monitoring**

Wellness applications that aim to support people to live healthier are a growing group among all health applications. Consumers can buy directly without a health consultation. There are solutions with AI model to monitor or track health conditions, as well as, to provide personalised plans and guidance based on individual health goals. Moreover, longitudinal data collected from large groups of consumers can be used for population health and studies of triggers for disease onset or deterioration. AI systems have evolved from generating large amount of unprocessed and unorganised data to clinicians for decision making, to assessing the patient's condition and outlook, increasingly involving independent learning components[135].

- **AI for Personalised Care**

Precision medicine is, in some ways, the holy grail of healthcare; AI technologies continue to move towards that goal, helping health systems deliver personalised and contextual care[137].

- **Reducing self-harm**

Online behaviour can provide clues that point to an imminent suicide attempt, AI can also read health records and identify with high probability the likelihood of future attempts. For example, Jvion is specifically focusing on reducing self-harm[140].

Chronic care management

AI solutions help patients to manage their chronic disease on a day-to-day basis and potentially remain independent and stay at home longer. For example, patients with congestive heart disease may be supported by virtual-nurse systems monitoring vital signs and symptoms, ensuring medication is taken and encouraging the adoption of healthy habits by sharing data recorded in the application. Such solutions may be particularly helpful for people with increased frailty or with

Ardigen	Ardigen is a Polish bioinformatics company that combines science with advanced technologies to support Life Science & Healthcare organisations that use huge amounts of data on the way to new solutions for personalized medicine. Ardigen applies its expertise in bioinformatics and artificial intelligence (AI) to areas like genomics and transcriptomics, proteomics, and immunomics, which could help us to make sense of all of this information and speed up the development of precision cancer medicine[138, 139].
Microsoft Sensyne	Microsoft and UK clinical AI company Sensyne Health will use their SENSE clinical algorithms to help provide more personalised care for COVID-19 patients as part of a new agreement with Chelsea & Westminster Hospital. SENSE is a clinical algorithm engine that generates AI algorithms (called SYNEs) for real-time decision support across multiple medical conditions.

Table 31: European examples of AI applications in personalised care.

Infermedica	From Symptom Checker to API, Infermedica develops AI tools for triage and preliminary medical diagnosis. Infermedica tackles the problem of inappropriate use of medical services and misdiagnosis, providing insurance companies, hospitals, and health systems with a set of advanced preliminary diagnosis and triage tools. They provide four different products: Symptom Checker, Call Center Triage, Emergency Room Triage, and Infermedica API[143].
Babylon Health	The company offers an advanced chatbot that can converse with patients and either triage them to over-the-counter treatments or suggest more traditional medical evaluation.
Sensely's Molly	AI-powered virtual nurse Molly not only has instant access to the latest medical and drug knowledge and a direct line to your physician, she is also algorithmically programmed to interact empathetically, detecting a person's emotional state and using machine learning algorithms to respond more effectively and accurately to you over time. Molly currently assists hundreds of thousands of patients globally and can communicate in 32 languages with a customizable avatar and voice.
INF **Robotics and Intuition Robotics** **Start-up**	Prototypes for AI-guided live-in robotic assistants were designed to offer engagement and support to senior citizens. None is yet a full-fledged substitute for a nursing assistant or home health aide. A new class of anticipatory AI agents that can communicate with patients and healthcare providers about a health need based on data or behaviour— before symptoms even begin to show themselves.

Table 32: European examples of AI applications in remote diagnosis.

cognitive impairment or dementia, where a monitoring and alert system could provide enough oversight to allow them to live at home, while knowing that healthcare services could help in a timely manner if needed[141].

- **Remote Diagnoses and Patient Triage**

When faced with acute or perplexing symptoms, patients often seek out emergency care or rush to see a specialist. In healthcare, new technologies are giving patients the knowledge they need to avoid a frantic trip to the Emergency Room[142].

- **Cardiovascular monitoring**

Advanced data analytics and AI lie at the heart of many of the new tools that are allowing patients to take a more active role in managing their health. AI are poised to make a significantly wider range of healthcare options and interventions feasible at the edge where people go about their daily lives[144]. Wearable sensors can already monitor blood glucose levels, temperature and other main vital signs. Drug Monitoring - in the realm of medication management, a host of advances in apps are emerging that allow patients to prevent adverse drug interactions over, and under, dosages.

iRhythm	Digital healthcare company iRhythm has launched its Zio service in the UK to support the identification and clinical diagnoses of cardiac arrythmias such as atrial fibrillation (AF). The Zio system is a small wearable heart monitor that attaches to the patient's chest for a period of up to 14 days – providing monitoring of a patient's heartbeats as they go about their daily lives, including showering, sleeping and exercising. Underpinned by artificial intelligence (AI), the Zio patch detects arrhythmias, such as AF without the need for numerous patient visits. Between June and August 2019, iRhythm identified an arrhythmia in 72% of patients that were issued monitors, with nearly one in 10 then going on to be diagnosed with AF[145].
Ultromics	The technology "EchoGo Pro" makes predictions about coronary heart disease (CAD) risk through ultrasound analysis. It does so by analysing the ultrasound images, which is currently the primary test used, by using AI technology to identify disease. The device has been developed by Ultromics, a UK-based health technology firm, and is now CE marked, which allows it to be used across the UK and the EU[146].
Harmonize Health	Harmonize is a turnkey population health management company that sells health outcomes directly to customers and handles all the technological overhead needed to achieve those outcomes. For customers, Harmonize manages patient populations with minimal disruption to daily workflow. For patients, the technology is best-in- class. In the backend, Harmonizes combines a platform for sensors, analytics, and interventional services to deliver on population health goals.
Think Biosolution	Think Biosolution is a digital health technology provider with multiple remote patient monitoring devices and platforms. The Remote Patient Monitoring (RPM) platforms include the wearable QuasaR™ device, App for patients and next-of-kin, HIPAA compliant cloud, EMR compatible dashboard for physicians, and REST APIs for integration. Think Biosolution has developed fifteen remote patient monitoring platforms which include at-home stress monitoring, at-home geriatric care, at-home post-hospitalization care, at-home cardiac care, at-home respiratory care, etc. covers almost all aspects of at-home chronic care.
Sleep Genius	Uses neurosensory algorithms to create sounds that guide your brain through the complete sleep cycle, based on the same science that NASA uses to help astronauts get rest. Even "smart" beds can leverage AI to improve sleep. Smart beds for better rest, which deploy machine learning to monitor players' sleep habits and adjust mattress settings to maximize REM cycles.

Table 33: European examples of AI application in cardiovascular monitoring.

Babylon Health (UK)	Babylon's AI powered chatbot uses NLP to understand symptoms defined in the patient's words and provides relevant health and triage information using algorithms trained on NHS data. It offers an initial diagnosis with possible scenarios and a percentage-based estimate of each being correct. Babylon is also working on a technique, inspired by quantum cryptography, that would allow medical databases to be tapped for causal links.
Mediktor (Spain)	Uses an approach also focused on e-triage and has been validated in a prospective observational study in a tertiary university hospital emergency department.
Ada Health (Germany)	Its system connects medical knowledge with AI and the app compares answers to questions about symptoms to similar cases drawing from extensive clinical literature.
Intermountain Healthcare	Utah-based Intermountain Healthcare uses AI as part of its Precision Genomics cancer treatment program

Table 34: European examples of AI applications in assessing chronic disease.

Brite Health	Brite Health provides an AI platform for clinical trials that improves patient engagement and compliance in clinical trials. The platform's competitive advantage lies in its ability to 'know' patients and classify them based on their needs and preferences, providing them with a uniquely personalised experience to improve engagement, retention rates, and loyalty.

Table: 35 European examples of AI applications in discovering early stage disease.

Triage and diagnosis

- **Assessing and scoring chronic disease risk**

AI can start to tease out the root causes of risk for chronic illnesses by integrating a variety of considerations, from environmental hazards to poor living conditions [147]. These predictions can go beyond conditions into prognostications of the need for healthcare services.

Symptom checkers can help triage patients and provide guidance if the symptoms require additional healthcare resources, which is a promising way to provide direct and immediate access to care. It is also potentially a very effective way for hospital systems to ensure that only patients for whom hospital care is essential actually turn up in emergency rooms[148].

- **Finding early-stage disease**

Given their capacity to come through enormous volumes of patient data, AI can even predict problems before they happen. At Stanford, medical researchers are developing a model to find patients who have a genetic condition that leads to fatal heart attacks at a young age.

Diagnostics

When further clinical work is needed to determine the underlying reason for symptoms, diagnostic AI solutions may help by improving accuracy or saving time. Across the different diagnostic areas, a variety of applications were adopted for diagnostic tests, such as OLO, an AI-enhanced blood testing device that counts blood cells at the point of care. Some medical specialties lend themselves naturally to AI applications, due to their large emphasis on pattern recognition, such as radiology, pathology, dermatology and ophthalmology.

- **Improving Medical Diagnosis**

With the rapid increase of medical knowledge, it is ever harder for medical professionals to keep up to date. AI solutions that retrieve relevant medical knowledge for each patient and present it in a structured way can help the physicians decide on the best treatment option, saving time and leading to a more comprehensive evidence-based decision- making process[149].

- **Detect a disease**

Some doctors spend a lot of time screening patients for disease which is time consuming, while AI could save time.

Arterys	An AI-enhanced medical image-analysis platform with several applications including LungAI for lungnodule analysis allowing for the early detection of lung cancer.
Corti	Denmark company Corti is an AI-powered "co-pilot" for emergency medicine staffers. By listening in on patient interviews, analysing the caller's voice and background noises, and taking insights from historical data and artificial neural networks, the AI is able to understand the context and patterns in criticalconversations. In this way, it can assist emergency medical professionals by alerting them if, say it identifies a heart attack in progress, and making life-saving decisions.
Sight Diagnostics	Israeli company Sight Diagnostics has developed OLO, a point-of-care blood testing device that can perform a full blood count (FBC) using AI machine-vision technology. The device allows a healthcare professional to carry out an accurate test within 10 minutes from a finger prick and requires only minimal training. This makes it suitable for use in primary care settings, emergency departments or outpatients, and settings without a lab. The AI technology interprets multiple images of a small blood sample producing an FBC test of similar quality to a traditional laboratory test.

Table 36: European examples of AI applications in clinical diagnostics.

Volta Medical	Founded in 2016 in the south of France by three physicians and a data scientist, Volta Medical is a young med-tech company based in Marseille (France). Volta develops artificial intelligence (AI) algorithms intended for interventional cardiologists. With VX1, Volta Medical's first artificial intelligence software, the manipulation of mapping catheters, the analysis of highly complex electrograms and the treatment of complex arrhythmias are greatly facilitated150.

Table 37: European examples of AI applications medical diagnosis.

IDx	IDx developed an AI solution to detect a disease, which uses a camera, operated by primary care physicians, to take pictures of the eyes. Data uploads to the cloud and undergoes analysis with AI algorithms—usually in less than a minute. The product became the first medical device the FDA has approved that can diagnose a condition without a doctor's interpretation. IDx's detection system gives doctor more time to treat those who actually have the disease. In addition, the system can reduce the cost of exams. IDx is now working on AI for glaucoma, skin conditions and other diseases.

Table 38: European examples of AI applications in disease detection.

Clinical decision support

Electronic health records, patient sensors and medical imagery can provide unprecedented amounts of information that can improve care. AI eliminates tedious data-sorting chores from medicine. It also gives doctors the tools to make faster, more accurate diagnoses and helps them predict problems before they evolve into full-blown emergencies. In addition, doctors can acquire detailed information about patients between visits, so they know just what to do during appointments, without wasting precious face time[151].

- **AI for doctor productivity / efficiency**

More than three-quarters (78%) of physicians experience periodic feelings of professional burnout in 2018. Contributing factors include loss of clinical autonomy, diminished time with patients, and the administrative burdens of updating EHRs[152].

For physicians in acute care, AI's time-saving capabilities can make the difference between life and death. AI can also dramatically streamline the creation of treatment plans for time-sensitive conditions like cancer. Currently, when radiation is proposed, a team of doctors typically takes about 12 days. With AI input, this process can be completed within a day or two. AI's agility in the tricky task of distinguishing organs from each other in images, a process radiologist call "segmentation," is a major factor in this advance. In one study from Philips and Intel, segmentation took place 38 times faster than it would have with conventional methods[153].

- **Streamlined workflow**

Clinical decision support (CDS) systems were conceived as software tools that could link physician observations with EHRs, and theoretically help streamline doctor workflows in real-time clinical care [154]. For example, emerging machine learning tools can predict critical situations before they happen, which helps to lessen the "alert fatigue" doctors experience when working with CDS systems and EHRs.

Dragon	An AI-enabled speech recognition platform, which is built into Clinical decision support systems. Transcription now happens in real time and with improved accuracy. This is saving doctors valuable time and allows them to focus more on patients.
EmpowerMD	Among the products that Microsoft is piloting with UPMC is EmpowerMD, an AI that can listen into and learn from doctor conversations with patients in the hospital room. Today, many doctors barely look at a patient during their brief hospital rounds, tending to focus their eyes on a medical chart instead. The goal of EmpowerMD is to allow a physician to engage fully with a patient during an exam while the AI analyses their communication and makes notes and suggestions in the patient's electronic health record.
Sopris Health	Sopris is a patent-pending digital assistant that uses voice and A.I. to complete documentation tasks for clinicians, typically in less than 45 seconds. The Sopris Assistant is fully automated, completing its work in real time without help from human scribes. No human scribes mean the tool is highly scalable and available at a price point that works for all clinicians - physicians, advanced practitioners and nurses alike.
Human Dx app	Uses machine learning algorithms to crowdsource medical knowledge from more than 10,000 physicians in 80 countries. When doctors are uncertain about a particular diagnosis, they type their working hypothesis into the Human Dx app, along with uploaded, patient-approved images, test results and medical data such as prescriptions and medical history. Next, doctors refer the case either to diagnostic specialists or the Human Dx community at large. Within 24 hours, the Human Dx platform aggregates physician advice into a single report, analyses it and then ranks the most likely diagnoses.

Table 39: European examples of AI applications in doctor productivity.

MaxQ AI	Worked with Intel to develop an AI system that analyses CT scans for head trauma and stroke victims. Speeding up image processing and computing time, it provides results in less than a minute, instead of the usual three to four minutes. That lets doctors get to work quickly on patients with critical needs.
IBM's Watson	Able to deliver actionable insights from genomic data in tumour cells in just 10 minutes—a process that took 160 hours via human analysis.
GE Healthcare	Applying AI's rigor to MRIs, CT scans and PET scans, helping doctors find disease sooner. Earlier treatment means better outcomes and less invasive and expensive carefor patients. By improving radiologists' productivity, AI could also reduce the money spent on equipment by as much as 25%, GE estimates.

Table 40: European examples of AI applications in image processing.

- **Automating clinical records & intelligent dictation**

Dictation is another area that is finally getting a much-needed upgrade with an assist from AI. In the past, physicians would dictate notes into recorders and send them out for transcription, but dictation quality was often spotty, and the expansion of required EHR documentation slowed the process[155]. Natural language processing (NLP) is an area of AI that helps computers understand and interpret human speech and writing. It has great potential for dramatically slashing the administrative burden on physicians.

- **Reduce human error**

Human error is inevitable in medicine. An AI-powered app could help a doctor make the right diagnosis the first time[156].

- **Speed up image processing and data analysing**

By sorting through data quickly and homing in on useful results, AI also empowers doctors to diagnose problems at an earlier stage, when they're more manageable[48]. Pharmaceutical companies and healthcare providers alike are using new technologies to identify and match patients into clinical trials, as well as to identify when a patient may be developing a new health condition, or when their current condition begins to deteriorate.

Care delivery

In care delivery, NLP-based solutions could support practitioners in various areas. Such as nurse-assistant robot. Another potential use of AI in care delivery is in monitoring or treatment devices such as AI-powered artificial pancreas solutions for patients with type-1 diabetes. A third area where AI can support care delivery is patient monitoring in an inpatient setting. Healthcare organisations aim to provide timely delivery of care but emergencies or unexpected changes in schedule can lead to longer waiting times, a poor patient experience, and worse clinical outcomes[157].

Improving population-health management

AI can be used on large datasets to predict health outcomes within a population, which helps health systems focus more heavily on prevention and early detection, improve population health outcomes and, over time, ensure the financial sustainability of the care system.

Using AI to analyse large datasets may prove useful both in healthcare settings and epidemiological studies. AI-powered models based on clinical data from a large population (e.g., patients within a health region, or an integrated provider system) may help identify early risk factors that can trigger preventative actions or early interventions at a system level. They may also be useful in determining what to prioritise during times of staff shortages. Similarly, identifying an increased risk of unplanned hospital admissions could help practitioners intervene pre-emptively to avoid them[158].

In population health research, AI may be able to uncover previously unidentified correlations between factors, for example combining data collected by wearables and health outcomes, which can be investigated together in hypothesis-driven studies with the goal of a better understanding of underlying factors that cause diseases. Such algorithms are already

Blue Ocean Robotics	UVD, the Danish autonomous disinfection robot, can sanitize contaminated areas autonomously, without the intervention of medical staff. The robot uses UVC light and an autonomous robotic base. The UVD mobile disinfection robot developed by Blue Ocean Robotics together with its subsidiary UVD Robots and Odense University Hospital, won the euRobotics Technology Transfer Award 2020.
PAL Robotics	In Barcelona, Catalunya, Spain, the TIAGo Base robot of PAL Robotics can deliver food and it can carry objects such as medication and samples around in hospitals and similar environments. Check everything that PAL Robotics can do to alleviate COVID-19 crisis.

Table 41: European examples of AI applications in care delivery.

Karantis360	UK company Karantis360 has developed an automated, personal monitoring and alerting system that enables elderly people to live independently, ensuring caregivers and families can stay informed. Karantis360 has partnered with IBM Watson and EnOcean to provide a comprehensive solution using AI and Internet of Things capabilities combined with intelligent sensors linked to a mobile device. The device shares information via a web and mobile dashboard and can send reports and alerts to caregivers and family members. The sensors can provide information about the patient's daily routine, e.g., when individuals get up or go to bed, use the bathroom or leave the house. Using AI, the system identifies deviations from typical behaviour that could indicate that something is wrong – such as a fall – and informs caregivers and families about these abnormalities in order to inform the plan of action.

Table 42: European examples of AI applications in population health management.

used in systems that are at least partially integrated across provider settings and on a population-health region basis, or that have shared incentives to deliver population-based outcomes (clinical, operational or financial).

Improving healthcare operations

The use of AI in healthcare may be more readily accepted when it helps free up practitioners from routine, low value-add administrative tasks, to increase direct time with patients. Potential areas for improving healthcare operations include scheduling, hospital admissions, discharge and capacity management, optimising processes in the operating room and the emergency department, as well as moving patients between diagnostics and the ward. Such applications can significantly and directly affect patients by reducing waiting times, and increasing transparency on process, times and outcomes – all of which lead to a better patient experience, as inefficiencies along the patient pathway are ironed out[159].

AI can help hospital improve efficiency and boost hospital capacity. The next-generation "cognitive hospital"—a seamless integration of the physical facility and advanced technologies that optimise resources, streamline operational processes and workflow and, most importantly, improve patient outcomes[160]. With the cognitive hospital, technology is poised to transform not just the tools that physicians use but the hospitals where they use them, making "smart" facilities themselves strategic partners in patient care. The University of Pittsburgh Medical Centre (UPMC) recently announced a $2 billion partnership with Microsoft to create three new, highly specialised "digital hospitals." Microsoft has also joined with Cleveland Clinic to integrate virtual assistant Cortana into its eHospital system.

- **Streamlining scheduling'**

The centre's AI crunches that data to manage patient movement and volume, and trigger interventions to prioritize high-risk cases. Emergency room patients are assigned a bed 30% faster; transfer delays from operating rooms have been reduced by 70%; ambulances are dispatched 63 minutes sooner to pick up patients from other hospitals; and the ability to accept patients with complex medical conditions from other regional and national hospitals has improved by 60%[161].

Not all predictable outcomes come with vital signs or prescriptions. Some just tell you if a patient won't make his or her appointment on time. Predictive analytics has successfully spotted circumstances where a late cancellation or a plain old no-show is the most likely outcome for a given appointment. These insights can help clinics staff and book appointment with more flexibility and better prepare themselves to fill potential gaps.

- **Saving Lives with Sensors**

Among the greatest challenges facing the hospitals of the future will be the management of terabytes of unstructured data generated by IoT sensors, connected devices, and mobile health apps and wearables.

- **Predicting patient decline**

The steady, growing stream of data associated with every patient gives practitioners and AI alike the opportunity to spot health challenges before they fully manifest themselves[162].

- **Reducing hospital readmissions**

Common reasons people return to the hospital include congestive heart failure, mental health issues, septicaemia and surgical complications. Predictive AI can dig deeper and identify social causes for readmission, such as the inability to keep up a post-discharge care regimen or the lack of a safe living space. The Hospital Readmissions Reduction Program (HRRP) is introduced as part of the Affordable Care Act. HRRP measures unplanned returns to the hospital by patients who fall under six broad condition categories, including pneumonia and heart failure[163].

Novartis & Intel	Researchers developed a method that exposes cells representative of a specific disease to many drug candidates simultaneously. A high-quality camera observes these assays, collecting thousands of images of the cells and documenting their reaction to the drug candidates. This method is called high-content screening (HCS). A neural network that Novartis and Intel developed reduces the time required to train an AI system on the images from the HCS process from 11 hours to just 31 minutes. Speed and accuracy are critical factors in drug discovery and development, where a mere 14% of candidates emerge from the exhaustive testing process to gain FDA approval.
VastBiome	VastBiome is a drug discovery company that is leveraging the power of deep learning, distributed supercomputing, and next-generation sequencing to disrupt the drug discovery process. The core technology builds on recent research that describes a central role for the human gut microbiome in directing the host immune system and determining outcomes in many disease indications including autoimmune disease and immunooncology. VastBiome has developed methods to identify, prioritize, and isolate the key bacterial metabolites that drive these outcomes.
BioVista	BioVista The BioVista platform leverages validated augmented intelligence for better biomedical decision-making that enables better, faster, less expensive drug discovery and development. Biovista's AI has ingested much of the world's biomedical data and has organized it and connected it in ways to enable efficient answering of biomedical questions such as: "What else can my drug do?"; "What adverse events am I likely to experience when I enter the clinic?"; and "What patient sub-populations should be included or excluded in my clinical trial?".

Table 43: European examples of AI applications in drug testing.

- **Robotic Surgery with a Human Touch**

A surgeon can track every step of a complex procedure on a monitor in magnified 3D; machine learning applications can correct human hand tremors, ensuring steady, precise motions; a robotic "hand" can access hard-to-reach areas while minimising risk[164]. A robot can dramatically reduce physician fatigue because doctors using the AI-equipped devices are seated during surgery instead of hunched over a patient for hours.

Strengthening healthcare innovation

AI is being applied to many pharmaceutical R&D activities although, as in clinical practice, the opportunities identified are often far ahead of the impact on the ground. Early applications include disease state and target understanding, lead selection and optimisation, clinical dose and endpoint selection, therapeutic tailoring and portfolio management. Applications in development, regulatory and safety support include protocol optimisation, adaptive development plans, trial planning and execution, portfolio management and active safety surveillance. AI is now applied in different elements of the business system in the pharmaceutical and MedTech industries in order to increase the speed to market of new products, reduce costs, enhance clinical outcomes and serve a variety of organisational goals165.

Among the business processes most in need of reform, drug discovery likely is near the top of the list. The average cost to bring a new drug to market is $2.6 billion—and the average time it takes is 10 years. Researchers have been trying to accelerate drug discovery with computers for decades, with limited success. By finding the best drug candidates, shedding new light on disease and crunching an unprecedented amount of patient data, AI is revolutionizing drug discovery and development from start to finish166. By deploying AI capabilities, such as predictive modelling and analysis of sensor data, could generate up to $100 billion in value annually across the U.S. healthcare system.

Start-ups such as Recursion Pharmaceuticals and BenevolentAI are innovating, while big pharmaceutical and technology players are focused on realising opportunities from AI. Big Pharma is also making major investments and partnerships to address opportunities. In 2019, Novartis and Microsoft announced a partnership to apply AI to developing personalised therapies for macular degeneration, cell and gene therapy and drug design; Bristol-Myers Squibb entered a multiyear strategic agreement with Concerto HealthAI to use machine learning to help design protocols for precision treatment; and AstraZeneca announced partnerships with BenevolentAI and Schr.dinger to accelerate drug discovery using machine learning. Sanofi's DARWIN platform, for example, applies AI to anonymised data from the records of 450 million patients to accelerate and deepen insights on treatment effectiveness, safety and value.

Intel's Pharma Analytics Platform	Relieve clinical trial participants of many of their burdens while giving researchers better information. Instead of keeping a journal and visiting a doctor far from home, patients don a wearable connected device that can measure heart rate, breathing, gait and a host of other biometric measures. Data collects in a continuous stream and securely uploads to the cloud, where it undergoes analysis to reveal disease progress and measure the drug's effectiveness in combating the disease. By providing objective data and analysing it in vast quantities, AI can reduce the cost of drug discovery trials and speed time to market for new drugs. It also helps researchers learn more about how drugs are metabolized. In addition, these wearable devices let trial physicians learn about unintended adverse reactions to the drug far quicker than they would if they waited for the patients to visit the doctor again.

Table 44: European examples of AI applications in precision medicine.

Roche's Navify Tumour Board solution, which curates and presents data to promote collaboration and accelerate workflow in tumour boards, also highlights the potential for structuring data in a way that can improve the efficiency of healthcare delivery to develop datasets with consistent formats of high value for research.

- **Reduce drug testing time**

AI can evaluate potential drug candidates exponentially faster and better than humans. A study by Carnegie Mellon and a German university suggests AI could lower their discovery costs by 70%[167]. Computational neural networks are ideal for unearthing those possibilities that stand the best chance of working, including some that scientists may not have considered.

- **Better way to measure drug effect & Precision Medicine**

Medicine has become more and more individualized since the days of leeches and humours, but in the last 15 years, an explosion of patient data in the form of genetic information and electronic health records (EHRs) has sharpened the doctor's picture of the individual patient—and of treatments tailored to their precise needs [52]. By analysing complex genomic data from patients who have the disease, AI allows drug discovery researchers to select participants whose genetic profile suggests they will benefit from the drug candidate undergoing testing in the trial. Then, once trials start, AI helps scientists collect more and better information from patients[51]. ▪

- **Model the diseased protein**

In parallel with identifying strong drug candidates, scientists create a 3D model of the disease protein the drug candidates are designed to fight[168]. The 3D model is used to perform molecular dynamics and "docking" studies to further evaluate the drug candidates. Achieving a 3D model of the diseased protein has, however, traditionally taken place via crystallography.

Over the past several years, drug discovery researchers have started using a new Nobel Prize-winning process called cryogenic electron microscopy (cryo-EM), which can shorten the process of obtaining a 3D model of the disease protein from years to weeks. Other software algorithms, some using AI, then analyse these images to create a detailed 3D model of the disease protein. With the 3D model in hand, researchers can use computers to further study the interaction of the drug candidates with the disease protein. During the recent Zika virus outbreak in Brazil, scientists used cryo-EM to create a high- resolution 3D image of the virus within months, giving them a powerful tool in the search for a treatment.

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8. AI APPLICATIONS IN OTHER SECTORS

8.1. AI IN SECURITY

AI-based tools must develop systems capable of monitoring in real time large amounts of data obtained from the network and perform analysis of security camera images in real time, allowing the detection of attacks on the security of society and businesses. The field of security includes other fields such as the aspect of assistance to groups at risk of exclusion. AI can intervene to improve the safety of these groups through the analysis of social patterns for prevention. Another essential element that is linked to the development of the transport industry is safety[169]. '

- **Cyber Attacks and Software Failures**

The software that powers our computers and smart devices is subject to error in code, as well as security vulnerabilities that can be exploited by human hackers. The need for systems that can search out and repair these errors and vulnerabilities, as well as defend against incoming attacks, has grown out of this urgency, with many projects and eventual companies getting their start in research and/or being funded by the military (i.e. DARPA) and research universities. Automated attacks and so-called "advanced and persistent threats" (APT) carried out by AI systems require developments provided by equally advanced defence systems in AI capabilities.

- **Security & Crime Prevention**

It's worth emphasising that AI prediction tools introduced with the proper precaution sand regulations in place have the potential to lessen or remove human bias as opposed to substantiating its effects. For example, the European Union, through its Horizon 2020 program, currently supports AI-simulated security training efforts through projects like LawTrain, where the next steps are to move from simulation to real investigations that utilise such tools in machine-human collaborations. Predictive analytics and other AI-powered crime analysis tools have made significant strides.

8.2. AI IN ENTERTAINMENT

Currently the aim of AIs like Google's Assistant, AI advancements will soon enable assistant to search and select songs based on users' current and desired mood or movies carefully picked out to bridge users and their friends' watching preferences[170]. AI startups are leaping onto the music scene with creation of novel melodies and underlying beats. For example, Flow Machines is a song writing algorithm already in commission and has been used by numerous musical artists as a creative assistant.

8.3. AI IN EDUCATION

AI can modernize the education systems, presenting new opportunities in Education. The key aspect is that AI techniques enable the application of new educational models oriented to personalised learning. Firstly, students would play a more active role in their learning process by knowing their own evolution and being more aware of how to optimise it. Secondly, it would allow educational and training centres to identify those students who require more support.

The use of AI systems would make it possible to transform education from different technologies, guaranteeing inclusive, renewed and adapted training to the needs of students and teachers according to the preferences, knowledge and individual evolution of the student. For instance, the evaluation and identification of high competences in students (AI predictive models), the treatment of students with functional diversity (learning analytics, adapted AI-based systems), new tutoring models (intelligent tutoring systems), recommendation and feedback systems; prediction of early failure and detection of abnormal students through machine learning systems and the evaluation of competences could be addressed.

8.4. AI IN PUBLIC ADMINISTRATIONS

The use of chatbots based on the natural language processing as the first interface between citizens and Public Administrations already makes it possible to reduce response times and increase the ability to focus public officials on tasks of greater social value. The AI can improve the performance of the Public Administrations is to ensure interoperability between administrations and generate automated administrative procedures where natural language processing techniques and language technologies are essential in the use of co-official languages.

Another sector of the Public Administrations in which the

AI is crucial is that of the National Security Strategies. For example, building information systems that unify criteria, share information and analyse all entries favouring collaboration between the security forces and corps of different countries.

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9. EIT SUPPORTED INNOVATIONS IN AI

AI Thematic Area	AI in Action	EIT Community Support
Health **ALTOIDA** **A smartphone test to predict the onset of Alzheimer disease.** **altoida.com**	The Alzheimer's Disease Prediction Service (ADPS) uses a simple smartphone test to predict the likelihood of the neurodegenerative disease emerging within the next six years. The test claims accuracy of 90%. It will be one of the first commercially available solutions able to predict the risk of Alzheimer's for people over 50 in the EU. The team has conducted longitudinal EU-funded studies at 22 sites with 4,500 candidates. ADPS developer Altoida has been recognised as one of the Rice Alliance's 10 most promising life science companies at the 2017 Texas Life Science.	EIT helped increase the visibility and acceptance of ADPS across Europe. It was also a catalyst for collaboration with healthcare professionals, industry and academia. The company won the EIT Innovators Award 2018
Health **FIBRICHECK** **Stroke prediction in 60 seconds.** **fibricheck.com**	FibriCheck is the world's only medically certified application able to help prevent strokes. It does so by detecting atrial fibrillation and other heart rhythm disorders. Users can measure their heart rhythm simply by placing their finger on the camera of their smartphone. This award-winning application created by Qompium is built around highly accurate, patented measuring and detection algorithms. It can detect atrial fibrillation (AFib) and other common arrhythmias in only 60 seconds.	Winner of EIT Health's European health catapult contest in the Digital health category in December 2017; winner of the Social Care Award at the Arch Summit organised by Vodaphone in May 2018; winner of EIT Venture Award at Innoveit. EU-wide promotion and EUR 50 000 grant in October 2018.
Health **DISQOVER** **Big-data aggregation for better healthcare.** **ontoforce.com**	Disoover is a unique data aggregator to support decision-making in healthcare. The platform facilitates access to information and democratises big data for citizens, hospitals and companies who can easily find the right schools, therapies, doctors, and treatment. Created by Ontoforce, Disqover aggregates data from various sources (public, third-party or private big data). It presents this data on an intuitive platform where it can be easily interpreted and used. Once the system understands the semantics of the data and searches, it automatically generates the correct interface, presenting complex, seemingly unrelated data in a simple, connected manner.	EIT support: EUR 72 000 Funding obtained: EUR8.8 million EIT Health's top prize for digital innovation; EIT Health catapult winner 2016; EIT Health Go Global 2017; EIT Venture Award 2017; EYs scale-up of the year 2018.
Health **Diabeloop-D4Kids**	Diabeloop - D4Kids has developed an automated type-1 diabetes management system specifically for children, taking into account their particular physiology and the fact that they rely completely on adult caregivers. The personalised solution acts as a sort of artificial pancreas, enabling the whole family to live their lives to the fullest while keeping the disease under control. People with type-1 diabetes have to take dozens of therapeutic decisions each day to avoid major health issues. Diabeloop wants to help them achieve better glycaemic control and relieve them as much as possible of the burden of the disease.	The EIT Community has helped Diabeloop - D4Kids foster cross- border cooperation and facilitated the open innovation process in a major way 2019 EIT Innovators Award winner
Transportation and logistics **KONUX** **Predictive maintenance for railways.** **konux.com**	KONUX's smart sensor systems allow industrial and rail companies to reach a new level of asset performance and help digitise the rail industry. The IoT solutions combine smart sensors, data fusion and artificial intelligence-based analytics to increase asset availability and optimise maintenance. Won the EIT Digital idea challenge 2014 in the Cyber-physical systems category; listed in Forbes' 30 under 30 list in 2017; 2017 technology pioneers at World Economic forum; 2018 CogX Award in the 'outstanding innovations in AI: IoT and Sensors' category.	Konux was awarded EUR 40 000 in the EIT Digital idea challenge cyber-physical systems category in 2014. Funding: EUR 51 million in total investment attracted to date

AI Thematic Area	AI in Action	EIT Community Support
Transportation and logistics NAVYA A fully autonomous electric shuttle.	NAVYA of France has produced a 100% electric and autonomous transport vehicle. This innovative and intelligent driverless shuttle can transport up to 15 passengers, safely drive at up to 45 km/h and run for 13 hours between charges. NAVYA joined the EIT Digital Accelerator in 2015 in the Urban Life & Mobility Action Line to help grow its business, find customers and attract investment.	EIT Digital helped the scale-up to raise funds by introducing it to investors (EUR 4.1 million in 2015. EUR 30 million in 2016)
Transportation and logistics **AWARD** **Automated warehousing and last-mile delivery.** **brightcape.nl/owl**	The AWARD platform increases efficiency of the logistics process from warehouse to last-mile delivery. The easy to implement solution uses intelligent planning algorithms, machine learning and smart robotics (i.e. drones and AGVs). The AWARD solution will be able to coordinate a fleet of autonomous vehicles using advanced planning and scheduling techniques to improve productivity and reduce the costs of logistics operators in dealing with movement of goods within a warehouse and in preparation for last mile delivery in areas where traditional solutions are expensive. Further developments in 2019 include integration with AGV and unmanned aerial vehicles for last mile delivery.	This is an innovation project of EIT Digital with a budget of EUR 825,663 in 2019.
Transportation and logistics **ENWAY** **Driverless street sweepers.** **enway.ai**	Thanks to AI, Enway's robots increase the efficiency of sweeping operations compared to manual vehicles. The use of this technology is expected to accelerate the cleaning process, provide better results, and reduce operating costs by 65 %. The company already operates trucks across Germany thanks to a partnership with EAD Darmstadt (waste management services). In 2019, Enway plans to introduce its city sweepers in Singapore and Scandinavia. European Transportation Innovator prize by the European Union, as an innovative start-up in the transport sector, in 2017; AI Start-up of the year by the Deep Berlin Community in 2018; Top 100 most innovative start-ups of Germany by The Hundert Magazine (Volume 11, 2018).	EIT support: EUR 45 000 EIT Climate-KIC Accelerator Award in 2017
Waste management **ZRR** **Smart Waste Sorting Robot.** **bitly/2N6aBv9**	The "ZRR for Municipal waste" project aims to evaluate the performance of ZRR, a robot from Finnish start-up, ZenRobotics, that continuously monitors waste flows by means of sensors. An AI module analyses the information captured by sensors in real time, while the robot's articulated arms pick waste items of different shape, size and materials with a speed and precision of up to 6,000 picks per hour (three arms). Robotics in waste management is expected to remove the need for long conveyor belts to separate waste mechanically and manually in waste-treatment plants. The robot has been installed at the Ecoparc 4 waste treatment plant in Els Hostalets de Pierola, a municipality close to Barcelona. The installed unit features two robotic arms and will initially be trained to identify up to 13 different materials.	EUR 488,441 and partners co-funding EUR 488,445
Environment **Leaftech**	Leaftech examines a building and develops a digital twin to generate a thermal building model. By feeding that model with weather insights, energy usage patterns and user behaviour, Leaftech anticipates future energy and comfort demands. The analytic results transform the smart home and building automation systems from reactive to proactive control. Leaftech combines Building Information Modelling, 3D-City models and satellite scans to set up the digital twin. The intel Leaftech collects is assembled and merged in an automated process and linked to user data and weather APIs. Leaftech's processes are designed in the leanest way possible to keep the services fast and efficient without compromising on quality data.	2019 EIT Change Award winner

Table 45: EIT supported innovations in AI.

10. CONCLUDING REMARKS

The rapidly developed technologies, such as AI and IoT, are leading us to the Fourth Industrial Revolution, completely different than the previous three. Thanks to those advanced technology, the way we live, work and relate to one another will be exponentially changed. AI can collect and organise large amounts of information to make insights and guesses that are beyond the human capabilities of manual processing. Machines are connected and interacted, analysing the entire production chain and make decisions autonomously which is leading to further advancements in business.

The widespread adoption of AI raises ethical challenges, while there is no globally agreed set of standards. Europe is the largest and most diverse region with high levels on international collaboration within the field of artificial intelligence research. EU's AI strategy focuses on ensuring 'humans remain at the centre of AI development, and to prevent the harmful creation and use of AI applications, EU intend to be a leader in 'ethical AI'.

There are different AI business models based on the nature of the company (AI developers & AI adopters) but two major business models emerge when systematically scanning the current AI applications across sectors. They are the model of providing AI Application-as-a-Service (AIA-a-a-S) and AI Infrastructure-as-a-Service (AII-a-a-S).

For AI Application-as-a-Service, AI technology start-ups develop applications for specific use cases defined by their customers and provide AI applications that could be integrated with other components. Such AI applications are priced by transactions and completed computations, i.e. per study or monthly subscriptions.

For AI Infrastructure-as-a-Service, AI technology companies provide computational services including both infrastructure for computing power and pre-trained algorithms. Typically run by leading AI global firms with rich resources, AII-a-a-S charge customers based on API calls.

AI driven business models could sometimes be assessed as data driven business models (Brownlow, 2015). Data collaboration became very common among AI related companies regardless of companies' size. Some company may decide to partner with AI development start-ups specialised in tailored-made solutions through a revenue-sharing business model. They both agree to build a PoC and if it works, they share the benefits.

Our survey with XKIC AI partners strengthened our understanding of usage of data, algorithms, business model and application of AI in the current EIT ecosystem. We received over sixty responses from XKIC AI partners affiliated with EIT Climate, Manufacturing, Urban Mobility and Health. The survey results suggested that although recognising significant benefit potential from industrial and enterprise AI solutions, the AI development and deployment is still at an early stage with much room for improvement in EU. The biggest barriers in deploying AI solutions were lack of technical feasibility, lack of data availability & quality, and budget constraints. Cybersecurity, compliance, personal privacy was raised as three top risks by XKIC AI partners.

To drive AI value in EIT ecosystem, our responders recommended three main actions: (1) showcasing use cases of AI application; (2) increasing funding for AI tech; (3) EIT to participate in AI ecosystem/hubs/centres of excellence.

This report further explores existing examples of AI applications across Climate, Manufacturing, Mobility, and Health sectors in EU. Not surprisingly, a growing number of AI companies are emerged and AI technologies have almost penetrated into each sector. For example, AI mobility services is going to reform passenger experience through the deployment of automatic vehicles and buses, and largely improve road efficiency by advanced traffic management operations as well as robot logistics. Healthcare is one of the most important sectors benefiting from AI's rapid development. Applied to large data sets, AI can identify new drug solutions, enable selection of candidates for clinical trials and monitored patients with specific conditions; AI can also enable remote patient care, increase diagnosis accuracy, improve hospital efficiency etc.

In summary, to be successful in the age of AI, companies demand new competencies, including the vision to embrace AI and a shift in mindset; data sets to train and deploy AI algorithms; the ability to diligence AI partners effectively; the ability to manage work-flow changes; the ability to manage challenges of organisational design and culture.

There is a great deal of work to be done to establish a common understanding on how, when and why AI should be used. We envisage the AI Impact project would be built on the work in 2020, and enhance EIT's position in leading AI ecosystem creation through the following actions:

- Create a back end database to capture evolving AI applications with proven business models
- Create an online platform showcasing those AI technology applications (some of them have been mapped in 2020)
- Encourage partners to continuously update their cases in the database, and facilitate an online business ecosystem for AI technology applications
- Use the online presence to demonstrate European leadership in building AI-driven businesses
- Leverage the platform to enable close interaction and engagement among EIT AI communities, including both SMEs, incumbent and academia
- Establish the wider EIT European AI ecosystem by incorporating synergies with other European-wide initiatives (i.e. European AI Alliance)

Ongoing, EIT XKIC will engage with the AI Alliance to support the technological, ethical, legal and socio-economic aspects that boost EU's research and industrial capacity in AI, and to put AI at the service of European citizens and economy. In particular, it seeks to ensure that policies are in place to secure each EU citizen during this initiative.

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Dr. William Wu

EIT Urban Mobility
Barcelona, 30th December, 2020

ANNEX 1

Table 46: AI companies in health (Source: MC (2020), Top Healthcare AI Companies in Europe. https://mc.ai/top-healthcare-ai-companies-in-europe/).

1. AI in Drug & Medicine

Functions	Origin	Company	AI Solution
Reduce drug testing time	Switzerland	Novartis & Intel	Researchers developed a method that exposes cells representative of a specific disease to many drug candidates simultaneously. A high-quality camera observes these assays, collecting thousands of images of the cells and documenting their reaction to the drug candidates. This method is called high-content screening (HCS). A neural network that Novartis and Intel developed reduces the time required to train an AI system on the images from the HCS process from 11 hours to just 31 minutes. Speed and accuracy are critical factors in drug discovery and development, where a mere 14% of candidates emerge from the exhaustive testing process to gain FDA approval.
	US	VastBiome	VastBiome is a drug discovery company that is leveraging the power of deep learning, distributed supercomputing, and next-generation sequencing to disrupt the drug discovery process. The core technology builds on recent research that describes a central role for the human gut microbiome in directing the host immune system and determining outcomes in many disease indications including autoimmune disease and immuno-oncology. VastBiome has developed methods to identify, prioritize, and isolate the key bacterial metabolites that drive these outcomes.
		BioVista	The BioVista platform leverages validated augmented intelligence for better biomedical decision-making that enables better, faster, less expensive drug discovery and development. Biovista's AI has ingested much of the world's biomedical data and has organized it and connected it in ways to enable efficient answering of biomedical questions such as: "What else can my drug do?"; "What adverse events am I likely to experience when I enter the clinic?"; and "What patient sub-populations should be included or excluded in my clinical trial?".
		SaliencyAI	SaliencyAI enables pharmaceutical companies to leverage artificial intelligence in their R&D. They provide a suite of tools that streamline each step in the data science pipeline for pharmaceutical companies: 1. Data Labeling; 2. Data Unification; 3. Training artificial intelligence models; 4. Deployment Empower your teams with user-friendly research tools backed by AI. Automatically convert trained models into intuitive web apps that are HIPAA- compliant. SaliencyAI focuses on the requirements of AI development and deployment that are specific to the pharmaceutical industry. This includes special focus on data security, HIPAA compliance, and algorithms designed to perform well on biomedical data. Meeting this industry's specific analytics needs requires a nuanced understanding of both biomedical research and data science. Their combined expertise spans AI, computer vision, software architecture, and medicine, placing them in a unique position to address these needs.
		Owkin	Owkin combines life-science and machine learning expertise to make drug development and clinical trial design more targeted and more cost effective. Owkin's machine learning algorithms create models that predict disease evolution and treatment outcomes. These predictive models are used for enhanced analysis, surrogate endpoints, patient stratification and selection, and subgroup identification. The impact of this research is faster discovery of better treatments at a lower cost. To train its models, Owkin has developed a real-world data access network through collaborations with top tier hospitals. This network is the first at-scale solution for federated on-site machine learning for the healthcare industry. Through this network, Owkin can interrogate heterogeneous real-world data, while preserving patient privacy. Owkin works hand in hand with world-class clinicians to interprets its models' features to discover and validate novel multimodal biomarkers. Owkin has launched an AI-powered network comprised of 44 hospitals and research institutions in the United States and Europe. Members include Cleveland Clinic, Mount Sinai and Groupe AP-HP, a group of 39 hospitals in France.
Measure drug effect & Precision Medicine	US	Intel's Pharma Analytics Platform	An edge-to-cloud artificial intelligence (AI) solution that enables remote monitoring to continuously capture clinical data from study subjects using a variety of sensors, including wearable devices. Relieve clinical trial participants of many of their burdens while giving researchers better information. Instead of keeping a journal and visiting a doctor far from home, patients don a wearable connected device that can measure heart rate, breathing, gait and a host of other biometric measures. Data collects in a continuous stream and securely uploads to the cloud, where it undergoes analysis to reveal disease progress and measure the drug's effectiveness in combating the disease. By providing objective data and analysing it in vast quantities, AI can reduce the cost of drug discovery trials and speed time to market for new drugs. It also helps researchers learn more about how drugs are metabolized. In addition, these wearable devices let trial physicians learn about unintended adverse reactions to the drug far quicker than they would if they waited for the patients to visit the doctor again.
	Canada	Deep Genomics	A Toronto start-up, uses AI to reduce the amount of costly trial and error in drug discovery by analysing large genomic databases, but its first clinical trial won't be held until 2020.

2. AI for doctors

Functions	Origin	Company	AI Solution
Improving Medical Diagnosis	US	Idx	Developed an AI solution to detect a disease, which uses a camera, operated by primary care physicians, to take pictures of the eyes. Data uploads to the cloud and undergoes analysis with AI algorithms—usually in less than a minute. The product became the first medical device the FDA has approved that can diagnose a condition without a doctor's interpretation. IDx's detection system gives doctor more time to treat those who actually have the disease. In addition, the system can reduce the cost of exams. IDx is now working on AI for glaucoma, skin conditions and other diseases.
		Human Dx app	Uses machine learning algorithms to crowd-source medical knowledge from more than 10,000 physicians in 80 countries. When doctors are uncertain about a particular diagnosis, they type their working hypothesis into the Human Dx app, along with uploaded, patient-approved images, test results and medical data such as prescriptions and medical history. Next, doctors refer the case either to diagnostic specialists or the Human Dx community at large. Within 24 hours, the Human Dx platform aggregates physician advice into a single report, analyses it and then ranks the most likely diagnoses.
		iCAD	iCAD deals with computer-aided detection, breast cancer, healthcare, colorectal cancer, xoft electronic brachytherapy system, breast density assessment, breast tomosynthesis, artificial intelligence software solutions, AI, deep learning, skin cancer treatment, breast cancer detection solutions, breast cancer treatment, technology, women's healthcare, and mammography. iCAD offers advanced breast cancer detection solutions built on artificial intelligence, that enable radiologists to find cancers earlier while improving reading workflow. Since 1984 iCAD is one of the best providers of advanced image analysis, workflow solutions, and radiation therapies for the early detection and treatment of cancer.
		InformAI	InformAI is an AI company with a healthcare focus on products that speed up medical diagnosis at the point-of-care and improve radiologist productivity. InformAI's AI-enabled image classifiers and patient outcome predictors are developed within the world's largest medical centre complex as well as with national physician groups and a leading medical imaging company. InformAI with its partners are transforming the way healthcare is being delivered. The company has key differentiators, such as access to 10X larger privileged medical datasets, direct access to world-class medical experts and proprietary AI data augmentation, model optimisation and 3D neural network tool-sets. InformAI was selected by NVIDIA in 2018 to join their AI Healthcare Inception Partnership and was cited by Forbes as one of 8 Start-ups Ahead Of The Pulse In Healthcare.
	Finland	Blueprint Genetics	Offer tests that analyse patient DNA for genetic disorders using machine learning, which can help healthcare providers assist patients in learning about hereditary diseases they may have and finding preventive treatments. The company conducts DNA tests to detect cardiovascular, dermatological, metabolic, neurological, and pulmonary disorders, among others. Hospitals submit DNA samples to them, after which they conduct targeted next-generation sequencing, a process where they analyse patients' DNA. Changes in the DNA sequence could result in severe medical conditions that could be inherited by the next generations in a family. The algorithms work to map the patient's DNA with other normal DNA in the internal database of disease-related mutations that were sourced from the web or licensed from commercial sources. Errors in the DNA sequence are considered genetic defects and potentially puts the patient at risk of a severe condition. Being able to determine genetic defects will enable healthcare providers to diagnose hereditary diseases and find preventive treatments to ensure these are not passed on to future family members. As certified laboratory of the Centres of Medicare & Medicaid Services – Clinical Laboratory Improvement Amendment Survey and Certificate Group, it eligible to operate in most states in the US, aside from being an accredited lab in Finland. The company has raised €21.4 million in funding from Stanford University, MTIP AG, Pontos Group, Creathor Ventures, and Inventure.
	Sweden	EXINI	EXINIs most widely distributed platform is used to calculate the automated Bone Scan Index, which quantifies the bone tumor burden in patients with metastatic prostate cancer. EXINI has established automated analysis platforms for cardiac, brain, and bone scans. This platform has been installed at about 1,000 hospitals worldwide. EXINI Diagnostics AB was established in 1999 to commercialize AI methods for automated analysis of diagnostic images developed by a research group at Lund University.

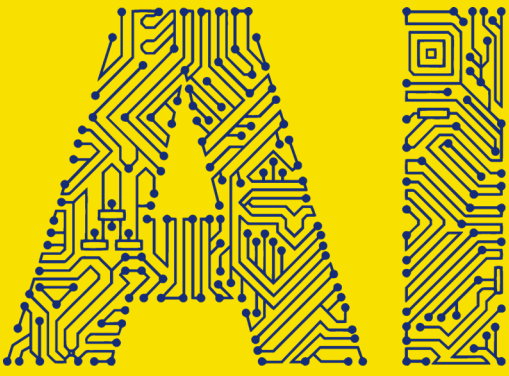
Functions	Origin	Company	AI Solution
Saving Time	US	Dragon speech recognition	An AI-enabled speech recognition platform, which is built into Clinical decision support systems. Transcription now happens in real time and with improved accuracy. This is saving doctors valuable time and allows them to focus more on patients.
		EmpowerMD	Among the products that Microsoft is piloting with UPMC is EmpowerMD, an AI that can listen into and learn from doctor conversations with patients in the hospital room. Today, many doctors barely look at a patient during their brief hospital rounds, tending to focus their eyes on a medical chart instead. The goal of EmpowerMD is to allow a physician to engage fully with a patient during an exam while the AI analyses their communication and makes notes and suggestions in the patient's electronic health record.
		Sopris Health	Sopris is a patent-pending digital assistant that uses voice and A.I. to complete documentation tasks for clinicians, typically in less than 45 seconds. The Sopris Assistant is fully automated, completing its work in real time without help from human scribes. No human scribes mean the tool is highly scalable and available at a price point that works for all clinicians - physicians, advanced practitioners and nurses alike.
Images/data processing & analysing	Israel	Zebra	Zebra is empowering radiologists with its revolutionary AI offering, which helps health providers manage the ever-increasing workload without compromising quality. The company is specialised in big data, computer vision, healthcare, machine learning, deep learning, medical device, Medical imaging, and radiology. The company's AI solutions analyse millions of clinical imaging data in real-time, detecting various medical indications, enabling it to be the only AI Medical Imaging company with such a wide range of products.
		MaxQ AI	Worked with Intel to develop an AI system that analyses CT scans for head trauma and stroke victims. Speeding up image processing and computing time, it provides results in less than a minute, instead of the usual three to four minutes. That lets doctors get to work quickly on patients with critical needs.
	US	Subtle Medical	Subtle Medical has developed a suite of deep learning software solutions that enhance images during the acquisition phase of the radiology workflow, improving workflow efficiency and patient experience. SubtleMR and SubtlePET, both FDA cleared, and CE Mark approved, utilise deep learning algorithms that integrate seamlessly with any scanner and PACS system with no change in the imaging specialists' workflow. SubtlePET and SubtleMR bring the latest imaging enhancement technology to existing scanners. Subtle Medical's technology is well recognized by the AI and radiology community and awarded by RSNA. Subtle Medical won the 2018 NVIDIA Inception Award as a Top 1 AI. Healthcare startup globally. Subtle Medical is partnering with top industry vendors such as AWS, Google Cloud, NVIDIA, and Intel to bring the best AI solution to hospitals.
		IBM's Watson	Able to deliver actionable insights from genomic data in tumour cells in just 10 minutes—a process that took 160 hours via human analysis.
		GE Healthcare	Is applying AI's rigor to MRIs, CT scans and PET scans, helping doctors find disease sooner. Earlier treatment means better outcomes and less invasive and expensive care for patients. By improving radiologists' productivity, AI could also reduce the money spent on equipment by as much as 25%, GE estimates.
		QMENTA	QMENTA is a cloud-based platform using unique AI and ML techniques to store, share, and analyse multi-site medical imaging data throughout clinical studies and trials. It allows experts to save valuable time and money in drug development and empowers their objective decision-making based on imaging data insights. The company accelerates and improves the chances of successful drug development and clinical care for brain diseases. Their team, composed of 25 international neuroimaging and IT experts, designed a cloud-based platform using unique AI and machine learning techniques and large amounts of MRI and CT brain images drawn from an extensive database.
	Netherlands	Aidence	Aidence brings together the brightest AI and software developers, medical specialists and industry experts to apply AI for automated medical image analysis. The team is driven by this purpose, with a keen eye on what adds value to their customers and the patients they care for. The human factors that shape Aidence are radiologists provide critical input and feedback, AI developers refine their solution, scientists independently validate the solution, and they are dedicated to improving patient care.
		Promaton	The company has two sets of advanced algorithms designed to automate image analysis and virtual treatment simulations. With its 2D algorithms the company enhances the accuracy of image analysis for dentists, reducing costs and saving time. Promaton's 3D algorithms aiddentists in automating the complicated data processing, segmentation, and 3D modelling specification steps in the creation of a virtual treatment simulation system.
		Thirona	A high-tech company focusing on the development and marketing of automated analysis tools for medical images by using state-of-the-art image processing techniques such as deep learning. The company's products use state-of-the-art image processing techniques, such as deep learning. Thirona has developed a cloud solution as a service for its products based on AWS. Since its establishment in 2014, Thirona has developed three software products focusing on the analysis of thoracic CT scans (LungQ), chest X-rays (CAD4TB), and retinal images(RetCAD). Thirona is ISO 13485 compliant, and all products have obtained CE certification and are actively used all over the world.

Functions	Origin	Company	AI Solution
Finding Early-Stage Disease	US	Brite Health	Brite Health provides an AI platform for clinical trials that improves patient engagement and compliance in clinical trials. The platform's competitive advantage lies in its ability to 'know' patients and classify them based on their needs and preferences, providing them with a uniquely personalised experience to improve engagement, retention rates, and loyalty.
		Remedy Health	Remedy Health's AI-assisted platform equips non-physician staff with clinical expertise to uncover hidden chronic diseases through phone screening interviews. Early diagnosis allows them to find the best fulcrum point for intervention to positively affect health outcomes and decrease cost. Finding undiagnosed patients will also drastically increase a health system's RAF scores and profitability. Remedy Health's system empowers low cost, non-physician staff to proactively screen patients through virtual interviews and capture clinically relevant data outside of the 4-walls of the hospital for timely decision-making.
Predicting patient decline	US	Montefiore Health System	A comprehensive predictive analytics program monitors patient for warning signs of respiratory failure. Going on a respirator is a serious medical intervention with a high risk of death within six months, so identifying — and, if possible, averting — that risk is a high priority for hospital staff.
Saving Lives with Sensors	US	Insight	The Insight Location Intelligence system, which Nicklaus Children's Health System developed in-house through its incubator NESA. It combines Bluetooth low-energy (BLE) technology and a proprietary AI to automate tracking of doctors, patients, and medical equipment. All of facility equipment is managed through an iPad, basically, the hospital manger can track anything from a wheelchair to a major piece of equipment anywhere in the facility and can create reports about how a department is utilizing a piece of equipment.
Efficient Operation s	US	Healthfinch	Healthfinch's Practice Automation Platform, Charlie, leverages EMR data to automate, delegate and simplify routine, repeatable tasks, like prescription refill requests, visit planning, diagnostics results management, and more. The flagship, award-winning application, Swoop for prescription refill requests, is used by major health systems across the country to improve workflows and get providers and their staff working top-of-license.
		BioSymetrics	Traditional ML technologies are incompatible with biomedical raw data formats, and there are few standards for data standardization, normalization, and harmonization. BioSymetrics solves this problem by deploying its primary solution, Augusta, which is a pre-processing and analytics platform that can process large amounts of data (siloed and raw data) for predictive analytics. This is useful for capturing the exabytes of data released from the 25B IoT devices and other biomedical data types (EEG, MRI and others) and deriving actionable insights from them. The customized and flexible tool can be used for scientists, providers, hospitals, biopharmaceutical companies.
		Quid	Quid inspires full-picture thinking by drawing connections across massive amounts of written content, enabling senior leaders to draw insights from big data (e.g., media, patents, employee reviews, analyst reports, company descriptions). Quid supports 300+ companies across the globe and was recently recognized by CNBC on their list of "2017's top 50 disruptors" (joining the ranks of Google and Airbnb In this unique honour). Leveraging proprietary algorithms, Quid is able to read through the world's data in minutes,creating dynamic visualizations. These visualizations allow senior leaders to understand the contextual element of any topic/narrative, versus the traditional static report or list search.
	Germany	Siemens Healthineers	Offers a population health management software called Proactive Follow-up, which it claims uses natural language processing to help healthcare providers and medical professionals identify and take action on the discrepancy between hospital best practices and the care that patients at the hospital actually receive. Hospital management can use the software to collect structured and unstructured data. Its machine learning algorithm was trained on data pertaining to patients xfd who missed a seasonal screening, vaccination, follow-up appointment, or post-admission compliance. The algorithm then takes in data on the hospital's care guidelines and real-time data on the care patients are receiving. If the software finds discrepancies between the patient data and the guidelines, it will recommend how to remedy the discrepancy, possibly allowing hospital personnel on staff to prioritize their patients based on the care they need. Medical University of South Carolina, Mater Private Hospital, Queensland Health, and the University Hospital Bonn as some of its past clients.
Patient management	Italy	PatchAI	PatchAI is an AI-powered conversational platform for clinical trials with data collection and analysis in real-time. It is a digital health solution that aids patient engagement and data collection in clinical research. PatchAI is an ideal companion for patients throughout their complicated trial journey, promoting patient retention and engagement through a variety of easy-to-use tools. It is an expansive interface that assists researchers and sponsors in assimilating thousands of data points. With state-of-the-art technology, trial efficiency will reach new frontiers. The platform helps in streamlining the clinical trial network of patients, researchers, and sponsors
		Gyant	GYANT helps hospitals, health plans, and pharma companies engage and support patients at scale. GYANT's accessible chat-based AI takes a medical history and navigates patients to the appropriate next step, including a visit to the doctor, labs, or an efficient telemedicine encounter on GYANT's platform. Proactive check-ins keep patients engaged and supported along the patient journey.

3. AI for patient

Functions	Origin	Company	AI Solution
Remote Diagnoses and Patient Triage (AI-chatbot)	US	Sensely's Molly	AI-powered virtual nurse Molly not only has instant access to the latest medical and drug knowledge and a direct line to your physician, she is also algorithmically programmed to interact empathetically, detecting a person's emotional state and using machine learning algorithms to respond more effectively and accurately to you over time. Molly currently assists hundreds of thousands of patients globally and can communicate in 32 languages with a customizable avatar and voice. While medical colloquialisms vary among cultures, Sensely hires translators who have both language expertise and a medical background to ensure the language used matches a patient's particular culture. A recent Harvard Business Review study estimates that AI-powered health assistants like Molly could save €16.3 billion annually by reducing the time nurses spend on patient communication tasks. Support for 32 languages is included, making Sensely ideal for large organisations with broad geographic and language coverage. With offices in London and San Francisco, Sensely's global teams provide virtual assistant solutions to insurance companies, pharmaceutical clients, and hospital systems worldwide.-
		Zipnosis	Zipnosis has designed an algorithm that can analyse answers to a series of detailed questions about a patient's health complaint and send a preliminary diagnosis and treatment plan directly to a physician for approval, without the need for the doctor to see the patient in person.
	Israel	Intuition Robotics	Many AI-driven healthcare start-ups focus on self-help aspects of wellness, such as sleep improvement and stress reduction, developed prototypes for AI-guided live-in robotic assistants designed to offer engagement and support to senior citizens. None is yet a full-fledged substitute for a nursing assistant or home health aide. A new class of anticipatory AI agents that can communicate with patients and healthcare providers about a health need based on data or behavior—before symptoms even begin to show themselves. Many AI-driven healthcare start-ups focus on self-help aspects of wellness, such as sleep improvement and stress reduction.
	Germany	Ada Health	Offers a smartphone chatbot called Ada, can help patients manage their personal health and help community health workers support rural patients by providing health information and keeping patient records using machine learning and natural language processing. Patients can start using the app by creating an account and answering a series of questions related to symptoms they are experience. Ada's algorithm will then in effect search its database to find conditions with similar symptoms, although it is unclear on what data the algorithm was trained. Ada also has the capability to connect a patient with a human doctor if the patient requests and share the patient's symptoms via SMS or other chat applications. Ada could recommend a pharmacist or emergency care as needed and allows a patient to track their symptoms by inputting a value that describes its severity and monitoring that severity. Its chatbot is also targeted at mental health patients by providing immediate responses to psychological symptoms and connecting them to medical professionals capable of providing care on or offline.
	Spain	Mediktor	A privately held company, Mediktor is the most accurate AI-based medical assistant for triage, pre-diagnosis, and decision-making support. Special features of the company include Artificial Intelligence, Symptom Checker, Machine Learning, Triage, Natural Language Processing, Natural Language Recognition, Digital Health, mHealth, eHealth, Healthcare, Medical Device, Health Insurance, Health Tech, Insurtech, Hospital, Emergency Department, Emergency Room, Health Systems, and Medical Schemes Mediktor has already performed 3 million symptom evaluations in 181 countries. This has led to the development of an intuition comparable to the full life experience of 10 physicians. The platform has undergone a clinical study with 1,015 patients achieving a success rate of 91.3% accuracy.
		Babylon Health	Offers an advanced chatbot that can converse with patients and either triage them to over-the-counter treatments or suggest more traditional medical evaluation.
Remote patient monitoring;	US	Alignment Healthcare	California-based Alignment Healthcare developed an AI-powered command centre that analyses data from a home monitoring kit—which includes a connected scale, blood pressure cuff and data collection table—to coordinate care for its sickest population. The kit engages with patients about their medication and vital signs on a daily basis, answers care-related questions and reports relevant data back to Alignment's command centre. There, predictive analytics algorithms work on identifying at-risk patients and triggering follow-ups, such as a call from a nurse or the services of an in-home medical technician, either of whom might be able to identify a superior course of treatment. These algorithms showed potential early on, by identifying a small population of patients who had a pattern of hypoxia (oxygen deficiency) but were not undergoing home oxygen treatment.
		AccuHealth	In Chile, AccuHealth has reduced emergency room visits by 42% while saving insurers 50% per patient on average. AccuHealth's biometric sensors track patients' vital signs at home, while AI identifies warning signals, nipping health problems in the bud—and often saving patients expensive trips to the emergency room.

Functions	Origin	Company	AI Solution
Healthcare at home	France	Chronolife	Chronolife builds predictive medical solutions to aid in diagnosis through wireless, wearable technology. Chronlife also aims to bring a paradigm shift in the healthcare industry, where they improve quality of life, provide better care, and reduce costs. From 2015 Chronolife is bringing a new era in the field of diagnostics that accompanies doctors & clinicians in faster & more efficient decision making. The solutions offered by the company are Artificial Intelligence, Medical device, and Neuromorphic Engineering. The power of Artificial intelligence & Neuromorphic engineering is harnessed into a disruptive algorithm able to single out & characterize even sparse clinical events builds predictive medical solutions to aid in diagnosis through wireless, wearable technology. Chronlife also aims to bring a paradigm shift in the healthcare industry, where they improve quality of life, provide better care, and reduce costs. From 2015 Chronolife is bringing a new era in the field of diagnostics that accompanies doctors & clinicians in faster & more efficient decision making. The solutions offered by the company are Artificial Intelligence, Medical device, and Neuromorphic Engineering. The power of Artificial intelligence & Neuromorphic engineering is harnessed into a disruptive algorithm able to single out & characterize even sparse clinical events
	Israel	Binah.ai	Binah.ai has released a series of non-invasive, video-based health and wellness monitoring solutions. Binah.ai gives an unparalleled advantage in health analytics as its technology transforms any device equipped with a simple camera into a medical-grade healthcare gadget. The video-based digital health use cases include heart rate and heart rate variability (HRV) measurements, providing the data for stress measurements. Binah.ai is the only company offering clearly defined, pre-built use cases and offers signal processing-integrated data science. They have a custom-built, proprietary, comprehensive, and complete mathematical back end and actionable intelligence strengthens the on-site data science team's capabilities. With end-to-end solutions focused on business results, Binh.ai solves real-world challenges with a production focus.
	US	Intermountain Healthcare	Utah-based Intermountain Healthcare uses AI as part of its Precision Genomics cancer treatment program.
		Applewatch	Applewatch ability to perform an ECG and tell in real time whether its results are normal or if it detects an arrhythmia, such as atrial fibrillation.
		SomaLogic	Developing a number of cardiovascular tests, for example if a person is in a high-risk group for a stroke or heart attack. Insights like these will empower patients to seek out early interventions, change their diets, or boost their fitness regimen to cut the risk of a potentially life-threatening outcome.
		Harmonize Health	Harmonize is a turnkey population health management company that sells health outcomes directly to customers and handles all the technological overhead needed to achieve those outcomes. For customers, Harmonize manages patient populations with minimal disruption to daily workflow. For patients, the technology is best-in-class. In the backend, Harmonizes combines a platform for sensors, analytics, and interventional services to deliver on population health goals.
		Dosecast	Allows patients to enter detailed information about their medications, including type of drug, dosage, and schedule, to determine if a different pill will interact with it safely. The app also learns the patient's daily routine and adjusts to changes in it, alerting the patient if they have missed a dosage. By tracking quantities taken, the app sends refill reminders and logs medication adherence.
		Sleep Genius	Uses neurosensory algorithms to create sounds that guide your brain through the complete sleep cycle, based on the same science that NASA uses to help astronauts get rest. Even "smart" beds can leverage AI to improve sleep. Smart beds for better rest, which deploy machine learning to monitor players' sleep habits and adjust mattress settings to maximize REM cycles
	Sweden	Natural Cycles	Offer a fertility awareness smartphone app that assists women in family planning by allowing them to stay on top of when they are fertile. Natural Cycles claims women could use the app to plan pregnancies. First, a woman can take her basal body temperature daily in the morning, when her temperature is lowest, and enter it into the app. Over time, the body of data that is built in the app becomes the woman's indicator of fertility. The machine learning model behind the software learns the woman's cycle and informs her through a color-coded system: red is for fertile and green is for not fertile. The woman and her partner can choose when to use protection to minimise or maximize the possibility of conceiving. The app lessens the need for prolonged and manual tracking used in traditional methods of family planning. The collected data could help healthcare professionals could also better understand their patient's menstrual cycles, fertility status, and possible underlying medical conditions. This enables the healthcare professional to counsel the patient on the right conception and contraception methods. Natural Cycles has raised €30.5 million in funding from e.ventures, Sunstone Capital, Bonnier Ventures, EQT Ventures, and Innuvik Ventures.
Personalised care	US	InsightRX	InsightRX is a software platform that incorporates the principles of quantitative pharmacology and machine learning to provide an individualized understanding of a patient's response to treatment. The platform guides treatment decisions at both the individual level and the population level. InsightRX combines real-time patient data and machine learning to understand individual patient pharmacology and inform dose optimisation
		MotiSpark	MotiSpark delivers a mobile-based, delightful therapeutic experience that improves the hardest to change behaviours by combining cognitive behavioural therapy, entertainment and social media. The patent-pending software delivers personalised video messages that reinforce coping mechanisms, and prescribed behaviour plans when and where people need them most - right on their phones.



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