Urban Mobility Next #3
AI Mobility Landscape in the EU

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Contents

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List of abbreviations

AI	Artificial Intelligence
AI AaaS	AI Application-as-a-Service
AI IaaS	AI Infrastructure-as-a-Service
API	Application Programming Interface
AV	Autonomous Vehicles
DRT	Demand Responsive Transport
DG	Data governance
EU	European Union
IoT	Internet of Things
KIC	Knowledge and Innovation Community
MaaS	Mobility-as-a-Service
OEM	Original Equipment Manufacturers
PoC	Proof of Concept

1. Introduction

1.1. Context

Artificial Intelligence (AI), capable of driving productivity and economic development, is radically transforming and impacting citizens, business, and public service. Its prevalence in everyday life will only continue to grow. Indeed, business leaders, regardless of company size or sector, understand the potential of AI to change their business operations and models. A Forbes Insights survey in 2018 showed that among over 300 executives, 95% believe that AI will play an important role in their responsibilities in the near future[1]. While discussions around AI tend to focus on technological possibilities and ethical considerations, new business models are critical for large scale AI adoption.

Currently, the US, China and Europe are the main actors in AI development and adoption. The AI research landscape is highly dominated by the US and China, with the US the current number one in AI development and China is a close second with an aim to be number one by 2030. Europe is among the geographical areas with the highest number of AI players (25%), just behind the US (28%) and ahead of China (23%)[2]. It is also the most balanced region in respect to the composition of research and non-research AI players.

AI research in the European Union (EU) focuses largely on security, regulation, and ethics. In this way it is staying true to its fundamental values by focusing on human-centred, ethical, and secure ways to embrace AI opportunities. This approach is to be lauded and will serve to strengthen European leadership in AI, retain expertise and improve cybersecurity.

The development of AI requires a multidisciplinary approach. The EU has technological and industrial strengths with high-quality digital infrastructure and an unparalleled regulatory framework based on fundamental values. While the EU is a global leader in innovation and its applications as set out in the European data strategy[3], it does lag in technological marketisation and access to funding to scale new solutions. Often in technology, free accessible volume usage decides the dominant practices and standards, not legislation of ethical principles. On that basis, EU society and economy, including citizens, businesses, and public services, will benefit from a dynamic AI ecosystem (Table 1).

Target Groups	Example of AI Benefits
For citizens	Improved health care, fewer household machinery breakdowns, 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 such as machinery, transport, cybersecurity, farming, the green and circular economy, and healthcare. High value-added sectors like fashion and tourism also stand to gain.
For services of public interest	Reducing the costs of transport, education, energy, and waste management services. Improving the sustainability of products. Equipping security and law enforcement authorities with tools to ensure citizens safety while safeguarding rights and freedoms.

Table 1: AI Benefits to European Society and Economy[4]

1.2. Methodology

In June 2020, the European Institute of Innovation and Technology (EIT) launched a 'AI Impact' survey across four EIT Knowledge and Innovation Communities (KIC), Urban Mobility, Climate, Manufacturing and Health[5]. The survey targeted AI firms and institutes from the EIT ecosystem and conducted field research in AI business model taxonomy grid and industrial applications. Sixty-four valid responses were generated, among which 68% of respondents were AI solution providers, and 28% AI technology adopters[6].

Covering a variety of topics including data governance, privacy, barriers and risks to deployment, business drivers, and impact in the EU, focus group meetings with EIT AI technology partners from both academia and industry informed the survey design and identified collaboration areas.

This report focuses on the business models supporting AI deployment and expansion of its applications in various sectors. The report presents findings ranging from barriers and risks for AI adoption, algorithm development methodology, revenue/cost models and AI applications across different industrial sectors, with a focus on urban mobility.

The report presents four main contributions. Firstly, it maps the AI landscape in Europe and compares national policies, regulatory framework, and ethical guidelines. Secondly, it discusses AI business model taxonomies and identifies priorities for strengthening the EU's current ecosystem. Thirdly, it illustrates how AI applications have driven business transformation in urban mobility and other sectors. Finally, it makes recommendations on developing a database of Europe's proven AI business models and applications. The report reaches concluding remarks on policy stances of the EU to foster AI innovation and growth.

2. AI Landscape in the EU

In the global AI race, the world's largest economies have announced national strategies and investments into research, development, and deployment. EU member states have been and continue to be active in AI. AI entrepreneurship is becoming a mainstream skill sought and expected in innovation circles. Europe is home to over 1,600 early-stage AI software companies. In Europe the UK, Germany and France are progressing from strategic frameworks to AI practices[7] at a rapid pace. Collectively, European AI start-ups raised €6.7 billion in 2020, almost doubling the figure raised in 2017. In 2019 French AI start-ups gained the highest investment funding €1.14 billion[8].

Currently the top 5 industries in which AI is making impact are FinTech, HealthTech, MadTech (marketing, advertising, and technology), business intelligence, and automotive[9]. 76% of AI companies operate within the business-to-business (B2B) space. Digitised B2B industries are expected to continue benefiting from AI as industrialised and distributed edge cloud architecture take over from consumer focused, centralised cloud-based systems (Table 2).

	Current Practices	Future Practices
Data Source	Related to consumers	Related to 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: Current and Future Data Management Practices[10]

In France the government intends to spend €1.51 billion over the next five years to support AI ecosystems, including the creation of large public datasets[11]. Germany aims to become a leading centre for AI by pursuing speedy and comprehensive transfer of research findings into business applications[12]; and between 2016 and 2021, Spain invested €90 million in digital society and language technology.

However European countries are also facing risks linked to early AI adoption. Some have found themselves subsidising talent for global AI giants and accelerating the wealth of countries outside the region[13]. Strict regulations on data privacy and ethical AI have also slowed down European AI innovation. Given data, digital privacy and AI services are being offered across the single EU market, such recurring challenges highlights the need for coordinated actions at the EU level.

2.1. The EU emphasis on ethical AI

In addition to standard business drivers, the EU's activities related to AI are guided by social, ethical, legal, and regulatory frameworks. All 28 EU member states plus Norway have signed the Digital Day Declaration on AI cooperation. 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. The Declaration raises a clear concern for ethical issues and commits its signatories to ensuring that "humans remain at the centre of AI development and preventing the harmful creation and use of AI applications". The EU has also published various ethics guidelines on AI[14] complementing its strategy, and demonstrating thought leadership in the area. Articulating new areas for AI deployment in the EU requires a new generation of applications, supported by ethical AI policies, regulations, and proactive sharing of AI benefits[15].

Importantly, in April 2021, the European Commission published its proposal for harmonised regulation and rules on artificial intelligence[16] with the aim to streamline development, placement on the market, and use of systems across the EU. The proposal still needs to be approved by the European Parliament and EU Council but illustrates the EU's ambitious stance on regulation. Following a risk-based approach, the Commission identifies several levels of risk (unacceptable, high, low) linked to different use of AI to establish a framework protecting people's security and fundamental rights. While an unacceptable level of risk means the ban of the product from the market, the higher and lower risk tiers impact the requirements that a specific technology must comply with.

To stimulate AI innovation, the newly drafted framework also proposes the creation of regulatory sandboxes, where new technologies can be tested in controlled environment over a limited period. These sandboxes aim to facilitate the development, testing and validation of innovative AI systems before their placement on the market.

2.2. Europe's leading research

The EU has many factors which make it a leader in AI development and deployment, including academic research in key areas, vibrant start-up environment, well-established and advanced technology market, and national government initiatives. Leading the development of AI algorithmic foundations, the EU takes advantages of its own scientific excellence to develop machine learning, deep learning, and symbolic approaches. Successful examples of cross-disciplinary research collaboration vary from European Molecular Biology Laboratory (EMBL), Mila, Cyber Valley to The Paris Artificial Intelligence Research Institute (PRAIRIE). European academia actively counteracts fragmentation between different AI-related disciplines and uses opportunities to cross-pollinate with industry and government. For instance, the EU's 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 to apply the new quantum solutions to a range of industrial and academic sectors. Europe also leads in neuromorphic solutions and low-power electronics, crucial for the next generation of specialised processors for AI and ideally suited to automating industrial processes and transport modes[17].

2.3. Challenges to AI Deployment

According to survey respondents, the most widely deployed AI solutions are image processing, computer vision and diagnosis. In the next 5 years, AI solution developers feel that the market for their solutions will be mainly in Europe, North America and Asia, with Europe having the biggest estimated market growth. Regarding how AI is approached in the management context, European companies are quite evenly split across deploying AI as a top-down process (35%), as a bottom-up process (29%), or as a combination of the two (28%)[18]. The approach varies as to whether central units take a leading role in pushing the AI adoption, or instead focus on gathering experience from already existing effects that are decentralised within the organisation.

Based on survey results, industrial partner collaboration and in-house development are the two main approaches to developing AI algorithms. Over 50% of AI developers rely on external partners to develop solutions, helping them with scaling up, testing and design.

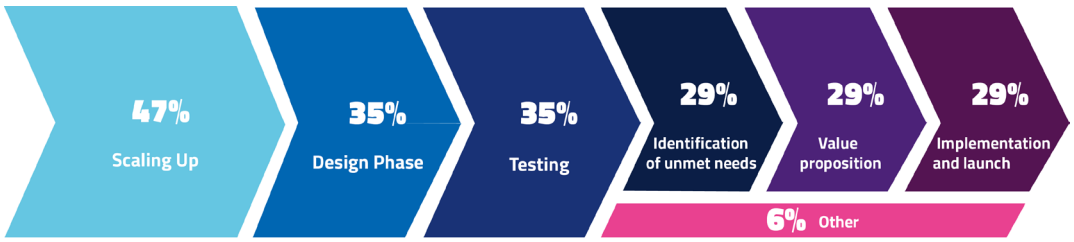


Figure 1: Business Areas Needing External Partners to Develop AI Solutions

2.3.1. AI Benefits

AI solution adopters expect AI's impact to mainly focus on 'customer service improvement' and 'data analysis and management'. On the same topic, the AI technology providers believe that the main AI benefits go to 'data analysis', and 'management and reduction of waste of resources'. While many AI adopters focus on improving customer relationships and identifying new customers, AI providers have a stronger belief that the benefit comes from supporting R&D activities and improving manufacturing efficiency. Both adopters and providers recognise the AI benefits across the business value chain, including data management, resource savings, operational cost reductions, employee productivity improvement, downtime prevention and logistic optimisation.

	AI Adopters	AI Providers
Support of R&D Activities	6%	10%
Identification of new customers	6%	2%
Reduction in waste of resources	9%	11%
Reduction of costs of business operations	9%	9%
Improved marketing and advertising	3%	2%
Data analysis and management	11%	13%
Improved employee productivity	9%	9%
Growth in business revenue	6%	5%
Prevention of outages/downtimes	9%	8%
Increased manufacturing output and efficiency	6%	10%
Optimised logistics	9%	9%
Relieve employees from routine tasks	6%	7%
Improved customer service	14%	6%

Figure 2:
AI Impact – from the view of AI Adopters and Providers (based on a multiple-choice question)

More than 60% of survey respondents have yet to feel that AI solution deployment would lead to revenue generation, while 54% of respondents felt that AI solutions had not been impacting costs. For those respondents who have experienced the impact of revenue generation or cost reduction, they identified supply-chain management as the most benefited business department in revenue growth, followed by manufacturing and R&D.

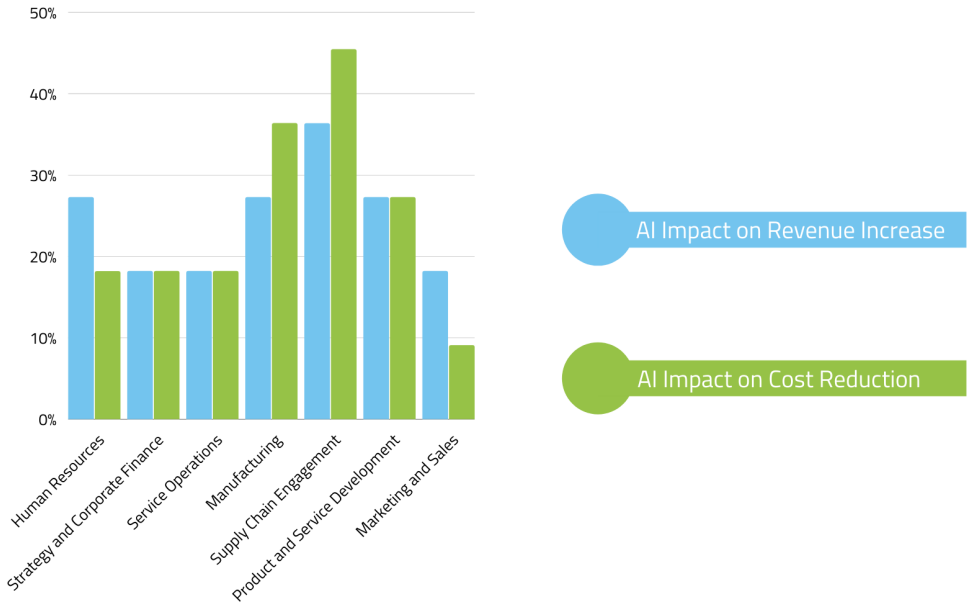


Figure 3:
AI Impact – from the view of AI Adopters and Providers (based on a multiple-choice question)

Value driver of AI solutions

To fully drive value and positive impacts of AI solutions, providers and adopters take different approaches. Inherently, AI providers and AI adopters have opposite priorities. On the organisational level, the top three approaches for adopters are 'alignment between AI strategy and business goals', 'ensuring adoption and value' and 'investment in AI talent and training'. In comparison, the top three approaches of AI providers with their customers include 'improving their data practices', 'helping them establish standard protocols and methodologies' and 'supporting collaboration across functions'. Similarly, providers and adopters also present a big difference in their value drivers. AI adopters are oriented towards business development focus, while AI providers are more system and data integration focused. This difference leads to adopters searching for more managerial level AI talent and expertise. It also raises the concern that AI providers are not sufficiently customer focused.

	AI Adopters	AI Providers
Ensuring adoption and value / Helping customers develop adoption and value creation	21%	15%
Establishing standard protocols and methodologies / Helping customers establish standard protocols	14%	23%
Applying strong data practices / Improving customers data practices	7%	25%
Collaboration accross functions/ Supporting collaboration accross functions	7%	18%
Investing in AI talent and training / Helping customers with AI talent acquisition and training	21%	9%
Aligning AI strategy and business goals / Aligning customer's AI strategy and business goals	28%	9%

Figure 4:
Approaches to Drive AI Value – by both AI Adopters and Providers (based on a multiple-choice question)

2.3.2. Barriers and risks for AI deployment

Still in its infant stage, it is widely accepted that AI deployment in the EU faces many significant challenges. According to the survey results, the biggest barriers to AI solution deployment are lack of technical feasibility, lack of data availability and quality, and budget constraints. Cybersecurity, compliance, and personal privacy were identified as three top risks for the survey respondents.

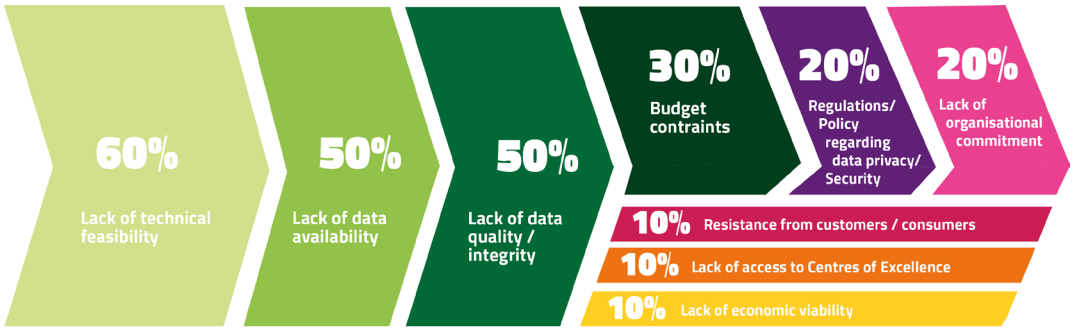


Figure 5: Barriers for Deploying AI Solution

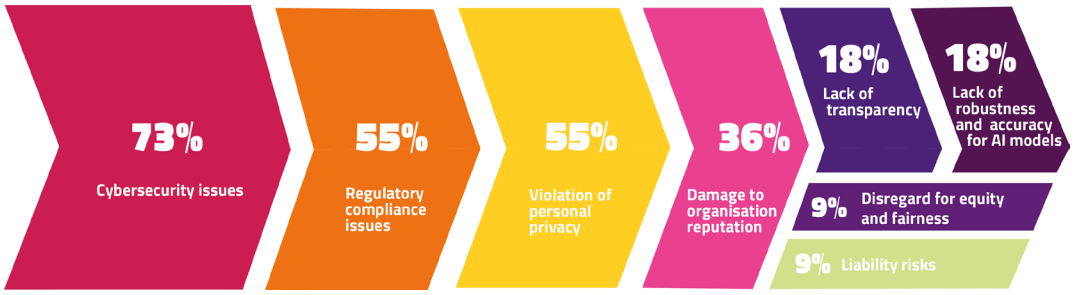


Figure 6: Risks for Deploying AI Solution

2.3.2.1. Data barriers

Data governance (DG) is the overall management of the availability, usability, integrity, and security of the data used in organisations. Data storage, quality and processors alongside algorithms, need to be well governed, particularly when sensitive data is used to make decisions that may affect the data owner.

In the field of data security, AI developers provided confident feedback about their own data practices with more than half of respondents indicating they have a functional DG body, but that there is room for improvement. AI developers however showed much less positivity toward their customers' data security practices with 75% of respondents perceiving customers as not having a functional DG body. As such, the AI solution providers highlighted the need for further development of related data regulations to enhance the mutual trust with their customers.

	Customers	Developers
Established DG body is working flawlessly / Most of our customers have a functional DG body	21%	8%
Established DG body is functional but with room for improvement / Some of our customers have a functional DG body	30%	54%
The DG body lacks essential functionality / Rarely any of our customers have a functional DG body	30%	15%
No established DG body in the organisation / Most of our customers do not have a functional DG body	15%	8%

Figure 7: AI Developers' Perception of Their Own and Customer's Data Governance Bodies.

Survey results suggest the need for talent and training on data governance in AI adopter firms. Additionally, respondents feel that specific policy and relevant training and education in AI is desired in most AI firms, in addition to the general knowledge of supporting policy, regulation framework and guidelines published by their national government.

Data quality and integrity are equally important to AI organisations but can present a challenge. There is limited data available for AI training for most developers, with good quality datasets still requiring additional processing. Similarly, significant time and energy must be devoted to reviewing, cleaning, and re-structuring datasets before carrying out any AI work.

Figure 8:
Data Security, Availability, Quality, and Integrity from

2.3.2.2. Cost barriers

Costs remain a key concern for AI adopters. Costly AI activities are caused by immature technology, consulting costs, software license fee, software configuration and customisation.

A review of the cost implications reveals that many adopters could be unclear about their actual need regarding AI technology. This concern validates the need for training and talent at managerial levels, and the market need for AI consulting services.

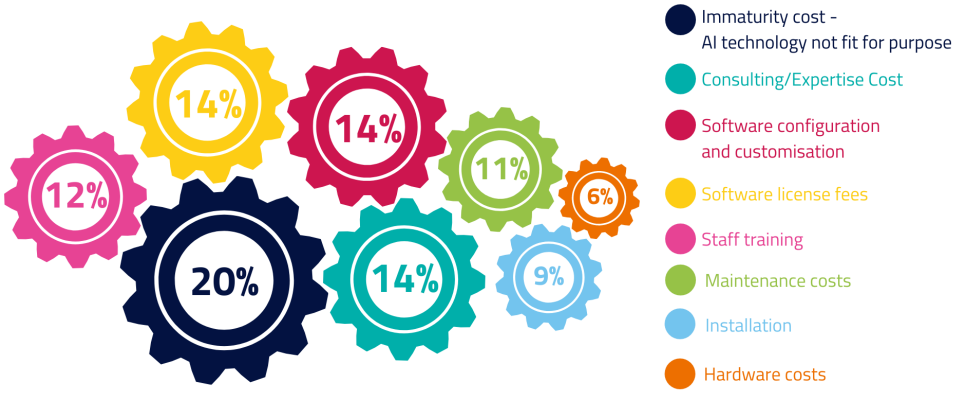


Figure 9:
Costs for Adopting AI

2.3.2.3. Culture and social barriers

A culture of resistance to change is another important barrier to AI adoption. AI will bring significant and uncomfortable changes to many workplaces and jobs. Disruption and expense need to be overcome to see the overall benefits.

Human bias is still a risk to AI development. Bias in training datasets directly affects AI effectiveness. AI's ability to monitor global information systems from surveillance data, cameras, and from mining social network communication has great potential for both good and for bad. Governments and business institutions must invest time formulating rules, regulations, and responsibilities to mitigate risks.

As an outcome of the culture and social barriers, the current approach to AI strategy could not fully capitalise the rapidly evolving AI capabilities in the market. On the one hand, AI adopters could foresee the potential beneficial impacts of AI deployment; on the other, they are concerned about the disclosure of their core data to a third-party for tailored AI solution development. Avoiding information disclosure and vicious competition, businesses could foster an environment of distrust towards each other as they seek to protect their commercial advantage and client data. This is key barrier to a common approach to data collection and access for AI developers. Moreover, many companies lack the necessary digital infrastructure, in turn discouraging data opportunities and innovations and making it more challenging to adequately address business needs[19,20]. Currently the EU is investigating whether a social media network's access to commercial data allows it to break into new sectors (Marketplace and Dating) as it garners volumes of data via business services such as User Authentication.

To succeed in the age of AI, businesses must hold a number of competencies, including a clear vision and shift in mindset to embrace AI, good quality datasets to train and develop highly effective algorithms, ecosystem partnerships, a viable AI business model, and the ability to address organisational cultural challenges.

3. AI Business Model

AI technology is the catalyst of business model innovation, disrupting industries and companies.AI transforms how businesses create and capture value, triggering business and technology innovation in the era of user-oriented digital economy[21,22]. According to Gartner Research (2018), global AI-derived business value will reach up to $3.9 trillion by 2022.

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

3.1. Impact of AI across the value chain

3.1.1. IT department

There is no denying that AI has revolutionised the very essence of IT, with the potential to change business models at every point of the value chain. AI effectively can be used to create expert systems that will exhibit intelligent behaviour, provide solutions to complicated problems, and further help to develop simulations equivalent to human intelligence within machines[23]. Impacts of AI on the IT sector include:

- **Improved Security**: Using algorithms, AI can protect confidential data by enabling high-security layers. AI can also help to identify potential threats and data breaches, while also providing the necessary provisions and solutions to avoid such loopholes.
- I**mproved Productivity**: AI can aid programmers to write better code and fix software bugs, increasing efficiency, productivity, and providing clean code for developers.
- **Application Deployment**: AI can be an integral tool in predicting problems during the versioning stage.
- **Quality Assurance**: Developers can use AI tools to fix bugs and issues within applications and adjust them automatically during development cycles.
- **Server Optimisation**: AI can help optimise the host server to improve customer service and enhance operations.

3.1.2. Human Resource

AI has the power to revolutionise hiring strategies. Internal hires are a more efficient and cost-effective solution compared to sourcing external candidates. AI can help to identify what drives performance within these various roles in the organisation, and assess whether an organisation has existing talent that can be trained or developed into certain roles. Data can also help to identify employees open to change, fast learners, agile and resilient (McLaughlin, 2020). This internal-first approach can be a resourcing game changer.

Moreover, AI could enable talent acquisition by automating elements of recruitment[25], onboarding and performance evaluation. Relieving employees of routine tasks can improve both productivity and job satisfaction.

3.1.3. Research and Development

R&D functions have largely benefited from AI technologies, as employees are often engineers who tend to have a good understanding and appreciation of the potential and impact of AI[26].

Whilst the process of discovering new materials is typically slow and imprecise, AI can accelerate this process by finding, designing, and evaluating new chemical structures with the desired properties[27]. For example, in the drug development process, innovative AI-driven R&D leads to a

new pharmaceutical and material discovery business model. Curation markets and collective intelligence for drug discovery entail the creation of an open, multi-sided marketplace for drug development with a platform of shared ownership rights to generate public markets for new drugs and therapeutics to attract funding and resources. AI-driven drug discovery suits the purpose well and will help to create incentives for a more open-source R&D process that will help to bring down costs, accelerate development, bring more diverse treatments to market, promote stakeholder collaboration, distribute risks and allow for participation of smaller organisations. This will incentivise and reward drug discovery with parties then able to move towards riskier areas of research with potentially higher reward for the industry.

3.1.4. Operations and Logistics

AI could benefit business in quality assurance and manufacturing efficiency by automating and optimising operations and logistics to save money through decreased downtime.

3.1.4.1. Predictive maintenance

With vast amounts of product testing and performance data, sensors, and advanced analytic embedded technologies in manufacturing equipment, AI can accurately anticipate when industrial machines will fail, determine the most probable cause of failure, and the best course of maintenance in a given situation.

3.1.4.2. Supply chain and sales forecasts

Manufacturers collect vast amounts of data related to operations and processes. Advanced analytics can provide valuable insights to improve supply chain and risk management, sales forecasts, product quality maintenance, recall prediction, and pricing.

3.1.4.3. Robotics

AI-powered robot abilities are far superior to those of conventional robots, enabling them to interpret CAD models, eliminating the need to program their movements and processes.

3.1.5. Marketing and Customer Service

AI solutions can analyse the behaviours of customers to identify patterns and predict future outcomes. Observing and understanding customer behaviour allows companies to better market products/solutions and answer their needs. AI thus shifts the focus of marketing from demographic targeting to intent, helping to improve identification of new customers and making Customer-Relationship-Management (CRM) solutions self-updating, and more effective and accurate[28]. AI can also improve customer services by answering queries quickly, analysing customer call data, classifying interactions based on positive or negative outcomes and analysing patterns to provide a script with the most effective phrases[29].

Google data means AI can combine knowledge of a person's longer-term interests with their more immediate ones and predict what they will do next. For example, based on the data collected by their recommendation algorithm, Netflix created a streaming service through Amazon Web Services, giving their customers the ability to customise their experience. They created a new product of high value replacing TV within the digital natives, building a scalable and profitable business, and successfully transforming the company.

3.2. Data-driven AI business model

To create effective AI systems that can be deployed within various products and services, businesses need access to algorithms, data, skills, and hardware. Companies often choose to restrict wider access to some or all of these resources to create and maintain a competitive advantage. On the other hand, businesses' access to data and algorithms is one of primary competitive advantages in creating AI systems. To realise the potential benefits of wider access while retaining competitive advantage, companies need to develop strategies on what and how to share data and/or algorithms. Within an individual AI system, data might be treated differently, for example data containing personal information used for training an algorithm may be closed, while a subset of suitably anonymised data could be published openly.

By considering products and services built on AI systems in terms of their position on spectrums of access to data and algorithms, the Open Data Institution (2018) has developed a matrix (Figure 10). This matrix identifies broad archetypes and trends in how businesses approach access to data and algorithms as a means of forming a competitive advantage.

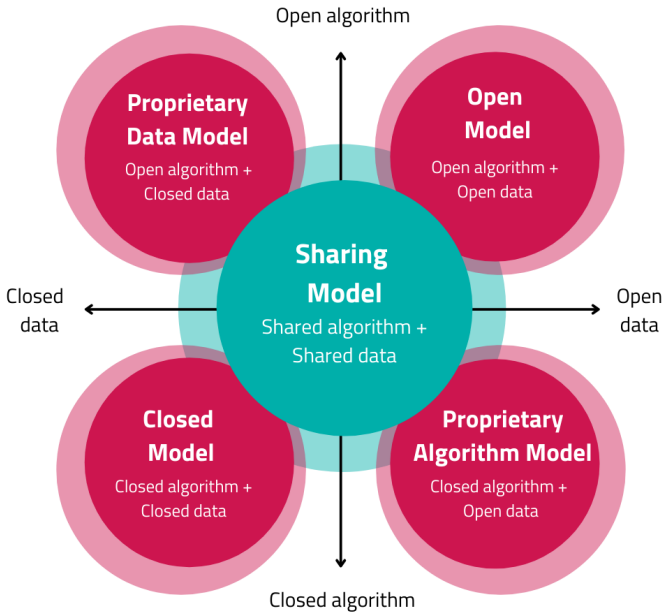


Figure 10: The Data-Driven AI Business Model Matrix[30]

AI business models	Description	Benefits & Limitations
Proprietary data model: open algorithm + closed data	This approach is characterised by restricting access to data while providing wider access to AI algorithms. Companies gain commercial advantage by restricting access to data used to develop AI systems to prevent others from developing competing systems.	Companies can benefit from the latest advances in AI modelling, receive feedback from others in the AI community and encourage the development of complimentary services through open innovation.
Closed model: closed algorithm + closed data	Businesses applying this approach restrict access to both the data and the algorithms under their control. Companies leverage their internal resources and develop their own skills and products, whereby the access to both data and algorithms constitutes intellectual property.	Comparatively more difficult to have meaningful interactions with the wider AI community. Businesses that adopt a closed model tend to not only make fewer, less impactful contributions to the broader AI community, but also reap fewer of the benefits that engagement with the community can provide.
Proprietary algorithm model: closed algorithm + open data	This type of approach is defined by greater access to data coupled with comparatively limited access to algorithms. Companies that adopt this model tend to want to use their skills and expertise to develop proprietary algorithms that are more effective than their competitors and then allow outside companies with large amounts of untapped data to use their model, and access the outputs of that model, at a cost.	The advantage of this approach, especially for many start-ups and smaller businesses, is that it does not require them to control their own large data set – success is not predicted on the aggregation of vast amounts of data. In addition, there are benefits for the wider AI community, since greater sharing of data encourages innovation.
Open model: open algorithm + open data	Companies that employ this type of approach tend to want both elements openly accessible to the general public.	This approach offers the most benefits in terms of innovation and speed of AI improvements, contributing to making society and the AI community better. Choosing this strategy might require businesses to generate a competitive advantage through other means, such as skills or hardware.
Shared model: shared algorithm + shared data	In the shared models, business access to data and algorithms are shared with select parties.	To derive competitive advantage from other facets of their business model, such as their skills and expertise. This might take the form of consultancies building bespoke AI systems for clients or licensing particular AI systems and associated services.

Table 3: Broad Archetypes of Data-Driven AI Business Models[31]

By restricting access to data and algorithm resources, businesses can create advantages over their competitors. At the same time however, businesses should also consider the benefits of sharing and opening access to their resources.

3.3. Revenue model

Companies are forecasted to spend €81 billion on AI worldwide in 2023 compared to €31 billion in 2019[32]. While money may be flowing, few companies have figured out the best way to harness AI while navigating new challenges it brings. Thus, AI companies build revenue models depending on the value generated for the target users and value capturing mechanism. The revenue models can be generalised based on the level of their business relying on AI as[33]:

- **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, such as software and hardware, to all companies.
- **AI adopter**
  Companies using AI as part of a broader product or technology stack.

3.3.1. AI Application-as-a-Service (AI AaaS)

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. Many of those AI application providers are start-ups and they run their business models based on an Application-as-a-Service (AaaS) licensing model, by developing applications for specific client use-cases.

Incentives

Little white-glove work, get the contract signed, send the invoice every year, focus on winning more contracts[34].

Features

- Offer solutions that play at the surface of existing systems.
- Often rely on Application Programme Interfaces (APIs), but not focussed on integrating with a client's existing infrastructure.
- One core corpus of training data often usable for almost all clients.
- May involve collaboration with client SMEs to calibrate the system and provide feedback.
- Requires almost no improvement in AI maturity on behalf of the client.

For AI adopters that decide to partner with AI provider start-ups to co-develop tailor-made solutions, a revenue-sharing or data sharing model could be adopted by both companies to meet a common interest. Both the provider and adopter can agree to build a proof of concept (PoC) and share the benefits in the form of revenue or data proprietary[35]. Adopting AI AaaS, providers charge their customers with monthly running costs 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 AaaS is a variation of the Software-as-a-Service (SaaS) model that accentuates the role of sectorally competent AI companies. However, different from SaaS that is normally sold on a per-user basis, AI AaaS is priced by transaction or completed computation. The more work AI does, the more customers need to pay for AI.

3.3.2. AI Infrastructure-as-a-Service (AI IaaS)

Organisations that are unable or unwilling to build their own AI solutions, can tailor technology services provided directly from a third-party vendor and use them nearly immediately. In such cases, the AI technology firms provide AI Infrastructure-as-a-Service by offering computational services such as infrastructure and pre- trained algorithms.

Incentives

These firms cannot focus on near-term value alone, and training clients on their product inherently implies AI maturity. While AI technology firms might use near-term 'lighthouse projects' to encourage the sale and gather momentum, they will make the most revenue when clients build AI capability for the long-haul[36].

Features

- Offers a platform with more open-ended, broad use-case potential.
- Must sell clients on a broader roadmap of AI transformation, not just an individual solution. This often requires lots of education and AI maturity-building through the course of the sale and adoption of the solution. Platform vendors are incentivised to encourage AI maturity and long-term thinking in their clients.
- Must educate clients on the potential of AI, and the specific features and workflows of their platform.

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 ex-

ample, IBM Watson provides AI services including Sentiment Analysis, NLP, and Entity Recognition. Primarily, this model has its benefits for AI IaaS customers in reducing capital, operational and staffing costs. However, its drawbacks include overt dependency on a number of external contractors, the risk of contract and service '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 start-ups with a higher level of sectoral competence. This business model would maintain a distance between AI business users and AI designers with 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 smaller companies would be challenged to match.

3.3.3. AI Technical and Management Consulting

AI technical and management consulting services can help companies flesh out an AI vision and roadmap to implementation. Echoing the survey results highlighting a need for consulting services, AI technical consulting firms bill projects for advisory services. AI service firms advise on strategy, education, and process by offering tools and SaaS integrations, however, they do not carry out actual technical work for their clients. These firms are normally operating across multiple functional areas which ideally positions them to help clients develop an enterprise-wide AI roadmap[37].

3.4. Cost Structure

To build AI-based solutions, companies need to take several unavoidable costs into account in addition to hardware for computing power. The expenditure includes cost of business consulting, feasibility studies, data scientists, minimum viable product, implementation, maintenance, and continuous learning.

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. Therefore, it is hard for AI start-ups to use freemium models. AI takes time to show its effectiveness as compared to traditional solutions. An AI product normally cannot be profitable at its first launch[38]. Depending on each individual business case, once the complete solution is fully operational and after the improvement of its learning curve, the added value of will become visible.

3.5. Discussion

For AI Infrastructure-as-a-Service model, the EU needs to determine if as we move adoption forward, it wishes to strengthen the existing dominance of key multinationals and see financial benefits possibly leave the EU. 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, solution providers would expand the B2B model thus lessening the role of large multinationals. While large multinationals may provide the computing capacity needed, they would neither be the primary developer of AI applications, nor the front for European AI innovators to EU companies. This AI AaaS model would create closer alignment and communication between adopters and 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, strengthening both the EU's resilience and autonomy in AI.

As evidenced from the survey, the development of AI also provides increasing needs and opportunities for technical consulting firms. Whilst technical services firms will largely focus on near-term value, they are unlikely to develop near-term ROI as compared to AI SaaS vendors who have a true focus on one business problem. Consulting firms must develop a niche to compete with others also capable of AI technical work.

4. Industrial Applications

Building upon the AI landscape, AI business model taxonomy grid, and the status of AI deployment in EU, this section explores practical AI applications across smart and connected sectors, demonstrating wide areas of impact.

4.1. Smart and connected urban mobility applications

Transportation represents 23% of global related carbon dioxide emissions. AI innovations are projected to improve the efficiency of transportation systems and save oil and gas companies as much as €41 billion annually in production costs[39].

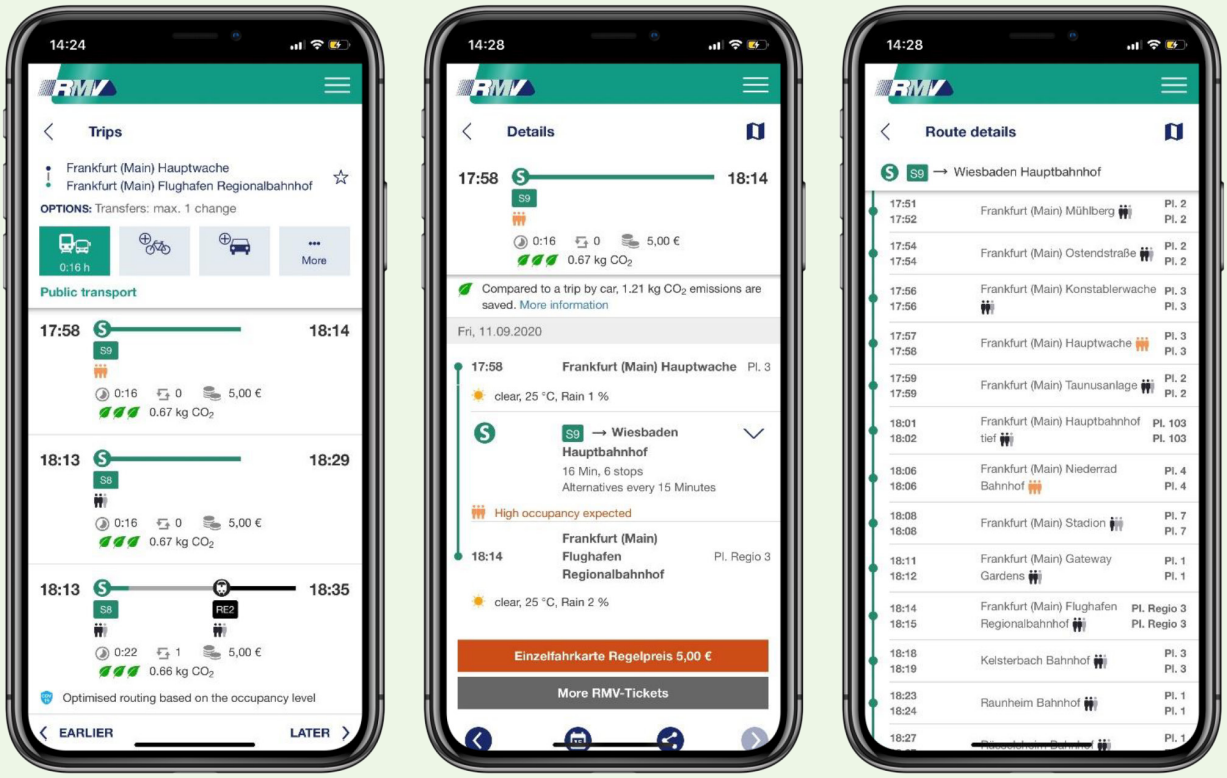
CASE 1

Smart Algorithms for Safe Distancing in Public Transport

Because of COVID-19, passenger numbers in public transport have dropped dramatically. For transport companies and associations, one of the greatest challenges is to restore passenger confidence and to offer the best possible level of safety. In addition to complying with the rules of social distancing, digital technologies can help to better protect vulnerable groups in public transport while at the same time enabling mobility.

Based on big data technologies and self-learning algorithms, Hacon and Siemens Mobility have joined to develop software that predicts passenger numbers. The German transport association Rhein-Main-Verkehrsverbund (RMV), a long-time customer operating in and around Frankfurt with +800 million passengers a year, implemented the system in September 2020. Passengers planning their trip via the RMV app can now check the estimated number of passengers along their route prior to departing. When route proposals show occupancy predictions as "too high," passengers can reschedule their journeys to avoid crowds.

The occupancy forecast is based on connection requests from the RMV's trip planner – with data fully stripped off any personal information before being processed. This trip planning data has been used to build and train a machine learning system which looks for patterns, such as variances in occupancy depending on time, day of the week, bank holidays, weather and, in particular, depending on trip planning requests. Collectively, these requests indicate the travel demand for the near-term future. In order to make the estimates more accurate, a calibration factor is created by using real counting data from the Frankfurt underground trains, trams, buses and the RheinMain S-Bahn. In addition, the self-learning algorithm takes into account predictable external influences such as construction sites and any major events. As the amount of available data increases, the predictions of passenger numbers will become even more precise.



Playing a significant role in transforming the sector, AI presents promising opportunities for a net zero carbon emission future (Table 4).

Reducing transport activities	Analysing data Remote sensing Forecasting Freight consolidation Alternatives to transport
Improving vehicle efficiency	Designing for efficiency Detecting loading inefficiency 3D printing Autonomous vehicles
Researching alternative fuels	Research and development
Empowering electrical vehicles	Charging patterns Charge scheduling Congestion management Vehicle-to-grid algorithms Battery energy management Battery research and development
Optimising modal shift (shifting to lower-carbon options, like rail)	Consumer choices Coordinating modes Bike share rebalancing Predictive maintenance Enforcing regulation

Table 4: AI Strategies to Mitigate GHG Emissions from Transportation[40]

Innovation in the mobility sector, highlighted by changes in how mobility is delivered, includes the rise of on-demand services, vehicle and ride sharing and the introduction of new transport modes. The future of mobility needs to be designed around consumers. Businesses and service providers that have already done this have seen rapid growth and successful integration into the mobility services landscape. There are different models offering integrated solutions to place-based mobility challenges[41]. Two prominent examples are: Mobility-as-a-Service (MaaS) and Demand Responsive Transport (DRT).

- **Mobility-as-a-Service**
  The core aim of MaaS is to deliver a service that can provide a reasonable alternative to personal vehicle use within a city. MaaS aims to 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 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, common in rural and regional areas, providing a wide array of localised benefits to congestion, liveability, loneliness, and isolation.

CASE 2

AI-TraWell

*AI-powered, proactive **TRA**vel assistant to self-monitor user's experience & craft personalised travel solutions for promoting **WELL**being.*

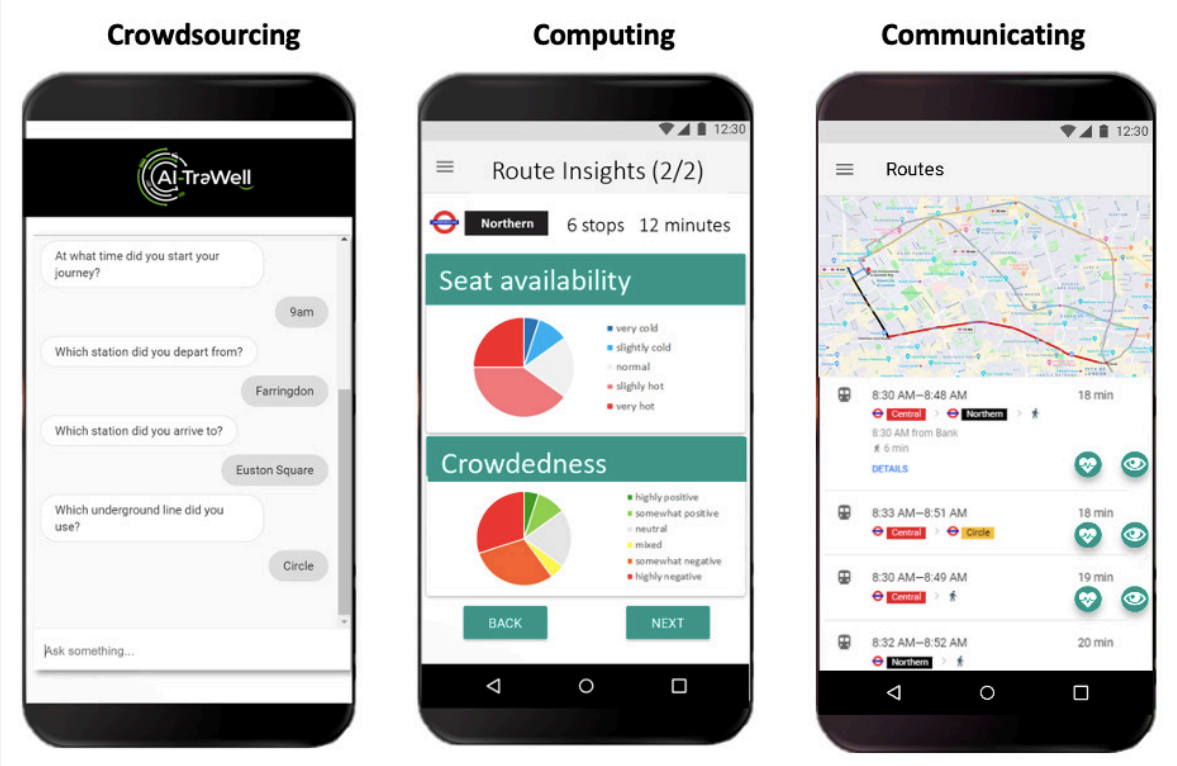
AI-TraWell is an Artificial-Intelligence-powered, proactive chat-bot for smartphone devices to recommend personalised Travel alternatives that fit travellers' needs/preferences and promote long-term health and Wellbeing for all citizens living/moving within our cities. Our solution is a smart phone application that promotes health and wellbeing of people moving around in our cities through crowdsourcing, computing, and communicating. Our app generates a new dataset by crowdsourcing preferences and feedback through a chatbot, computes the sentiment of the user and communicates personalised routes in line with the preferences.

AI-TraWell encourages citizens to share their personal preferences, mental state, and needs before a trip as well as feedback during and after the commute. The app will then analyse feedback of users, combine this data with objective mobility service information and suggest personalised travel routes to the user in line with their preferences and needs.

Currently, more than 200 million users rely daily on mobility apps in Europe and North America. The market size is rapidly growing. One of the key drivers are strict government plans to tackle climate change. Within only a few months from the start of developing this innovative solution in 2020, the team has identified and work closely with companies that have the capability and infrastructure to integrate the AI-TraWell algorithm into their mobility app such as MVV the mobility app provider in Munich, TomTom and IBB CapTrafik, the mobility app provider in Istanbul.

AI-TraWell fundamentally changes the way we travel in our cities through Artificial Intelligence by promoting wellbeing. Looking into the mobility app market, no app currently exists that crowd-sources personal preferences, computes personalised travel suggestions and promotes travel behaviour change using incentives. AI-TraWell will improve the long-term health & wellbeing of all of us living in our cities, with a chatbot interface that allows intuitive handling and navigating, and algorithms that are platform independent and can work with a wide range of mobility app providers.

AI-TraWell gives citizens a voice to shape the way they prefer to travel within their city, provides accessible & inclusive mobility services and, overall, improves the health & wellbeing of everyone living within our cities.



Digital technologies offer additional availability of data and connectivity in transport. While making our lives easier, technologies can also help to make transport modes safer, cleaner, smarter, and more efficient. AI technologies support many transport functions such as prediction, control, recognition, clustering, planning, decision making and optimisation, that are critical to enable a variety of transport use cases (Table 5)[42].

The following paragraphs present and explain existing AI applications in the transportation sector from a consumer perspective.

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 analternative route in an incident situation.

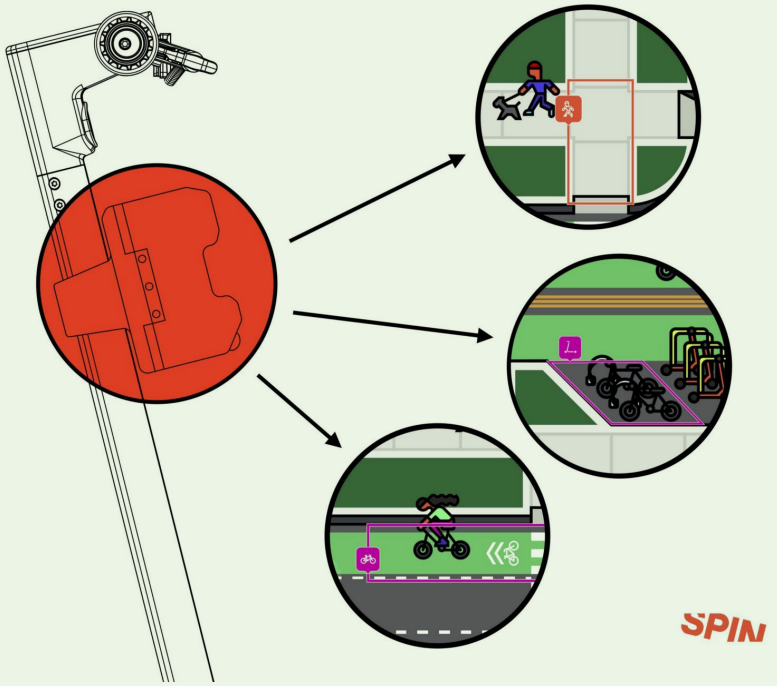
Table 5: Functions of AI Technologies in Mobility Service

Micromobility

Artificial Intelligence also helps enhance the safety of micromobility services in cities, as illustrated by the latest generation of shared e-scooters from Spin.

CASE 3

Powered by Drover AI, the Spin "Insight level 2" vehicles can recognize sidewalks within seconds, and consequently discourage sidewalk riding using sounds and optionally fines. The device notifies pedestrians when the scooter is on the sidewalk, indicates when a rider parks in an eligible spot, and notifies riders of improper parking before they get off the scooter.



These scooters point a camera at the ground in front of the scooter and examine images when the scooter is active. After identifying sidewalks, roads, bike lanes or parking areas a built-in speaker informs the rider with a short sound as they ride in. When riding on sidewalks the sounds run continuously to warn nearby pedestrians.

The benefits of such AI applications for micromobility are threefold:

- **For cities**, it means improved safety, scooters are parked and used at the right places
- **For riders**, it is more convenient to find available scooters and to ride them safely
- **For pedestrians**, it is easier to hear scooters approaching when they are on a sidewalk

4.1.1.Traffic management operations

4.1.1.1. Traffic management on the ground

AI can be applied to emerging traffic scenes, providing the driver with the best options to avoid unexpected traffic jams, and identifying alternative routes most likely to be congested by displaced traffic[43]. AI can optimise logistics with smarter route planning using both historical and real-time data.

- **Forecast traffic and optimise logistics**
  AI's processing, control and optimisation capabilities have been applied to traffic management and decision-making systems to enhance and streamline traffic management and make our roads smarter, i.e., smart traffic light systems.

Be-Mobile	Founded in 2006, 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, Original Equipment Manufacturers (OEMs) and government agencies to port authorities and parking operators.
Siemens Mobility	In Hagen, Germany, Siemens Mobility are using AI 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.

Table 6: European Examples of AI Applications in Traffic Control

- **On-demand bus services**
  On-demand bus services operate under flexible schedules and routes to improve conventional bus efficiency. The flexible services provide the door-to-door convenience of taxis at a fraction of its costs along with the efficiency of the bus model[44].

Tele-Bus on-demand transport	The municipality of Niepołomice 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 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.

Table 7: European Examples of AI Applications in On-Demand Transport

- **Vehicle tracking on transport networks**
  The Automatic Vehicle Location (AVL) system can improve operational efficiency of public transport, manage operational control, and enhance overall quality of public transport services. It extracts data to track transportation units in real time by using GPS signals, detects problems to inform vehicles on any changes and manage alternative routes. For example, in Portugal, by interacting AVL data with machine learning, it increased the performance of AVL system for planning bus schedules and could evaluate whether a change in a schedule will meet the network needs[45].

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 30 seconds. Such data is used to enhance the reliability of bus services, prioritise movement of buses at traffic signals; and provide information to passengers about the bus schedule near bus stops.
iBus system	The iBus is an Automatic Vehicle Location (AVL) system to improve London's buses using technology installed by Siemens AG. The system tracks all of London's 9,300 buses to provide passengers with audio visual announcements, more accurate information on bus arrivals, and to trigger priority at traffic junctions.

Table 8: European Examples of AI Applications in Vehicle Tracking

4.1.1.2. Air traffic management

AI has been acknowledged as more effectively managing aviation, including intelligent maintenance and flight route optimisation[46].

- **Fuel planning and optimisation**: based on data such as route distance, weather conditions, aircraft types, altitudes, aviation AI can predict the optimal amount of fuel needed for a specific flight.
- **Prediction of flight movements**: AI can be used to predict flight movements, increase safety when an airplane is landing, help avoid deviation from a pre-determined route, and enhancing air traffic control management.
- **Predictive maintenance**: Airlines can decrease delays and flight cancellations and significantly increase safety by deploying aviation AI's predictive maintenance for their airplane fleet.

Frankfurt Airport's AI's prediction on aircraft arrivals	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 daily 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 companies' 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 touchdown on one of Frankfurt's runways.

Table 9: European Examples of AI Applications in Air Traffic Management

4.1.2. Automatic passenger transportation

4.1.2.1. Self-driving cars

The global autonomous cars market reached a value of nearly $818.6 billion in 2019, the number has declined in 2020 due to the COVID-19 outbreak. It is then expected to recover and grow at a CAGR of 12.7% from 2021. The market is expected to reach €2633.86 billion in 2030 growing at a CAGR of 14.2%[47]. Automotive companies are running pilot projects, striving to make self-driving vehicles safe for passengers[48]. As this technology evolves, confidence in self-driving vehicles will grow and become mainstream in the consumer realm.

The more matured AI functions include automated valet parking and in-vehicle infotainment systems. For instance, the vehicle assistance systems and in-vehicle infotainment 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, and are able to be controlled via simple voice commands and hand gestures. AI software is 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.

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 10: European Examples of AI Applications in Autonomous Vehicles

4.1.2.2. Driverless buses

The rapid evolution of AI-powered autonomous technology has made it possible to have autonomous vehicles (AVs) for public passenger transport. Using sensors, cameras, GPS technology, and AI, buses are capable of carrying passengers to their destination without direct human intervention. The world's first driverless bus was introduced in 2016 to the French city of Lyon. In 2018, Stockholm introduced driverless buses that can travel at 20 miles per hour (mph)[49]. Small scale autonomous bus trials have been initiated all over the world, most prominently in Finland, Singapore, and China. The global non-uniformity in built-up structures, city infrastructures, road surfaces, weather patterns, traffic patterns etc. rely on AI applications to detect vehicles surroundings. AI can help autonomous trucks for on-time delivery of goods that are highly environment specific[50].

Sensible 4	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	Applied Autonomy delivers 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, Norway.

Table 11: European Examples of AI Applications in Driverless Buses

4.1.2.3. Autonomous taxis

Autonomous taxis aim to reduce service costs and increase public transportation modes within remote areas and are already operational in Tokyo, Japan.

NEVS and AutoX	Founded in 2012 in Sweden, NEVS design premium electric vehicles and mobility experiences that are simple, engaging, and distinctive, but that also contribute to shaping a cleaner future. In 2019, NEVS partnered with autonomous vehicle start-up AutoX to integrate their autonomous drive technology in NEVS' next-generation vehicle architecture, resulting in the deployment of Robotaxi pilots.

Table 12: European Examples of AI Applications in Autonomous Taxis

4.1.2.4. Drone taxis

AI is contributing to a roadmap where aircraft no longer need to have a pilot. Drones often incorporate AI, which enables them to use data from attached sensors to collect and implement visual and environmental data. This data enables autonomous or assisted flight, making operation easier, and increasing accessibility[52].

eVTOL vehicle (Lilium)	Lillium's all-electric, vertical take-off air taxi transported 5 passengers autonomously using AI. 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 VoloCity, the company is developing the first fully electric 'eVTOL' aircraft in certification to transport passengers safely and quietly 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'.

Table 13: European Examples of AI Applications in Flying Drone Taxis

4.1.3. "Robotisation" of logistics

4.1.3.1. Autonomous trucks

AI can streamline and optimise logistic processes by supporting different forms of autonomous trucks:

- **Unmanned last-mile delivery vehicles**: Unmanned ground vehicles can use AI to autonomously deliver packages from distribution centres to end customers. The last mile delivery robot can help take over the last step in the delivery process.
- **Route optimisation**: Neural networks help logistics companies in planning trips optimally, to minimise the number of empty runs.
- **Platooning of trucks**: Driverless truck platooning consists of vehicles which drive closely and communicate with each other through wireless communication technology. This will be beneficial to fuel economy due to a smaller distance between vehicles. Platooning can also be flexible and efficient since no rest time is required even in a long journey.

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.

Table 14: European Examples of AI Applications in Autonomous Trucks

4.1.3.2. Cargo transportation — Crewless Ships and Railway

Railway systems can be optimised by using sensors placed on rail switches to collect real-time data. AI analysis of the data can help to predict possible failures and decrease costs due to system downtime. AI is also being used to create crewless cargo ships. Rolls Royce has partnered with Google to create autonomous ships using sensors that track engine performance. AI technology will make shipments faster, ensure safety in bad weather[53] and make loading and unloading of cargo crewless.

Yara International	The vessel YARA Birkeland will be the world's first fully electric and autonomous container ship, with zero emissions.
Kongsberg	The UK's Automated Ships Ltd and Norway's Kongsberg Maritime 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 15: European Examples of AI Applications in Cargo Transportation

4.1.3.3. Predictive planning

AI can be used to predict the demands of goods. Supply chains, inventories and truck allocation can be optimised by AI, saving costs by avoiding an over or undersupply of goods according to demand.

4.1.4. Automotive industry

A digital twin is a virtual representation of a factory, product, or service. Producing an evolving profile of an asset or process in a plant, digital twins paired with AI captures insights on performance across the lifecycle. Digital twins are becoming increasingly important in transforming industrial operations and creating additional business value.

Siemens PAVE360	Siemens' Pave360 digital twin product, which incorporates Arm technologies, applies high-fidelity modelling techniques, incorporating everything from sensors and integrated circuits to vehicle dynamics and the environment cars operate in. PAVE360 provides a comprehensive environment for multi-supplier collaboration across the automotive ecosystem for the development of next-generation automotive chips. PAVE360 enables capabilities for full, closed-loop validation of the sensing/decision-making/actuating paradigm at the heart of all automated driving systems. This principle hinges on rigorous pre-silicon validation of deterministic (rules-based) and non-deterministic (AI-based) approaches to safe self-driving in the context of the full digital twin.

Table 16: European Examples of AI Applications in Digital Twins

In the automotive industry, 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[54].

4.1.5. Insurtech

Car insurance companies will be significantly impacted by the development of autonomous cars. This transition will require new processes, products, legal adaptation, and new models to estimate risk[55]. In the case of an accident, the connected car will be able to not only signal the local authorities for help, but also automatically report its state and the conditions under which the accident occurred. This will enable involved parties, including insurance companies, to minimise the effort required to analyse the incident, coordinate the activities, and resolve responsibilities and claims.

L'olivier Shift	L'olivier, 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. 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, etc), Shift recovers and analyses external information such as meteorological data, satellite images and even web data. The data increases the appraisal abilities of the AI model, thanks to the creation and balancing of new variables, and allows potential fraud to be reported in a very precise manner.

Table 17: European Examples of AI Applications in Car Insurance

4.2. AI Applications in Other Sectors

4.2.1. Buildings and cities

Buildings and cities represent 20% of global emissions. Leading European cities and companies have pledged to slash carbon emissions from their buildings to net zero. Helsinki, Finland and Valladolid, Spain signed the World Green Building Council's (WorldGBC) Net Zero Carbon Buildings Commitment, alongside property sector leaders BuroHappold, Carbon Credentials, Deerns, Grimshaw Architects, Grosvenor Group, Newsec Finland and Ylva[56].

AI technologies have wide applications in the smart city sector. For instance, AI control systems can be used to improve energy efficiency by incorporating data from smart meters and the Internet of Things (IoT). AI technologies assist to forecast energy demand and reduce a building's energy consumption by taking weather forecasts, building occupancy, and other environmental conditions into account. The AI applications adjust the indoor heating, cooling, ventilation, and lighting[57].

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 18: AI Strategies to Mitigate Greenhouse Gas Emissions[58]

Building utilities need better ways of predicting energy consumption to forecast supply and demand in real time. AI application predictions are based on local weather, climate patterns and household behaviour[59].

Building Utility Management	Forecasting supply and demand Improving scheduling and flexible demand Accelerating materials and fusion science Managing existing technologies
Reducing current-system impacts	Reducing life-cycle fossil fuel emissions Reducing system waste Modelling emissions
Ensuring global impact	Improving clean energy access Exploring low-data consumption mode

Table 19: AI Opportunities to Reduce Greenhouse Gas Emissions from Electricity Systems[60]

4.2.2. 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[61]. The EU parliament declared a global climate and environmental emergency on 28th November 2019. The declaration emphasises the development of renewable energy sources and high-capacity batteries to store energy and power electric vehicles. AI will be a powerful tool in reducing greenhouse gas emissions and helping society adapt to the changing climate[62].

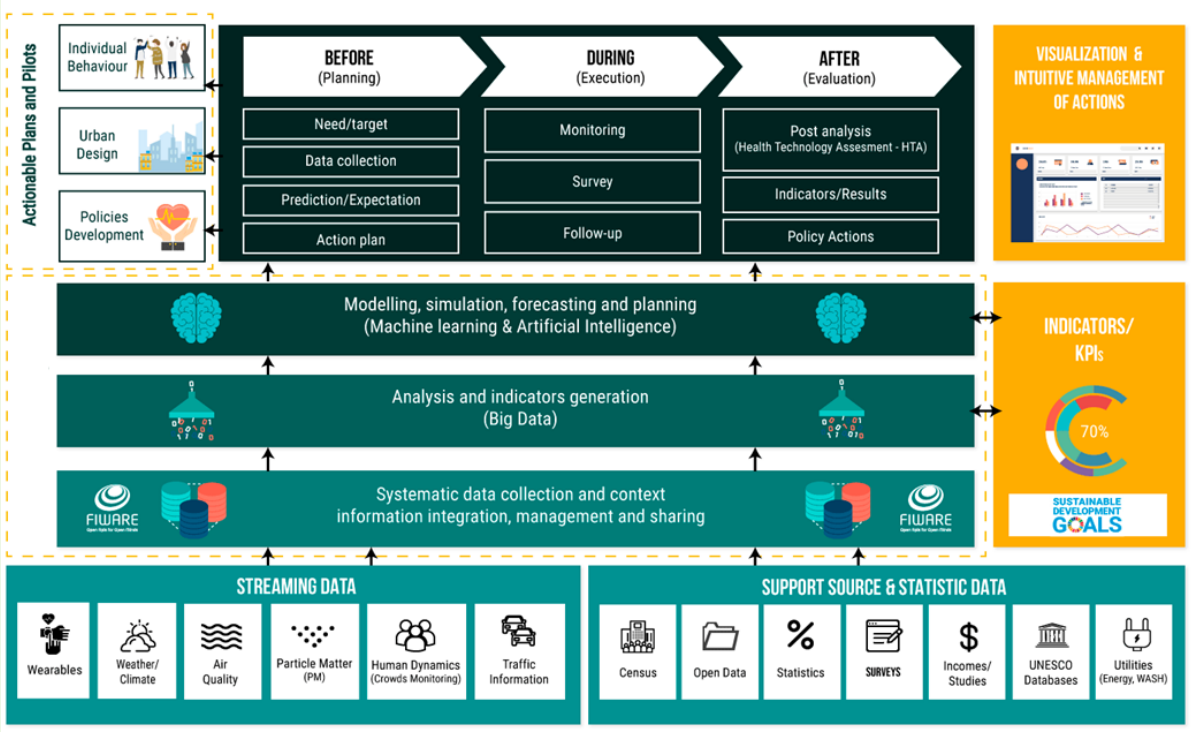
CASE 4

HOPU

HOPU solution brings a suite of dashboards with CO2 indicators related to mobility founded on predictive models based on real-time air quality measurements and AI to optimise the traffic flows in cities and ports over FIWARE open platform.

It allows third parties to provide high-value green and innovative mobility services for citizens, companies, and public administrations. This tool is focused on the decision-makers, providing a set of functionalities to analyse and simplify large amounts of data related to mobility and its impact. By leveraging on high-value open data, private data and satellite data sets available in the cities, **this process provides a context for the real-time data that allows the definition of new correlations and, for that reason, new mobility and urban design aspects that affect air quality.**

HOPU helps to mitigate the emissions, i.e. CO2 eq tons emissions from pollutant gases as NOx, H2S, SO2 and particles as PM10, by establishing correlations and context analysis. The solution will optimise the traffic flow in the cities and ports, providing models and indicators for potential optimisation actions such as creating low emission zones, the location of EV charge spaces, and the inclusion of alternative mobility solutions.



Artificial Intelligence is the main driver building a smart infrastructure to process, correlate and create new models to optimise the mobility for the CO2 eq. emissions reduction. These models are based on the analysis of data collected by sensors developed by HOPU (Smart Spot) and other existing data sources about mobility, traffic, and environmental data. They allow real-time analysis that will serve as the basis for developing applications for our customers that will enable them to make better decisions based on data contextualisation. These new functionalities will allow us to move from a system that only provides data to the client to a new intelligent service that advises and allows estimates (prediction) on future values.

The impact on cities and citizens is based on improving urban health and climate change mitigation, providing a clear structure for urban authorities' informed decision-making to reduce CO2-eq emissions. The solution is being supported by AI4Cities and Madrid city hall to identify the Low Emission Zones' evolution of nanoparticles (Madrid Central).

Global agricultural production must increase by 70% to feed the estimated 10 billion population by the year 2050. AI enables precision agriculture that enables waste management and reduces carbon emission while improving crop yield. AI is also a helpful tool in predicting food demand. AI helps to apply variable rates of inputs (irrigation water, fertilisers, pesticides, etc.) according to the actual needs of different areas in a field[63]. As a work package leader in the European Union's Horizon 2020 funded IoF2020 project, BioSense 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. It also aims to make IT an important tool to drive small farms towards sustainability, developing a free digital platform "AgroSense" to support farmers in decision making and field management.

4.2.3. Manufacturing Sector

The manufacturing industry represents 30% of global carbon dioxide emissions. Technologies are being developed to help manufacturers reduce both power usage and toxic emissions. Additionally, these technologies have the power to increase productivity, manufacturing efficiency and the discovery of new materials. It is estimated that by 2035, AI-powered technologies could increase labour productivity by up to 40%[64].

Value Chain	Functions
Product	Quality checks Generative design Discover new materials
Operations / logistics	Predictive maintenance Supply chain communication and price forecasts Digital twins Robotics
Distribution	Potential Customer Attraction and Existing Customer Repeat Customer Interaction Order Processing and Payment Order Delivery and Customer Care

Table 20: Opportunities of AI in Transforming Manufacturing Sector

4.2.4. Healthcare Sector

From hospital care to clinical research, drug development and insurance, AI applications are revolutionising the health sector – helping to reduce spending and improve patient outcomes[65]. A EIT Health report shows that since 2010, €7 billion of venture capital has been invested in the 50 best-funded AI companies in healthcare[66]. EU public healthcare systems hold a treasure trove of healthcare information at the population level that, if linked, could provide distinct advantages in accelerating AI adoption in healthcare.

Start-up executives put more emphasis on consumer-facing solutions, such as self-care, prevention and wellness, or triage and diagnosis[67]. It 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. The following table demonstrate the AI applications in healthcare in different areas.

Category	Sub-category
Chronic care management	Remote diagnoses and patient triage Cardiovascular and medication management
Self-care, prevention, and wellness	Enabling remote patient monitoring AI for personalised care Reducing self-harm
Triage and diagnosis	Assessing and scoring chronic disease risk Identifying early-stage disease
Diagnostics	Improving medical diagnosis Detect a disease
Clinical decision support	
Care delivery	
Others	Population-health management Healthcare operations management Healthcare innovation

Table 21: Areas of AI impact in healthcare

4.2.5. Cyber Security

Histories of online behaviour build profiles on users, assets, and networks, allowing AI to detect and respond to deviations from established norms. AI prediction tools introduced with proper precautions and regulations in place have the potential to lessen or remove human bias as opposed to substantiating its effects. For example, the EU, 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.

AI is also a critical technology in information security because it can quickly analyse and identify many different types of threats such as malware exploiting zero-day vulnerabilities (a software security flaw that is known to the software vendor but does not have a patch in place to fix the flaw). Automated attacks and so-called 'advanced and persistent threats' (APT) require security developments from equally advanced defence systems equipped by AI capabilities.

4.2.6. Education Sector

AI enables the application of new educational models oriented to personalised learning. It facilitates the evaluation and identification of high competences in students (predictive models), the treatment of students with functional diversity (learning analytics), new tutoring models (intelligent tutoring systems), recommendation and feedback systems, and prediction of early failure and detection of struggling students. This will allow students to play a more active role in their learning by understanding and optimising their processes. Additionally, it would help educators to identify and support those students who require assistance.

4.3. Risks of AI deployment

Apart from the many benefits that AI can offer, particularly for building a more sustainable planet, it also poses both short-term and long-term risks on individuals, organisations, society, and the environment. The following table categorises and summarises risks and potential impacts (Figure 11).

Risks of AI Deployment

Performance

Early-warning systems for natural disasters such as flooding are developed using historical data of weather patterns.
A lack of understanding of factors driving model predictions can create 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.

Control

Smart energy optimisation would see each building operate individually, assessing overall demand patterns to determine low-cost energy-use approaches. On a wider scale, smart-energy optimisation would allow for interactions between buildings and infrastructure. Interactions between buildings could potentially alter demand and crash regional energy systems.

Security

Misuse of AI could occur when systems fall into the wrong hands. Hackers could access automated warning systems, distributed energy grids or connected autonomous transport platforms, and cause significant disruptions or disasters. Poachers could profit from endangered-animal tracking tools meant for conservation efforts.

Social

Autonomous trucks and cars, along with energy-efficient IoT manufacturing, could lead to considerable unemployment. Goldman Sachs estimates that the US will lose an estimated 300,000 jobs per year when AV saturation peaks. Regional economic decline, widening social inequality and unrest could also follow in manufacturing towns or along truck routes.

Rebound Effects

AI relies on more computers and can thus have a large carbon footprint. A recent study from University of Massachusetts estimated training a large natural language processing model would produce 300,000 kilograms of carbon dioxide emissions (Strubell et al., 2019).[74] The rebound effects of more efficient technical infrastructures need to be understood and steps need to be taken to ensure it does not lead to an increase in fossil fuel consumption[75]

Environmental

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.

Ethical

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]

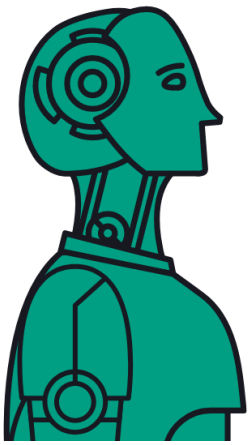


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Figure 11: Risks of AI Deployment

5. Concluding Remarks

Rapidly developed technologies, such as AI and IoT, are leading to a Fourth Industrial Revolution completely unlike its predecessors. Thanks to these technologies, the way we live, work, and relate to one another is exponentially changing. AI can utilise the collection of large amounts of information to make interpretations, assist judgement and generate insights that are beyond human manual processing capabilities.

The widespread adoption of AI raises serious ethical challenges. Despite this, there is no globally agreed set of standards. In the absence of such a global agreement, the EU has developed an AI strategy focused on ensuring 'humans remain at the centre of AI development, and to prevent the harmful creation and use of AI applications'.

Solid technological and industrial foundations, world leading research and academic institutions, high levels of international AI research collaboration, advanced digital infrastructure, and evolving regulatory framework means the EU has potential to generate more cross-nation collaboration and to take a leading role, particularly in 'ethical AI'.

There are different types of AI business models depending on the nature of the companies' role (developers and adopters). Three major revenue models including AI Application-as-a-Service, AI Infrastructure-as-a-Service and AI technical and management consulting shed light on how AI companies are developing themselves and engaging with customers. Data collaboration is very common among AI companies regardless of their size, and a revenue-sharing model could facilitate this collaboration.

European AI development and deployment is at an early stage. The largest barriers to deployment identified in the EIT survey were lack of technical feasibility, data availability and quality, and budget. Whilst cybersecurity, compliance, and personal privacy were raised as the top three risks.

Suggestions to accelerate and optimise deployment of AI are summarized in the infographic on the next page.

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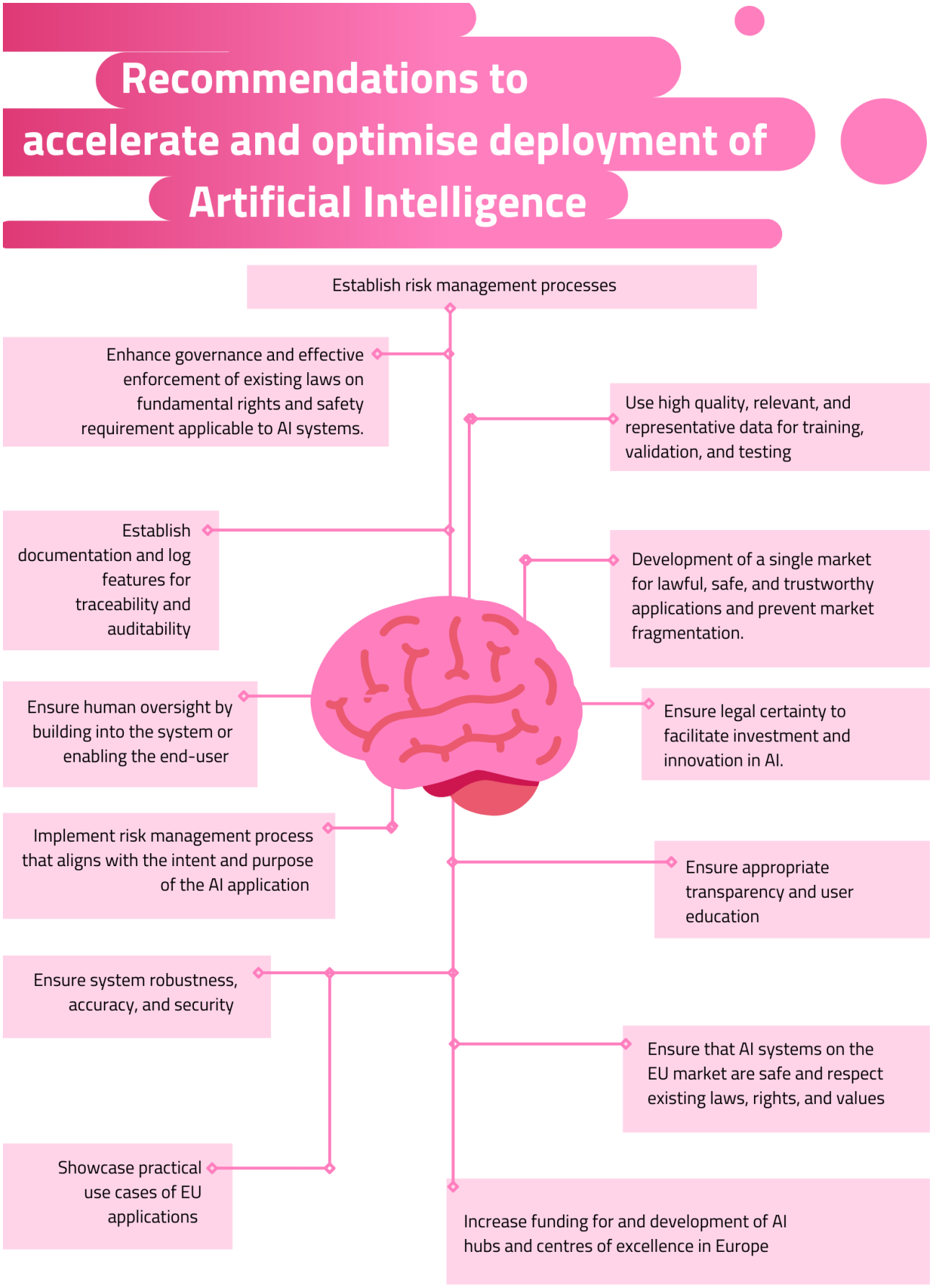

Figure 12: Recommendations to Accelerate and Optimise Deployment of AI

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