McKinsey&Company

The AI revolution

How artificial intelligence will change business in Poland

In cooperation with

Forbes

PL

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2017

Digital/McKinsey

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Preface

The AI revolution: How artificial intelligence will change business in Poland is a report by McKinsey & Company developed in cooperation with Forbes Poland. It investigates the adoption of artificial intelligence (AI) globally and in Poland, investment in the field, the potential of AI technology, and the steps that can create an ecosystem for AI in Poland.

The report reflects McKinsey's deep commitment to the development of the Polish economy and its success on the global stage. It aims to provide a fact-based perspective on how the country can accelerate growth in the next decade by using the latest technology. The ideas it presents build on those outlined in the previous reports *Digital Poland*, *Digital Poles*, *Poland 2025: Europe's new growth engine*, and *5 opportunities for Poland*.

We would like to take this opportunity to thank Paweł Zielewski, Editor in Chief of Forbes in Poland, for his contribution, inspiration, and guidance. The work on this report was led by the following individuals: Marcin Purta, Managing Partner at McKinsey & Company's Warsaw Office; Daniel Boniecki, Senior Partner and Leader of the Telecommunications, Media, and Technology Practice in Central and Eastern Europe, Middle East, and Africa; Tomasz Marciniak, Partner; and Wojciech Krok, Local Partner. They worked together with a team consisting of the consultants Zuzanna Kraszewska, Dariusz Smoleń, Adam Sokołowski, and Gustaw Szarek, with Joanna Iszkowska, Communications Manager, and Małgorzata Leśniewska and Robert Wielogórski, Senior Visual Graphics Specialists.

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This report is based on the McKinsey Global Institute (MGI) discussion paper *Artificial Intelligence: The next digital frontier?* (June 2017) by the following authors: Jacques Bughin, Senior Partner based in Brussels; Eric Hazan, Member of the MGI Council and Senior Partner based in Paris; Sree Ramaswamy, Partner based in Washington, DC; Michael Chui, Partner based in San Francisco; Tera Allas, Senior Fellow in London; Peter Dahlström, Senior Partner in London; Nicolaus Henke, Senior Partner based in London; and Monica Trench, Consultant based in London. It also draws on three previous publications by MGI, namely: *Digital America: A tale of the haves and have-mores* (December 2015); *Digital Europe: Pushing the frontier, capturing the benefits* (June 2016); and *A future that works: Automation, employment and productivity* (January 2017). We would like to thank the authors of these reports for sharing their expertise and insights with us.

In brief

Artificial intelligence (AI) is poised to unleash the next wave of digital disruption, and companies in Poland should prepare for it now. Globally, we are already seeing real-life benefits for early adopters. That makes it more urgent than ever for Polish companies to speed up their digital transformation and join the AI revolution.

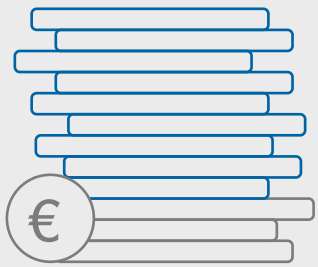
- Global AI investment, although still in its infancy, is growing fast. It is currently dominated by a few global digital giants, who spent an estimated €18-27 billion on AI in 2016, 90 percent of it on R&D and deployment. The remaining 10 percent was directed toward internal investments, including mergers and acquisitions.
- In Poland, as in most European countries, AI investment is at an early stage of development. It is mostly driven by grants and venture capital, amounting to around €11 million in 2016. This was roughly the same level as seed and venture-capital investment in AI in Sweden, a globally recognized technology hub.
- The majority of Polish AI developers are companies with experience in IT that are developing solutions for specific applications, especially in the areas of healthcare, media and entertainment, and manufacturing.
- Globally, the leading sectors in terms of digitization, such as telecommunications, financial services, and high tech, are also the first to adopt AI. This is the same in Poland, where several companies are already experimenting with AI, especially in the financial services and telecommunications sectors.
- Early evidence suggests that AI can deliver real value. The case studies that we present in this report, drawn from the retail, manufacturing, healthcare, and electric utilities sectors, highlight the potential of AI for boosting Polish business. In particular, we show how AI can improve forecasting and sourcing, optimize and automate operations, help companies develop targeted marketing, and enhance the user experience.
- AI – like all innovations – also poses some urgent challenges for government, companies, and workers. In particular, AI-powered automation could change the character and structure of employment. However, contrary to popular opinion, adoption of AI so far has increased demand for human labor, due to significant increases in productivity. AI will doubtless create new professions and many more will be fundamentally altered thanks to human-machine collaboration.
- Poland has the potential to become a regional center for the development of AI. The country has a large number of graduates in science and technology and a dynamic startup ecosystem, which enables the formation of future AI specialists. Moreover, the scale of investment needed to develop AI technology is relatively small compared to, for example, industry, which requires major investments in plants and machinery. In recent years, AI has seen successful implementation in specific applications and uses. This opens the way for smaller firms to develop in Poland. However, developing Poland as a center for AI requires not only the involvement of businesses but also decisive action by government in regulating data collection, training future AI specialists, investing in higher education, and so on.
- Effectively adopting AI requires a solid foundation, including access to large amounts of data. There are no shortcuts – companies in Poland cannot delay starting out on their digital journey. They should also make sure that they address all aspects of their digital transformation, identifying potential benefits and developing a business case, setting up the right data ecosystem, building or buying appropriate AI tools, and adapting their processes, capabilities, and culture.

THE AI REVOLUTION

How artificial intelligence will change business in Poland

Where are we today?

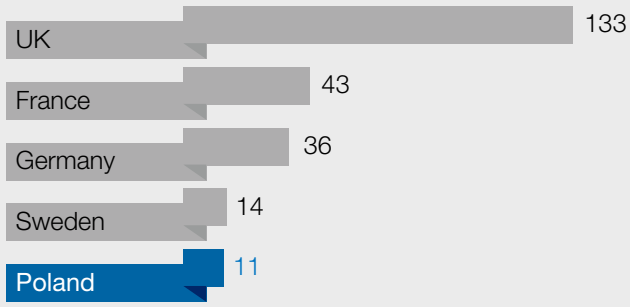
Investments in AI in 2016



Tech giants
€18-27 bn

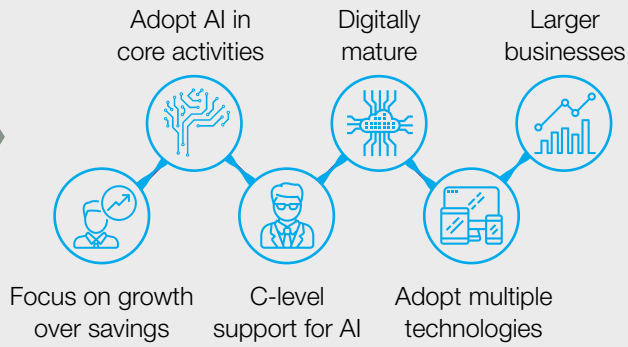
Startups
€5-8 bn

Seed and venture capital invested in AI (2016, € m)

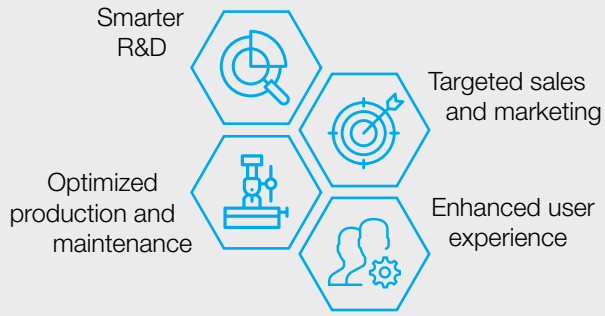


What are early AI adopters like and how can AI create value?

Six characteristics of early AI adopters



Four areas of the value chain where AI can bring benefits



What is the key to successfully implementing AI?

Country-level activities

1. Nurture local AI talent
2. Prepare the workforce
3. Build local AI industry
4. Ensure training data for algorithms
5. Deploy AI within public institutions
6. Resolve ethical, legal, and regulatory issues
7. Start the debate now

Company-level activities

1. Identify where AI adds value
2. Build the data ecosystem
3. Identify required techniques
4. Integrate AI into fundamental business processes
5. Create an open culture and organization

Artificial intelligence is getting ready for business, but are businesses ready for AI?

Claims about the promise and peril of AI are abundant and growing. AI, which enables machines to exhibit human-like cognition, can drive our cars or steal our privacy, stoke corporate productivity or empower corporate spies. It can relieve workers of repetitive or dangerous tasks. Twice as many articles mentioned AI in 2016 as in 2015 and nearly four times as many as in 2014[1]. Expectations are high.

In fact, AI has been around since the late 1950s. Its history abounds with booms and busts, extravagant promises and frustrating disappointments. Is it different this time? New analysis suggests yes: AI is finally starting to deliver real-life business benefits. It is not science fiction – real and early evidence shows that this time it will radically change the world. Leading AI expert Andrew Ng says that AI is "the new electricity" that will transform every sector of the economy[2]. The AI revolution at some point will mean machines enhancing human brain power, completely transforming the way we work, communicate, act, and do business. Poland should not miss out on this revolution.

Still, analysts remain divided as to the potential of AI: some have formed a rosy consensus about AI's potential while others remain cautious about its true economic benefit. This lack of agreement is visible in the large variance of current global AI market size forecasts, which range from €0.6 to €114 billion by 2025[3].

MACHINE LEARNING AND HUMAN-LIKE INTELLIGENCE

There is no universally accepted definition of AI. However, it generally refers to the ability of machines to exhibit human-like intelligence – for example, solving a problem without the use of hand-coded algorithms.

The broader public became particularly aware of the power of AI in 2016, when the AI computer program AlphaGo beat a professional human player of the board game Go[4]. This achievement is all the more significant as Go has a much higher number of potential combinations than chess does.

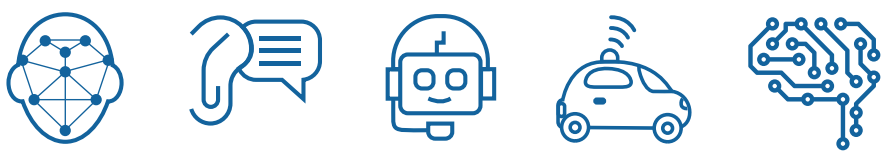
AI is already present in products such as Apple's Siri and Amazon's Alexa. It answers our questions or helps us organize our day. It's in our car, which parks autonomously while we run for the next meeting. Kiva robots in Amazon's warehouses collect our order; virtual chatbots conduct early diagnosis and direct us to the appropriate doctor during hospital visits. These are just some of the early examples of how AI is being used: many more applications are now reaching the market, changing the way in which we live and work.

There are several ways to categorize different AI technologies. The AI technologies that we consider in this paper are what are called "narrow" AI-technologies that perform one narrow task while working within defined rules: for example, Apple's Siri, as opposed to artificial general intelligence, or AGI, which aims to perform any intellectual task that a human can do. We focus on narrow AI because it has near-term business potential, while AGI has yet to deliver a business case[5].

In this report, we focus on the set of AI technology systems that solve business problems. We have categorized

Exhibit 1

Five key areas of artificial intelligence development – machine learning is the key enabler



these into five technology systems that are key areas of AI development: robotics and autonomous vehicles, computer vision, language processing, virtual agents, and machine learning (Exhibit 1).

The last of these five areas, machine learning, is particularly important. It is based on algorithms that learn from data without relying on rules-based programming in order to draw conclusions or direct an action.

Together with its subfield of deep learning[6], machine learning is at the heart of many recent advances in AI applications. It has attracted a lot of attention and a significant share of the financing that has been pouring into the AI universe – almost 60 percent of all investment from outside the industry in 2016.

A MATURE TECHNOLOGY – AFTER YEARS OF EXPERIMENTATION

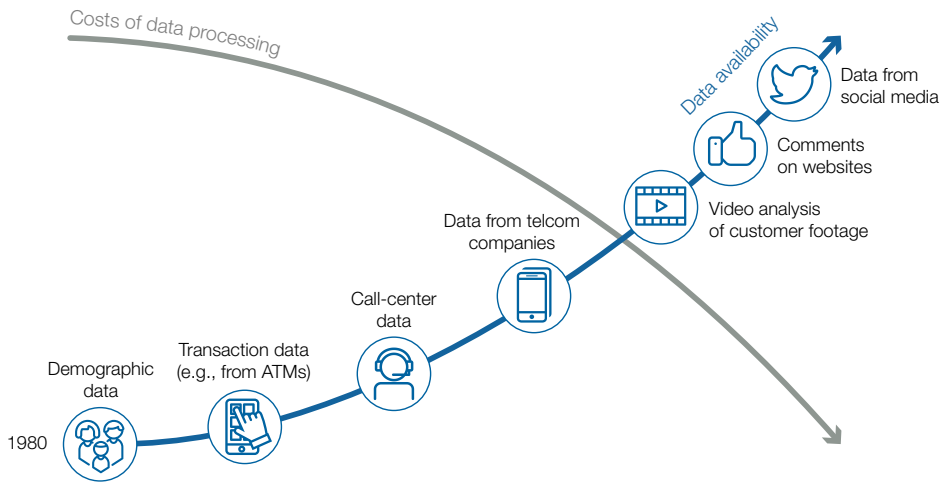
The idea of computer-based AI dates back to 1950, when Alan Turing proposed what has come to be called the Turing test: can a computer communicate well enough to persuade a human that it, too, is human? AI, like digital technology, has ridden waves of hype and gloom, with one exception: AI has not yet experienced wide-scale commercial deployment. That may be changing.

The ingredients for a breakthrough are in place. The world is generating vast quantities of the fuel that powers AI. Data algorithms are becoming more sophisticated, and powerful graphics processing units (GPUs) have brought new levels of mathematical computing power.

GPUs are specialized integrated circuits originally developed for video games. Adapted to AI, they can now process images 40 to 80 times quicker than the fastest traditional processors available in 2013. Advances in the speed of GPUs have enabled the training speed of deep learning systems to improve five- or sixfold in each of the last two years, and this is not even the most recent breakthrough in data processing hardware. Google, for example, has developed a customized chip for its platform that, as the company says, is able to execute machine learning code up 30 times faster than conventional chips[7].

What is perhaps even more important is that the world creates about 2.2 exabytes, or 2.2 billion gigabytes, of data every day (Exhibit 2). For AI, this translates into more insights and higher accuracy. It exposes algorithms to more examples that they can use to identify, correct, and reject incorrect answers. Machine-learning systems enabled by these torrents of data have reduced computer error rates in some applications – for example, in image identification – to about the same or an even better rate than for humans. Five years ago, machines were able to get image recognition right 70 percent of the time, while humans succeeded in 95 percent of cases. Today, machines have gone up to 96 percent[8].

Finally, interest in AI applications is starting to come directly from global tech leaders. Previous waves of AI development were mostly based on research from scientific institutes and funded with public finance. But nowadays the key AI research and breakthrough achievements are driven by technology



Approx. 80% of all data available today are estimated to have been generated in the past 2 years

50 billion devices will be connected to the Internet by 2020 – the Internet of Things

SOURCE: Dave Evans, "The Internet of Things: How the Next Evolution of the Internet Is Changing Everything", April 2011; McKinsey analysis

Exhibit 2

The amount of data available has boomed in recent years, while the cost of storage and processing has fallen dramatically

giants. This is important to bear in mind in the context of Poland, where no significant local tech giants exist and AI investment is still mostly the preserve of startups. In Chapter 3, we explore in more detail how Poland can strengthen its AI development and improve its adoption ecosystem.

INVESTMENT IS GROWING, BUT COMMERCIAL ADOPTION OF AI LAGS BEHIND

Globally, tech giants and digital native companies such as Amazon, Apple, Baidu, and Google are investing heavily in various AI technologies. The McKinsey Global Institute estimates that investment by tech giants amounted to between €18 billion and €27 billion in 2016, with internal corporate investment constituting 90 percent of this and M&A investment 10 percent. The buzz over AI has grown loud enough to encourage venture capital and private equity firms to step up their investment in AI. External investment from VCs, PE firms, grants, and seed funding was around €5 billion to €8 billion (Exhibit 3)[9].

Globally, AI development is dominated by the United States and China, with total external investment in 2016 estimated at between €5 billion and €7 billion in the US and between €1.5 billion and €2.5 billion in China.

In Poland, as in most other European countries, AI investment is still in its infancy. It has been driven mostly by grants and public-private venture capital funds supporting early-stage university startups. We estimate the total AI-related R&D and deployment grants spent in 2016 to be around €11 million, with an additional €21 million already declared for 2017.

The level of investment in AI in Poland is comparable to the amount of seed and venture capital invested in AI in Sweden (€14 million in 2016), a country known as a European digital hub with its famous firms such as Spotify. However, Poland is far behind France and the United Kingdom, the latter being the European leader (Exhibit 4). London is a global AI hub thanks to its mix of strong talent supply, funds availability, and the presence of companies supporting AI applications.

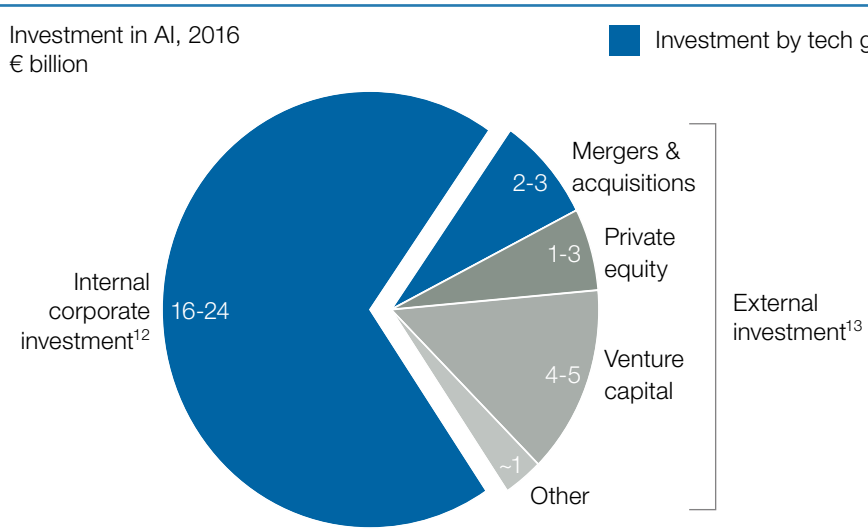
Despite the relatively small scale of investment from a global perspective, Poland has produced numerous examples of companies that have become recognizable, regionally at least, as promising developers of AI. Some already have a significant international presence. We identify 59 such firms, some examples of which we present in Box 1 (page 12).

Globally, most of the investment in AI has consisted of internal spending, R&D, and deployment by large, digital native companies. What is the large corporate investment in AI focused on? Amazon is concentrating on robotics and speech recognition, Salesforce on virtual agents and machine learning. BMW, Tesla, and Toyota are among the manufacturers making sizable commitments in robotics and machine learning for use in driverless cars. Toyota, for example, set aside $1 billion to establish a new research institute devoted to AI for robotics and driverless vehicles[10]. Industrial giants such as ABB, Bosch, GE, and Siemens also are investing internally, often in machine learning and robotics, seeking to develop specific technologies related to their core businesses. IBM has pledged to invest €3 billion in its Watson system, which is able to use natural language. The goal is to use the supercomputer to process large amounts of data generated from Internet of Things (IoT) solutions[11].

At the same time, big tech companies have been buying up AI startups, not just to acquire technology or clients but to secure qualified talent. The pool of true experts in the field is small, and Alibaba, Amazon, Facebook, Google, and other tech giants have hired many of them. Using M&A as a way to

Exhibit 3

Technology giants dominate investment in AI



SOURCE: Capital IQ; Pitchbook; Dealogic; S&P; McKinsey Global Institute analysis

acquire experts is a practice often known as "acqui-hiring" and involves sums that typically work out to €5 million to €10 million per person. According to a study by Paysa published in April 2017, US companies are seeking to fill 10,000 AI-related jobs and have budgeted more than €650 million for salaries[14].

Companies are also expanding their search for talent abroad. We can already observe this in Poland and the rest of Europe. Facebook, for instance, has opened an AI lab in Paris that will supplement similar facilities in New York and Silicon Valley and make it easier for the company to recruit top researchers in Europe[15].

To assist in their search for talent, companies are also setting up external R&D centers specializing in AI technologies. Google, for example, has built an R&D center in Paris. It has also acquired a number of French startups: Moodstocks, for example, was acquired in 2016 to improve visual recognition capability in Google's image and video-based products[16]. Recently, Google also launched R&D initiatives in Germany and Canada.

Poland is home to a large number of IT-related R&D and service centers working for top players (see Chapter 3). Some are beginning to work in the area of AI. For instance, at its R&D Institute in Cracow, Samsung already employs more than 2,000 specialists working on software in a number of relevant areas, including natural language processing (NLP)[17]. Intel's Compiler Center of Excellence in Gdańsk and TomTom's engineering center in Łódź are partly working in the field of AI, according to media reports[18]. And the Amazon Development Center in Gdańsk is also working on developing natural language processing technology.[19]

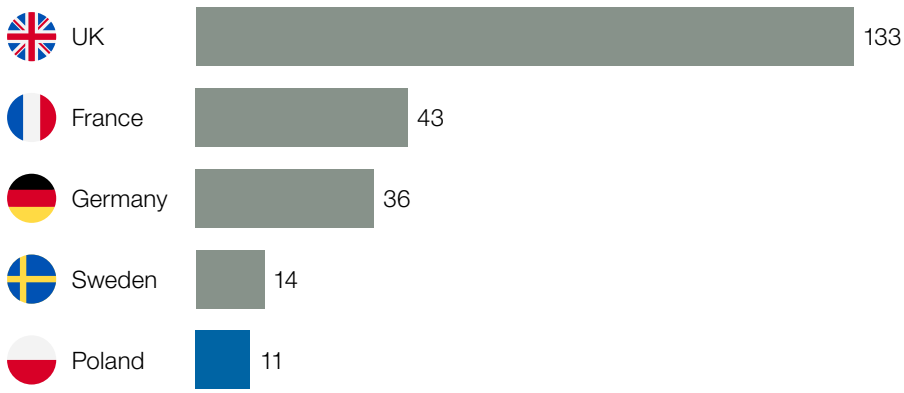
Some tech giants are actively searching for talent or planning investments in Poland. Google has had an engineering center in Warsaw since 2011, currently employing an engineering team of more than 160 people focused on developing the company's cloud portfolio, including machine and deep learning. In 2015, the company also opened Campus Warsaw – similar to its campuses in Tel Aviv, Seoul, São Paulo, Madrid, and London – to serve as a hub for entrepreneurs and developers[20]. Microsoft has announced that it will open a startup incubator in Warsaw focused on investing in startups working on AI, virtual and extended reality, the Internet of Things, and cybersecurity[21]. Siemens has reportedly announced plans to increase the scale of its cooperation with Polish businesses, universities and startups[22]. And Vienna Insurance Group (VIG) plans to identify and support the most innovative Polish startups, including an explicit focus on AI[23].

DEVELOPMENTS IN AI IN POLAND – EXPERIENCED TEAMS AND MACHINE LEARNING

Globally, among AI technology systems, machine learning attracts almost 60 percent of external investment. This is most likely because it is an enabler for so many other technologies and applications, such as robotics and speech recognition (Exhibit 5). In addition, investors are drawn to machine learning because, as has long been the case, it is quicker and easier to install new code than to rebuild a robot or other machine that runs the software.

The investment split is similar in Poland. Among the Polish startups in the field of AI that received funds in 2016, over 80 percent are developing machine-learning technology. Their work is mainly in the area of operational efficiency, fraud detection, customer forecasting, and healthcare diagnostic applications based on image recognition. A number of startups specialize in robotics, building autonomous robots

Venture capital and seed funds investment in AI, 2016[24]
€ million, selected European countries



SOURCE: Pitchbook; McKinsey analysis based on data from The National Centre for Research and Development, Polish Agency for Enterprise Development, Industrial Development Agency and The National Capital Fund

Exhibit 4

The level of AI investment in Poland is comparable to that of venture capital and seed funds investment in AI in Sweden

BOX 1. EXAMPLES OF POLISH AI STARTUPS WITH INTERNATIONAL PRESENCE OR UNIQUE TECHNOLOGY

IVONA

IVONA produces high-quality text-to-speech technology, voice guide, and explore-by-touch services. The company was acquired by Amazon in 2013, a move seen by many experts as a way to compete with Apple's Siri. IVONA is recognizable within industry thanks to the natural voice quality, accuracy, and ease of use[25]. As of September 2017, it offers 47 voices in 24 languages[26].

Growbots

Growbots was founded in 2014 and currently has offices in Warsaw, San Francisco, and Cleveland. It recently raised €2.3 million from Buran VC, Lighter Capital, and several angel investors. It provides a sales automation platform based on machine learning that, among other things, aims to find the right leads for sales teams and then conduct an automatic email campaign. Growbots has over 450 customers, most of them in the United States[27].

Nethone

Nethone is a Warsaw-based startup specializing in AI solutions for fraud prevention. Founded in 2015 by a team of data scientists, risk managers, and security specialists, it currently serves clients in Europe, North America, and South America. Its customer portfolio includes a major American airline, an online travel agency, and a leading video-streaming platform.[28]

deepsense.ai

Deepsense.ai provides deep learning solutions for enterprises. It was founded and is now managed by CodiLime, a company established by Polish computer scientists and mathematicians. Neptune, deepsense.ai's newest product, is a machine-learning platform designed to efficiently manage and monitor data-science experiments. The company lists Intel, IBM, Huawei, and BZ WBK among its clients and partners[29].

Neurosoft

Neurosoft is a Wrocław-based startup that develops speech, language, and image technologies. It specializes in intelligent transportation and road-safety systems and offers commercial solutions for the complex identification of vehicles in motion, including license plate, type of vehicle, manufacturer, and model name recognition in real time (less than 120 milliseconds). The system has already been implemented in Ankara, Turkey[30].

for specific industrial applications. And a few are developing virtual assistants and language technologies for Polish.

Interestingly, the Polish companies developing AI are mostly IT-experienced players with a market presence who are working on AI solutions for specific applications. In terms of targeted sector specialization, only 10 percent of AI companies receiving funds in 2016 are developing AI technology for general application.

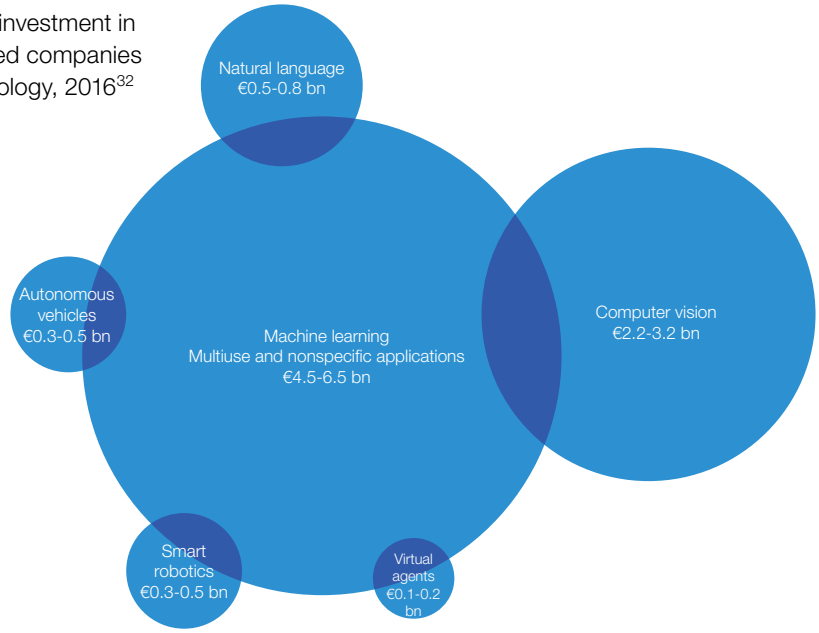
Healthcare represents the largest group working on AI applications, including solutions for operational optimization and diagnostics, where AI algorithms can help analyze medical records and images. A number of companies are also developing AI-powered robots for patient rehabilitation. The second-largest group consists of media and entertainment companies, mostly game developers that use machine learning to create virtual reality. The next-largest group consists of companies specializing in the field of manufacturing, working specifically on operational management systems and autonomous robots. Another significant group is developing solutions for sales and marketing, especially recommendation systems and chatbots for client support.

Although investment in AI in Poland is low compared to the United States or China, it is likely to expand substantially in the future. Investment in AI is relatively small globally compared with investment in the digital revolution. According to the McKinsey Global Institute[31], AI attracted just two to three percent of global VC funding by value in 2016, while IT in general soaked up 60 percent. But AI investment is growing fast: from 2013 to 2016, external investment in AI technology showed a compound annual growth rate of almost 40 percent. That compares to 30 percent from 2010 to 2013. Not only are deals getting bigger and more frequent, it suggests that investors are growing more and more confident in the sector and may now have a better understanding of the technology and its potential.

DIGITAL LEADERS ARE ADOPTING AI, BUT OTHERS ARE HESITANT TO ACT

Investors are pouring more and more money into AI companies in the hope that a market of AI adopters will develop and will be willing to pay for AI infrastructure, platforms, and services. However, the adoption of AI outside of the tech sector is at an experimental stage.

External investment in AI-focused companies by technology, 2016[32]



SOURCE: Capital IQ; Pitchbook; Dealogic; McKinsey Global Institute analysis

Exhibit 5

Machine learning received the most investment in AI

Few companies have incorporated AI into their value chains at scale.

Poland, like most other countries in Europe, lacks companies that are strong leaders in the area of high tech. However, several companies are experimenting with or have partially adopted AI technology. Many major banks include AI adoption in their strategic plans for the next few years and are already trying out chatbot applications in client service and AI tools for operations. One leading healthcare company uses AI to conduct patient interviews via its website. Some retail and e-commerce companies are already starting to use machine learning in their recommendation engines, or are planning to do so, while telecommunication and insurance companies are turning to AI solutions for improving their operations and safety. A number of mining companies are also considering using autonomous machines for work (including decision-making) in conditions too dangerous for humans.

We have yet to see AI adoption at scale worldwide. This is borne out by the results of the McKinsey Global Institute survey of C-level executives at 3,073 at least "AI-aware" companies from 14 sectors of the economy, 10 countries across Europe, North America, and Asia, and companies with workforces ranging from fewer than ten to more than 10,000. Of the respondents, only 20 percent said they had adopted one or more AI-related technologies at scale or in a core part of their business[33]. Ten percent reported adopting more than two technologies, and only 9 percent reported adopting machine learning[34].

One of the reasons for the limited scope of AI deployment in new products and services so far is that one beneficiary of that investment, internal R&D, is largely focused on improving the firms' own performance. But it is also true that there is lukewarm demand for AI applications for businesses, partly due to the relatively slow pace of the digital transformation of the economy as a whole. Many business leaders are uncertain about what exactly AI can do for them, where to obtain AI-powered applications, how to integrate them into their companies, and how to assess the return on an investment in the technology. In the MGI global survey, poor or uncertain returns were the primary reason given by companies, especially smaller players, for not adopting AI. Regulatory concerns are also an important factor, as we explore further in Chapter 3.

Just as with every new wave of technology, we expect to see a pattern of early and late adopters among the different sectors and firms. We identify six features of early AI adoption.

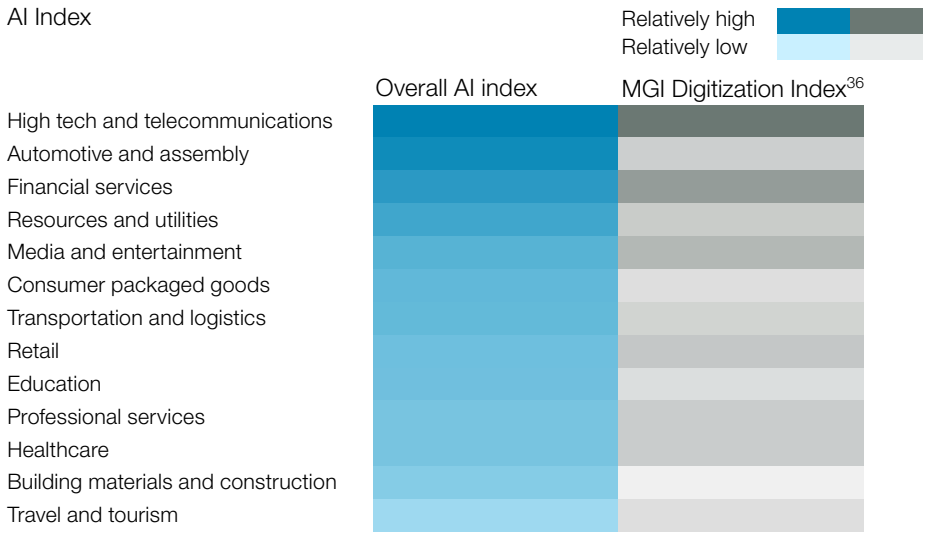
1. More digitized sectors adopt AI earlier

Early AI adopters are from sectors already investing at scale in related technologies, such as cloud services and big data. Larger companies and industries that adopted digital technologies in the past are more likely to adopt AI. For them, AI is the next wave of digitization. This implies that, at least in the near future, AI deployment is likely to accelerate at the digital frontier, widening the gap between adopters and laggards.

The leading sectors for AI include two that the McKinsey Global Institute's Industry Digitization Index found to be at the digital frontier, namely high tech and telecommunications and financial services (Exhibit 6)[35]. These are industries with long histories of digital investment. The automotive industry also ranks highly.

Exhibit 6

AI is being adopted faster in more digitized sectors



SOURCE: *Artificial Intelligence: The next digital frontier?* MGI, June 2017; *Digital Europe: Pushing the frontier, capturing the benefits*, MGI, June 2016; *Digital America: A tale of the haves and have-mores*, MGI, December 2015; MGI analysis

Further down the ranking are less digitized industries, including resources and utilities and building materials and construction. A combination of factors may account for this position. These sectors have been slow to employ digital tools generally, and some also have a particularly high number of small firms – an important predictor for AI adoption.

The traditionally less digital fields such as education and healthcare have the most catching up to do in the area of AI. Despite ample publicity about cutting-edge AI applications in these industries, the reality is that uptake appears to be low so far. The weaker adoption probably reflects challenges such as regulatory concerns and the low level of customer acceptance for AI technology's supporting or replacing procedures traditionally carried out by specialists, e.g., diagnostics.

2. When it comes to adopting AI, the bigger, the bolder

Irrespective of sector, large companies tend to invest in AI faster at scale. This again is typical of digital adoption, in which small and midsized businesses have typically lagged behind in their decision to invest in new technology[37].

Nonetheless, we find success stories among some smaller firms, too. Relative to larger companies, they benefit from fewer issues with legacy IT systems and lower levels of organizational resistance to change. Smaller firms can also benefit from AI tools provided as a service.

3. Early AI adopters tend to become serial adopters

Early adopters take a broader approach, implementing multiple AI tools addressing a number of different use cases at the same time. This is consistent with adoption patterns in other digital technologies[38].

4. Users keep AI close to their core

Companies investing at scale do it close to their core business. For example, operations are an important area of adoption in the automotive and assembly and the consumer packaged goods sectors, as well as in utilities and resources.

5. Early adopters see AI increasing revenue while companies experimenting with AI expect lower costs

Early adopters that adopt at scale tend to be motivated as much by the growth potential of AI as they are by cutting costs. AI is not only about process automation, it is also used by companies to shape innovative products and services that meet customer needs better and create new revenue streams.

6. AI is not only about technical adoption, it is about enterprise acceptance

Strong executive leadership goes hand-in-hand with stronger AI adoption. Respondents from firms that have successfully deployed an AI technology at scale tended to rate C-suite support nearly twice as high as respondents from companies that had not adopted any AI technology.

•••

After decades of false starts, AI finally has a chance to revolutionize our lives. AI may soon radically transform the situation for businesses and entire industries. In the following chapter, we explore what that may look like in particular sectors.

Artificial intelligence promises to boost profits and transform industries

AI technologies have advanced significantly in recent years. Adoption, however, remains in its infancy. This makes it challenging to assess the true potential impact of AI on firms and sectors. We do know that, for many companies, one barrier to adopting AI is their difficulty in understanding how to build value and competitive advantage based on it. But what about the firms that have adopted AI?

The McKinsey Global Institute's case studies of digital native companies provides initial evidence that those companies that have implemented AI at scale have achieved attractive returns. In the global case studies presented below, we explain how AI can transform entire industries and show how this can be relevant for Poland.

FIRMS ADOPTING AI ENJOY FASTER GROWTH

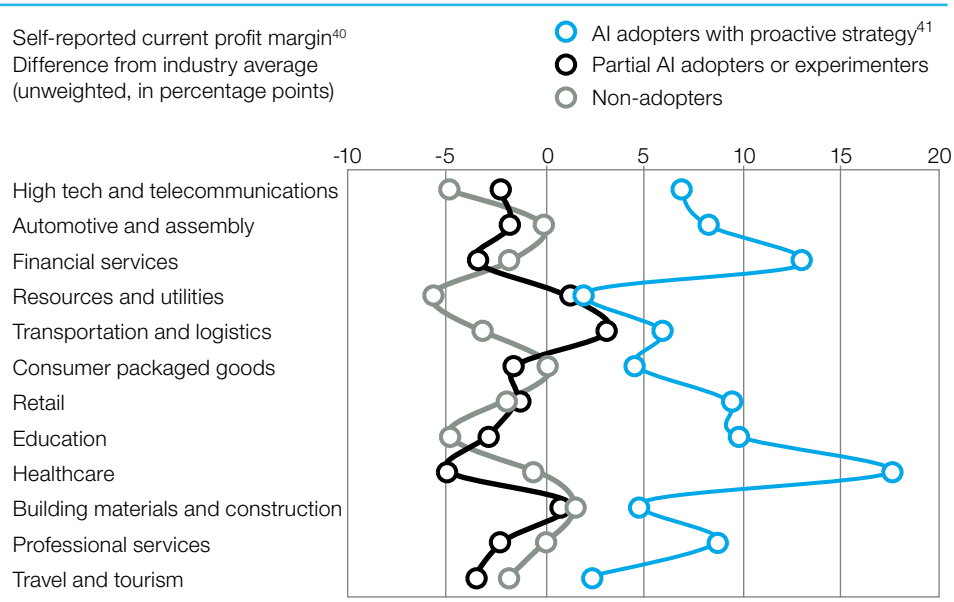
Companies immersed in the digital world, such as financial, high-tech, and ICT firms, made some of the most significant and earliest investments in AI. These companies provide test cases for the potential return on investment. One of the most interesting examples is Amazon, which achieved impressive results from its €700 million acquisition of Kiva, a robotics company that automates warehouse picking and packing. Amazon used Kiva robots to replace its traditional human-based warehouse operations. This enabled it to cut its "click to ship" cycle time from 60-75 minutes to just 15 minutes, while warehouse inventory capacity increased by 50 percent without any investment in additional storage space. The improvements in warehouse operations efficiency and space utilization reduced the company's operating costs by 20 percent, giving an annual return of close to 40 percent on the original investment[39].

Firms adopting at scale or in a core part of their business already see value from AI. Using its survey results, the McKinsey Global Institute compared the current self-reported profit margins of firms with differing levels of AI adoption, digital maturity (as reflected in their use of Big Data and cloud services), and, critically, strategic posture (Exhibit 7). The results show that companies that have made the strategic decision to build their value based on investments in AI have significantly higher margins than non-adopters.

This suggests that AI can deliver significant competitive advantages but only for firms that are fully committed to it. Take any ingredient away – a strong digital starting

Exhibit 7

Companies adopting AI with a proactive strategy have significantly higher profit margins than non-adopters



SOURCE: McKinsey Global Institute survey on the adoption and use of AI, MGI analysis

point, serious adoption of AI, or inclusion of AI in the strategic posture – and profit margins are much less impressive.

INDUSTRY CASE STUDIES DEMONSTRATE THE DISRUPTIVE POTENTIAL OF AI

To meet expectations, AI will need to deliver applications that significantly reduce costs, increase revenue, and enhance asset utilization. To develop a vision of AI as it could be applied across business domains, we created four case studies in different sectors that suggest how AI, in its many guises, could affect specific activities. Our choice of sectors (retail, manufacturing, healthcare, and electric utilities) was driven by an assumption of potential impact, expected scale, and depth of change as a result of AI, as well as the importance of these sectors for the Polish economy and society. Our choice was supported by evidence on the impact of AI on early adopters.

Retail

AI can help predict demand, automate operations, and deliver a better shopping experience

Driven by strong domestic demand, the Polish retail market, with 9 percent annual growth in gross value added (GVA) in 2012–14, is maintaining its stable growth rate. In 2015, the sector generated 7 percent of GDP[42] and accounted for almost 1.5 million jobs[43]. The Polish market is characterized by polarization of demand, a rapidly growing share of e-commerce and modern retailing in groceries, and the replacement of traditional retailing by discounters and convenience stores.

Like the rest of the global retail sector, Polish retail has faced some critical challenges in recent years, including low profit margins, price deflation, and rapidly growing demand for product variety and personalized offers. At the same time, sales are shifting online. In 2016, the Polish online retail market reached a value of some PLN 34 billion (approximately €7.6 billion) and a share in total retail of 7.7%[44]. Given the fierce competition, being able to leverage AI to improve forecasting of market demand and to reduce costs before others do so can create a sustainable competitive advantage for retailers.

AI is becoming a source of disruptive advantage in retail. Top global retailers, with regional leaders gradually following their example, are already beginning to apply AI in major parts of their value chain. The benefits for retailers are radical improvements in forecasting, supply management, and productivity. Digitally advanced e-commerce companies are leading the way here, using AI to predict trends, optimize logistics, set prices, and personalize promotions. Some even anticipate customers' needs by shipping goods without waiting for purchase confirmation.

Retailers based in Poland would be well advised to mirror these changes if they want to maintain their position on the market. Early adoption of AI can give them an opportunity to strengthen their local and regional position. We present some specific industry examples of how AI may affect retail below.

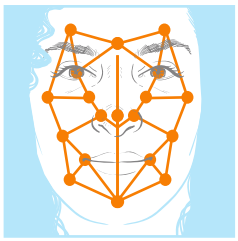
1. Predicting customers' needs

AI can help retailers make decisions in real time. Using new technology, companies can master an increasingly dynamic market by identifying and learning from the patterns found in large volumes of data. This data can come from many different sources, including previous customer transactions, social media trends, shopping patterns, online viewing histories, facial expression analysis, and weather forecasts.

The impact of AI-enabled forecasting is already visible in the industry. One European retailer was able to improve its gross profits by 1 to 2 percentage points by using a machine-learning algorithm to anticipate fruit and vegetable sales, taking into account both waste and lost sales to recommend an order quantity that was optimized in line with demand. By adjusting orders using both internal data and external factors such as weather and vacations, AI succeeded where traditional methods had problems, due to the dynamic fluctuations in daily sales[45]. Solutions of this type could have a major impact in Poland, where per capita sales of fresh, unprocessed fruit and vegetables were 6 percent higher than in Western Europe and 15 percent higher than on average in Eastern Europe in 2016[46]. It is worth noting that Poland is a leading exporter of fruit and vegetables, including apples and berries[47]. This type of technology could help Polish producers, wholesalers, and processors of fruit and vegetables optimize supplies and minimize losses.

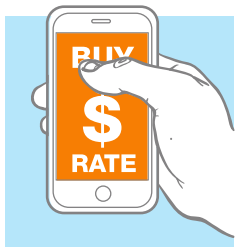
Similarly, German e-commerce retailer Otto has cut surplus stock by 20 percent and reduced product returns by more than two million items a year by using "deep learning" to analyze billions of transactions and predict what customers will buy before they even place an order. The system is 90 percent accurate in forecasting what the firm will sell over the next 30 days, so Otto allows it to order 200,000 items a month from vendors with no human intervention[48].

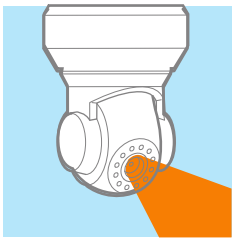
Potential impact of AI in the retail sector



Facial recognition software, machine learning, and natural language processing enable virtual agents to greet you personally, anticipate orders, and provide directions

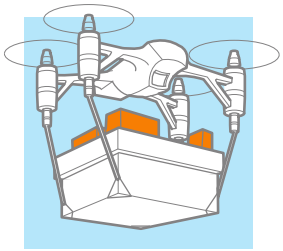
Machine learning personalizes promotions to match shoppers' profiles; in-store beacons send offers to their smart-phones as they browse through the store



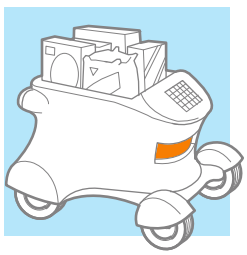


Computer vision with deep learning identifies articles bagged by shoppers; adding data from sensors, AI allows non-stop checkout and automatic payment

Autonomous drones using deep-learning technology complete last-mile delivery and are able to deal with obstacles or absent recipients

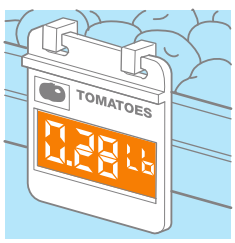


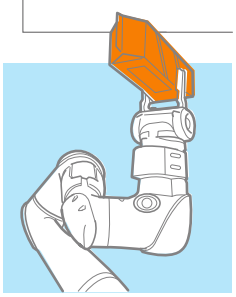
Interactive screens and tabletops enabled with computer vision and deep learning can identify articles and recommend complementary products and uses that fit shoppers' lifestyle profiles



An autonomous shopping cart follows customers around the store and can find its way to their vehicles or to a robot or drone for home delivery

Stores update and optimize prices in real time, with machine learning leveraging data on competitors' prices, weather, and inventory levels to maximize revenues





AI-enhanced robots continuously track inventory, recognize empty shelves, and replenish them; other robots fill bags in the warehouse

SOURCE: *Articicial Intelligence: The next digital frontier*, MGI, June 2017

2. Operations are ripe for automation

AI presents a wide range of opportunities for optimizing warehousing and store operations. Poland, which aspires to be one of the granaries of Europe, had a warehousing area of more than 11 million square meters and average annual growth of 15 percent in 2013-16[49]. It should therefore keep a close eye on recent developments in AI. Swisslog, for instance, has reduced stocking time by 30 percent since it began using autonomous guided vehicles in its warehouses. Similarly, DHL unleashed a pair of fully automated trolleys last year that follow pickers through the warehouse and relieve them of physical work. In store, machine learning can help optimize merchandising and assortment efficiency by up to 50 percent[50].

AI-powered automation will change our shopping experience, eliminating lines at cash desks. For instance, Amazon Go, a pilot retail outlet in Seattle, allows shoppers to log in to an app on their cell phones when they enter the store, take food off the shelves, and walk directly out of the store without stopping to pay at a checkout. The store relies on computer vision to track shoppers after they swipe into the store and associate them with the products taken from the shelves. When the shoppers leave, Amazon debits their accounts for the cost of the items in their bag and emails them a receipt[51].

3. Retailers are getting personal

Empowered by the ease, economy, and immediacy of online shopping, many consumers already expect personalized, pitch-perfect offers. Smartphone penetration also necessitates an omni-channel strategy, and AI can help optimize, update, and tailor it to each shopper in real time.

Drawing on analysis by the McKinsey Global Institute, we predict that insight-based selling, through personalized promotions, optimized assortment, and tailored displays, could increase retail sales in European countries by 1 to 5 percentage points. In online sales, personalization combined with dynamic pricing could lead to up to 30 percent growth.

Players operating mainly online are several steps ahead in personalized, automated marketing thanks to data gathered online. Traditional players are also getting in on the game. For instance, Staples, an office supply retailer, leveraged an IBM Watson solution to introduce its “Easy Button” system that allows customers to place orders via voice commands, text messages, or pictures of the product in question. Orders are simplified further still by adjusting them to the customer’s favorite brands, models, and quantities. The customer simply says what type of product they want, and the system figures out the rest for itself[52].

4. Bringing it back home

Enhanced user experience is the area that offers probably the most futuristic perspectives for AI in retail. In the home, virtual assistants push the convenience boundaries. Systems can look at usage patterns and changing circumstances – rather than just average order frequency, say – and on this basis alert users that they are about to run out of a product, and suggest buying more. Google’s smart speaker service, Google Home, allows shoppers to complete orders with 50 participating Google Express retailers[53]. Recent developments in smart home assistants pave the way for significant disruption in the area of shopping, with computer vision helping to identify the goods that customers are likely to buy. Amazon’s new Echo Look device, for instance, adds a camera to Alexa’s virtual assistant function and recommends styles based on the user’s wardrobe and body shape, combining machine learning and computer vision[54].

5. Moving forward

Keeping up with the competition in this new realm of retailing will be as hard as it is important. Retailers would be wise to invest in data gathering, both up and down their supply chain, to seek a competitive advantage. This implies shifting to a collaborative mindset where insights flow easily through the entire value chain. Partnerships between retailers and their suppliers will become important for improving supply chains and marketing, optimizing pricing, and achieving more efficient marketing campaigns. Cross-industry partnerships between retailers and other players will evolve to create better customer insights. Ecosystems will likely emerge with third-party legal entities that bring together stakeholders such as retailers, loyalty card providers, and payment service providers. The retailing revolution has room to run.

Unfortunately, there are no shortcuts to success. The situation on the market, in particular the speed with which margins are eroding and customer demands are changing, makes taking action imperative. As described at the beginning of Chapter 2, Polish-based retailers must master the immense amounts of data available to them from internal and external sources and build experience in Big Data and forecasting. Only when they have achieved maturity over data can they begin to introduce AI into their operations.

Manufacturing

Smarter, more nimble, and less prone to error

The Polish manufacturing sector generates €77 billion[55] of GVA annually, or 18.1 percent of the country's GDP. It creates employment for around 2.2 million people[56]. Unlike Polish retail, however, manufacturing in Poland falls far behind the European average in terms of productivity, with a gap of over 40 percent to the average for Western European countries (EU-15)[57].

To compete with regional and global competitors, Polish firms would be well advised to move up the value chain. They might consider increasing their investment in R&D and adopting new technology. Ideally, their focus should be on sectors that show major growth potential in Poland, such as the automotive industry, furniture, chemicals, and advanced electric and electronic devices.

Making changes here requires investment, and costs will go up. At the same time, the complexity of operations will grow significantly. Traditional drivers of the Polish manufacturing industry, such as its highly qualified labor force combined with low labor costs, may no longer be the key factors.

Manufacturing is on the verge of a global revolution. AI applications, from virtual assistants to advanced robotics, will disrupt end-to-end value chains amid radical shifts in demand. Thanks to AI, companies will be able to achieve significant improvements in supply and operations management, reduce their product development costs, and react faster and more accurately to shifts in the market. For Polish companies, which are trying to find a way to reduce the distance between them and the leaders in their sectors, AI represents a potential lever for accelerating growth.

1. Untangling the procurement process to get a better grip on costs

Keeping manufacturers stocked with raw materials, production materials, parts, and components is a complex challenge. In the most extreme cases, thousands of different parts must be sourced from thousands of suppliers all over the world. Even where the scale of operations is significantly smaller, supply chain management is still a complicated process. One way for Polish companies to move up the value chain is to open themselves to closer collaboration with suppliers globally. Implementing advanced techniques such as AI may help them manage their costs better and react faster than their competitors.

When manufacturers are digitally linked with their suppliers' systems, AI technologies can provide transparency about supplier machine availability, performance, and downtime. They can also help balance the supply chain and optimize inventories in real time. Machine-learning algorithms can spot differences between suppliers, and on this basis develop effective procurement levers and reduce administrative costs. Indeed, market leaders such as Siemens are already investing in AI solutions supporting procurement and supply chain management[58].

2. Helping companies rethink manufacturing processes

Manufacturing inefficiencies cost companies billions of euros every year. Existing fault detection and classification tools can be inaccurate and cause expensive and unnecessary interruptions to the production line. One semiconductor maker, for example, reduced its material delivery time by 30 percent by using machine learning to propose the best time to leave the warehouse. It also improved its production yield by 3 to 5 percent.

In heavy industries, AI is also bringing a new wave of quality and productivity improvements. POSCO, a global steelmaker, has already launched AI in its steel-coating process control. During the galvanizing process, keeping a constant coating thickness is difficult due to significant variations in operating conditions, environmental factors, and operators' skills. The quality of the zinc coating varies as a result, which leads to material losses in the production process due to the rejection of poor-quality products and higher costs where coatings are thicker than they need to be. In the solution implemented by POSCO, AI-powered technology controls the process precisely, predicting the coating weight in real time and meeting the target coating weight accurately[59]. Similarly, in the chemicals industry, Mitsui Chemicals has developed a technique for predicting the quality of gases produced by reactions. The solution is an AI-powered tool that analyzes 51 different factors in real time, including reactor conditions and raw material parameters. The new technology will help the company improve the accuracy of alerts, leading to safer and more stable operation of chemical plants[60].

In the future, plant managers will be able to apply deep learning to real-time information flows. This will improve the accuracy of predictions in standard operating

procedures, especially during ramp-up and modifications for the purpose of increasing production, and provide transparency for component availability and risk management. Asset reliability can also be enhanced using AI tools, for example, where machine learning improves the predictive accuracy of defaults or interruptions in production.

Moving up the value chain can mean that companies have to use more complicated machines. Assembly lines will be extensively automated, with optimizations taking place in real time. Virtual agents will help by delivering interactive instructions, guiding operators through the process and so reducing errors and flattening the learning curve.

3. Manufacturers can provide aftersales services as and when needed

AI gives manufacturers the opportunity to shape new business models. The aerospace industry, for example, is one of the most difficult industries in which to operate profitably. Aircraft maintenance and service represent a large part of the value chain for aerospace firms. Here, AI can make a real contribution, for example by improving the accuracy of forecasting MRO (maintenance, repair, and operations) and enabling sales efforts to focus on the most promising leads, which increases profits.

One company that has used AI to its advantage in its aviation business is GE. For example, the company's "power by the hour" service model, in which operators pay for aero-engines only when airplanes are in flight, required implementing AI that analyzes data from sensors in engines and takes into account external factors such as weather conditions. This has helped GE monitor the use of its products better and plan servicing more effectively, providing customers with pay-as-you-go services tailored precisely to their needs. The company's AI solutions examine the relationship between data records and outputs, such as breakdowns, and then create a data-driven model to predict potential outcomes. This technique makes it possible to identify patterns from historical events and predict future breakdowns, or even prevent them happening in the first place.

Another company using AI in a similar way is French railroad operator SNCF. The company is introducing an AI-powered IBM Watson system that analyzes data from a network of sensors located in the railroad infrastructure and the trains themselves. This data is then used to manage the scheduling, operations, and maintenance of the operators' 30,000 kilometers of track, 15,000 trains, and 3,000 stations across the country[61].

Polish companies could also benefit from applying such solutions. For example, AI opens up the possibility of new business models in maintenance for Polish companies that manufacture vehicles, advanced industrial machines, and heavy industrial machines. Such solutions may become part of the contract between Polish manufacturers of trains, trucks, and buses and their customers.

4. Collaborative agility is key

One of the key features of the future manufacturing paradigm will be collaborative agility, by which we mean the ability to adapt almost instantly to changes in demand, input prices, technologies, regulations, and other parts of the industry landscape. From a human capital perspective, manufacturing is expected to become more collaborative, based on increasingly complex processes and involving more and more workers at the same time. From a technological perspective, manufacturing plants around the globe, supply chains, and value chains will be more interconnected and collaborative via a global digital backbone. This may combine highly automated plants that extensively use smart robotics for mass production of limited product ranges, as well as a network of customer-centric plants close to higher-end market segments.

Broad implementation of AI in manufacturing will require significant investment and substantial changes to core operational processes. The potential benefits include more effective use of production lines, lower supply chain costs, improved product quality with less material waste, shorter design times for new products, and improved collaboration with suppliers, customers, and partners. It is also safe to assume that successful implementation will encourage more manufacturers to deploy AI in their plants.

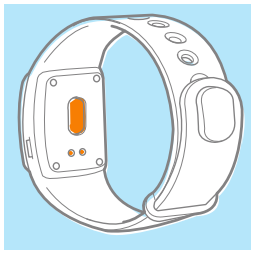
Healthcare

AI will lead to better treatment plans, new approaches to insurance, and faster diagnoses

Healthcare is another promising market for AI. The new technology's ability to recognize patterns in large volumes of patient histories, medical images, epidemiological statistics, and other data gives it enormous potential. AI can help doctors improve their diagnoses, forecast diseases, and customize treatments.

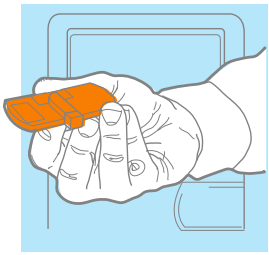
In Poland, where the quality and efficiency of healthcare lies far behind most OECD countries, AI has the potential to bring about radical improvements. Healthcare expenditure

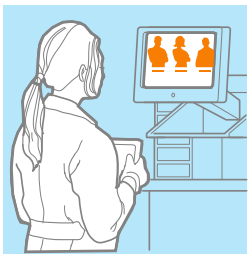
Potential impact of AI in healthcare



Machine-learning programs analyze patients' health remotely via mobile devices, compare it to medical records, and recommend fitness routines or warn of possible diseases

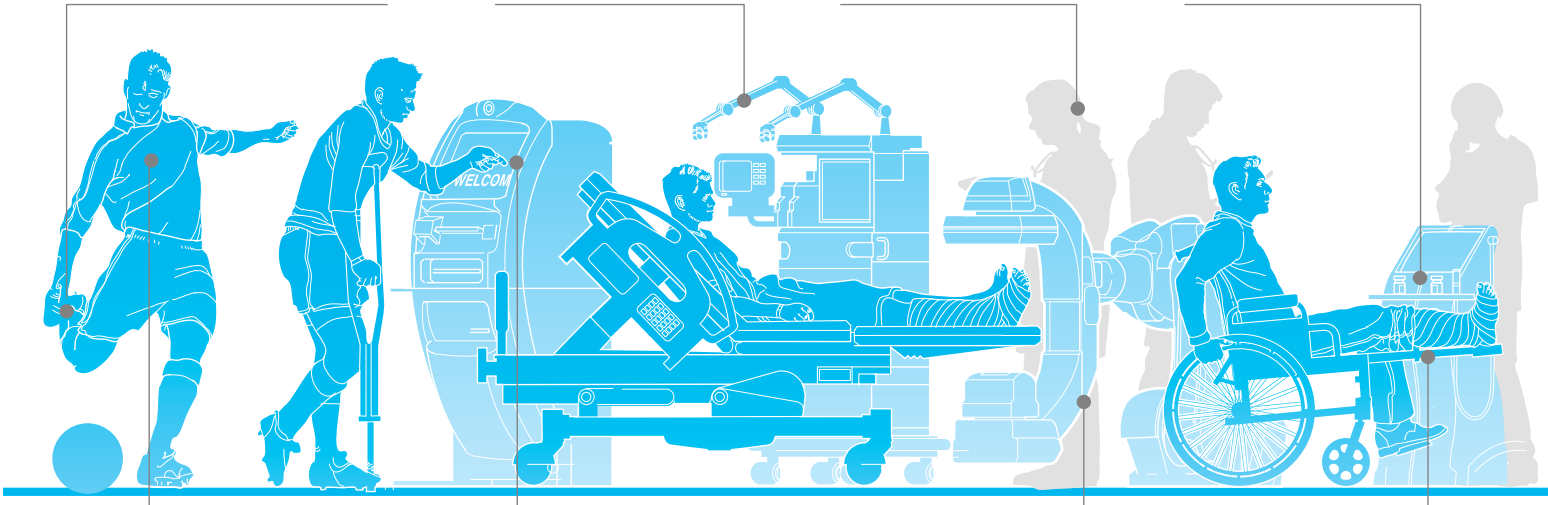
Autonomous diagnostic devices using machine learning and other AI technologies can conduct simple medical tests without human assistance, relieving doctors and nurses of routine activities



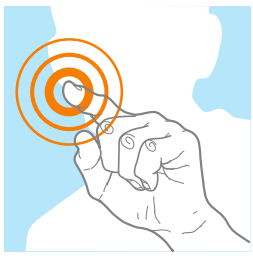


AI-powered diagnostic tools identify diseases faster and with greater accuracy, using historical medical data and patient records

AI algorithms optimize hospital operations, staffing schedules, and inventory by using medical and environmental factors to forecast patient behavior and disease probabilities

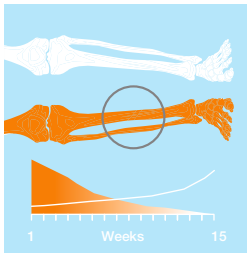


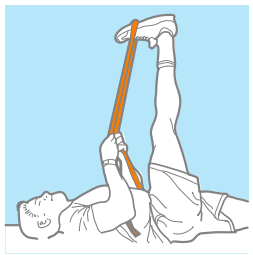
AI tools analyze patients' medical histories and environmental factors to identify people at risk of an illness and steer them to preventive care programs



Virtual agents in the form of interactive kiosks register patients and refer them to appropriate doctors, improving their experience and reducing waiting time

Personalized treatment plans designed by machine-learning tools improve therapy efficiency by tailoring treatment to patients' specific needs and medical histories





AI insights from population health analyses make it possible to reduce hospitalization and treatment costs by encouraging care providers to manage patients' wellness

SOURCE: *Articicial Intelligence: The next digital frontier*, MGI, June 2017

as a share of GDP is 2.6 percentage points below the average for the OECD and more than 4 percentage points lower than Germany or France[62]. Per capita healthcare expenditure is less than half the OECD average. Service quality also remains poor. Indeed, Poland ranks among the bottom countries in Europe for healthcare service quality in the European Health Consumer Index[63]. Key problems include long waiting times for treatment and a low level of effectiveness. In diagnostics, despite significant recent investment, the number of computer tomography and magnetic resonance imaging devices per one million inhabitants is 30 percent lower than the OECD average. The utilization rate is 35 percent lower than the OECD average, half that of Hungary, and one-third that of Slovakia. Moreover, Polish society is aging, a demographic trend that is expected to accelerate significantly in the coming years. After 2025, there will be more people aged over 65 (representing 22 percent of the population) than aged 0-19 (19 percent), creating even more challenges for the sector[64].

Improving spend effectiveness is critical for Polish healthcare. Full-scale deployment of AI can help bring about the necessary changes. With new technology it will be possible to make better use of patient hospitalization histories and medical data to forecast health risks, plan preventive care, and optimize the utilization rate of hospital services.

1. AI can identify threats to public health and the most at-risk patients

The ability to forecast the spread of certain diseases and identify which patients are most likely to succumb to them is one of the most powerful aspects of AI. This application has already been tested in the United States, Europe, and Asia. The information that AI provides makes it possible to manage patient health in advance through preventive care. It can also help payors and hospitals set budgets, optimize inventory levels, and schedule staff.

In the future, AI tools will allow healthcare to move much faster toward preventive medicine. Medical professionals will focus on managing patients' health remotely. AI tools will analyze not only patients' medical histories but also the environmental factors that can influence their health, such as pollution and noise where they live and work. AI can help identify risk groups and inform local authorities where to implement preventive care programs.

AI will also bring about changes in payments systems and the way in which medical professionals provide their services. Payors, including life and health insurers, will use machine learning to analyze historical in-patient data and devise new methods to encourage preventive care. Primary care providers will have information to engage patients in preventive actions that involve both medical services and lifestyle and environmental factors such as nutrition, exercise, and pollution avoidance. Hospital administrators will be better equipped to forecast spikes in admissions in ways not available today. Tracking the incidence of communicable diseases, combined with personal medical records, weather data, and other information, will help an AI tool estimate how many people will need hospitalization.

We estimate that the full potential of healthcare cost savings from AI-enabled forecasting initiatives would be an impressive €270 billion a year in the United States alone, where healthcare spend intensity is nearly three times as high as the average for OECD countries[65]. In Western European countries such as the United Kingdom, using AI to target preventive care and reduce non-elective hospital admissions could save €4 billion (£3.3 billion) annually[66]. In Poland, the main value of implementing AI may lie in the significant improvement in the effectiveness of treatments and access to medical care, thanks to simplification of diagnostic paths and patient treatments, and improvement in the hospital utilization rate. Additionally, capacity improvement will be followed by savings of around €180 million in annual healthcare costs[67].

2. AI can help medical professionals diagnose disease and improve operations

AI-powered tools have great potential to increase healthcare productivity and enhance diagnostic accuracy, enabling fast and easily available diagnosis and preventive care. This is especially relevant for Poland, where diagnostics is one of the weakest elements in the healthcare system[68]. AI has the potential to help the country significantly decrease diagnosis time, which leads to radical improvements in utilization rates without growth of medical personnel costs.

AI-powered automation has the potential to relieve doctors and nurses of their routine activities, giving hospital personnel a chance to focus on complicated cases and provide other patients with appropriate care. In hospitals, virtual agents will be able to register patients and refer them to the appropriate doctor. They will also help patients navigate hospital bureaucracy, prepare them for tests, and make sure they are on time for appointments. At some point in the future, chatbots equipped with deep-learning algorithms could even relieve emergency-room personnel of the task of tending to large numbers of walk-in patients with non-emergencies, such as sore throats. However, this scenario would require patients, providers, and regulators to become comfortable with fully automated diagnosis and prescription.

Machine learning also has enormous potential to accelerate and improve diagnostic accuracy. The Sloan Kettering Institute estimates that doctors use only 20 percent of the available trial-based knowledge when diagnosing cancer patients and prescribing treatment. AI applications can sift through millions of pages of medical evidence to provide a diagnosis and treatment options in seconds. AI-based image recognition and machine learning can see far more detail in MRI and X-ray images than human eyes can register[69]. And innovation is not limited to imaging: entrepreneurs are working to change each step in the patient care process.

Together, these AI-enabled operational efficiencies, ignoring the forecasting potential, could represent sizeable savings in developed countries. Estimates for the United States range from 1 to 2 percent of GDP. In other high-income countries, the estimated savings would be a half to 1 percent of GDP[70]. In Poland, given the relatively low spending on healthcare, the potential savings will not be as great: estimates lie at around 0.3 to 0.6 percent of GDP[71]. Full adoption of AI for optimizing operations and diagnostics could increase the productivity of nursing staff by as much as 40 to 50 percent while improving diagnostic utilization rates[72].

3. Doctors will be able to tailor treatments—and even drugs—to individual patients

Because of the complexity of patients' individual medical histories and genetic makeup, standardized treatments do not work for everyone. Several companies are already exploiting AI technology to tailor their treatments to individual patients. MindMaze, for instance, uses machine learning to optimize rehabilitation activities for stroke patients. Similarly, Ginger.io uses machine learning to recommend the best time to take medication based on each patient's metabolism and other factors.

Tailored treatments can potentially reduce health expenditures by between 5 and 9 percent, increase productivity, and add 0.2 to 1.3 years to average life expectancy. Globally, the economic impact could range from €1.8 to €9 trillion[73]. In Poland, where current health expenditure amounts to almost €1.1 billion annually, expenditure could be reduced by between 3 and 5 percent[74].

4. Several hurdles stand in the way

Despite the enormous potential of AI, healthcare lags behind other industries in adopting the technology. There is interest, but the sensitive nature of medical records and strict regulations form a significant hurdle to adoption.

At present, data is highly fragmented and spread across the healthcare industry. Merging information into large, integrated databases, which is necessary in order for AI to develop a deep understanding of diseases and their cures, is a difficult process. It requires decisions right across the industry and the introduction of data standards. Moreover, the data itself is highly sensitive. People may resist any attempt to allow wider access to their more intimate medical histories, particularly if they do not see it as a necessity and any potential benefit is abstract. Regulators would be well advised to proactively develop clear rules defining who can use the data, what it may be used for, how it must be stored, and how it should be anonymized.

The limitations of machine learning form another major hurdle. Humans know little about how AI technologies actually make a diagnosis or choose a treatment plan. When it comes to forecasting based on data at the level of the general population, there is little controversy; the problems start when the tools require data at the individual level. It is unclear how far patients would trust AI tools. Regulators would not be eager to risk an incorrect, harmful decision by a computer, especially when no one would be able to explain how the computer had reached that decision or knew how to prevent a repeat of the situation. This is a particular issue for the most powerful AI tools, such as deep neural networks, and could remain the case for some time – despite the fact that AI tools are, in theory, less likely to make mistakes than individual human clinicians.

Electric utilities

AI can make the smart grid smarter and reduce the need for utilities to build new power plants

The energy sector plays a significant role in shaping the competitiveness of a country's economy. The price of electricity is becoming more and more important for industrial manufacturing, especially as the number of automated production lines, data centers, and computing units grow. Furthermore, for advanced production and the IT sector, the reliability of the energy supply is also a critical growth factor.

In Poland, grid reliability is much lower than in many other European countries. The System Average Interruption Duration Index or SAIDI for Poland is 205 minutes per customer per year, compared with 14 minutes for Germany and 12 minutes for Denmark[75].

The majority of energy in Poland currently comes from conventional sources in the south of the country. However, the share of energy production from renewable sources, especially onshore wind, recently has been increasing. In 2015, wind farms generated 6.6 percent of the total energy supply, mostly in the north of the country, where 57 percent of capacity is located[76].

In addition, Poland currently experiences up to 60 percent variation in energy usage. Demand fluctuates dramatically and frequently by time and region. For many years, energy peaks occurred in winter, when household electricity usage soared due to the shorter days and industrial production sites experienced increased heating needs. However, summer peaks recently have been increasing, reaching 89 percent of the winter peak level, due to the increased use of air conditioners. This, combined with falling water levels in rivers and many power stations closing for repairs in summer, may result in a repeat of the situation seen in 2015, when the energy supply had to be temporarily limited to prevent the system failing.

Growing demand for energy, driven by the use of advanced technology such as automated production lines, may be boosted even further in the coming era of electric vehicles. This, combined with uncertain demand and supply, an increasingly complex network of stakeholders and assets, aging infrastructure, non-linear power loads, cost pressure, and price deregulation, could force Poland to change its energy model from centralized to district-based – a development that will make managing electric utilities even more complex and will require the development of appropriate tools.

Poland is not the only country facing these challenges. Early evidence from other European countries and the United States shows that the solution may lie with AI. At every step of the value chain, from power generation to end consumers, opportunities for AI are visible. Indeed, AI is already helping electric utilities better predict supply and demand, balance the grid in real time, reduce downtime, maximize yield, and improve end-users' satisfaction, as we discuss below.

1. Ultra-accurate forecasts enable additional renewable energy and excess power to be integrated into the grid

One of the most acute cases for AI in electricity is around demand and supply prediction. Electric utilities are starting to explore AI technologies to produce more accurate short-term load forecasts. DeepMind, the AI startup bought by Google in 2014, is currently working with National Grid to predict supply and demand peaks in the United Kingdom by using weather-related variables and smart meters as exogenous inputs. It hopes to cut national energy usage by 10 percent and maximize the use of renewable power, despite its intermittence.

Grid modernization and deployment of smart meters are already under way in most countries, aiming at creating a more dynamic matching of supply and demand; the use of AI enables suppliers to better predict and optimize load dispatch. Smart grid initiatives allow small, private energy producers and even individual homeowners to sell excess capacity back to the grid. The technology is developing quickly: the United States alone has committed more than €8 billion in public and private funds since 2010[77]. In Europe, Sweden and Italy have replaced nearly all meters with smart meters, and other European countries are on track to finish the conversion within ten years.

Although it has only just begun the gradual process of replacing regular meters with smart meters, Poland invests heavily in grid modernization and development – over €7.7 billion in the last six years[78]. The country would be well advised to now consider thinking about energy supply and demand forecasting. A lack of advanced forecasting appears to be risky. In Denmark, for example, the number of hours when electricity produced by wind turbines exceeds net demand is constantly growing. It hit a record high in 2015 at 519 hours (22 days)[79]. Occasionally, there were even full days of overproduction by wind turbines, forcing Denmark to distribute energy to other countries. In Germany, negative energy wholesale prices are observed when renewable sources unexpectedly produce too much energy, overlapping with conventional plants that are too costly to be temporarily shut down. As a result, the German government, in cooperation with local companies, has started working on its own AI system to help better forecast and manage such situations.

2. Yield optimization, predictive outage, and preventive maintenance can improve the grid

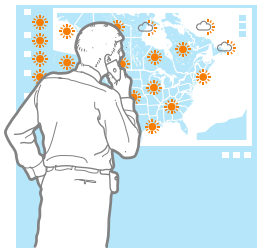
Another lever where AI and robotics could help reduce costs is operations from power generation to transmission and distribution.

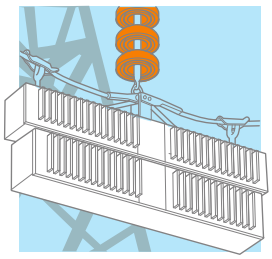
With AI, power providers could maximize their generation efficiency with real-time adjustments across assets. For instance, machine learning can help optimize wind turbines' yield based on their own past performance, real-time communication with other wind farms, the grid status, and changes in wind speed and direction. GE Renewables recently introduced a "digital wind farms" concept, which optimizes yields with machine learning applied to turbine sensors data, and modular turbines

Potential impact of AI in the energy sector

Sensors and machine learning allow for by-the-minute adjustments to maximize generation efficiency by adjusting to changes in wind conditions, for example

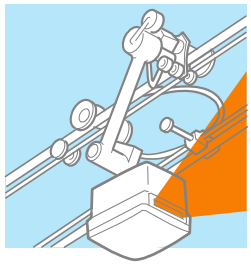
Machine learning-enabled forecasting anticipates supply and demand peaks, and maximizes the use of renewable power

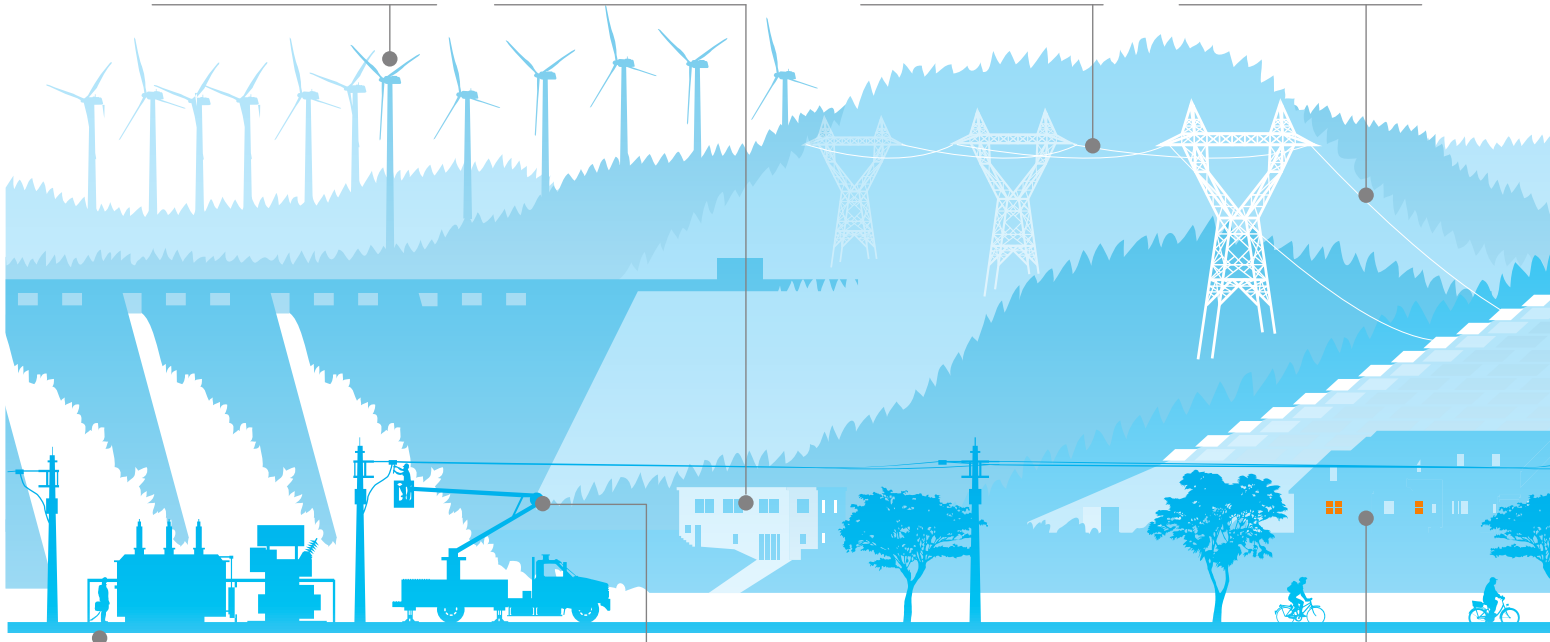




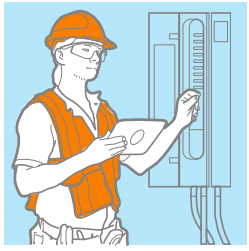
Smart wires combine with machine learning to enable real-time power dispatching and optimize it to current grid load and to buildings' asset portfolios

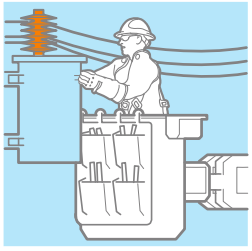
Drones and insect-size robots identify defects, predict failures, and inspect assets without interrupting production





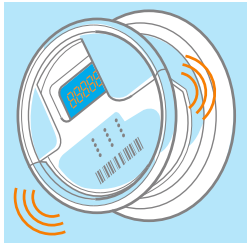
Few technicians remain, but they spend more time on problem-solving; instead of logging inspection status by hand, documents are automatically logged and routed





Field workforce receives real-time updates to decrease response times and reduce the impact of outages

Virtual agents automate call centers and automatically segment consumers based on service history; machine learning offers early warning of bad debts



Smart-meter data and machine learning enable utilities to offer services based on usage, weather, and other factors

SOURCE: *Articicial Intelligence: The next digital frontier*, MGI, June 2017

that can be customized to conditions at each installation site[80]. GE says that the technology could boost a wind farm's energy production by as much as 20 percent and create €90 million in extra value over the lifetime of a 100-megawatt farm.

Power generation yield can also be bolstered by reducing downtime and improving preventive maintenance. This is particularly the case in Poland, where SAIDI is more than 15 times that of leading countries in the European Union, as mentioned above[81].

Machine learning can be instrumental in reducing energy losses in transmission and distribution. Looking across multiple assets on a customer site, AI tools can make intelligent, real-time decisions to balance the grid. By shaving off demand peaks during the day, utilities could also postpone or even forgo the need to add generating capacity that would be required – and would generate revenue – only for short periods.

Transmission and distribution firms could also shift from time-based maintenance to condition-based maintenance. One European power distribution company was able to reduce its cash costs by 30 percent over five years by analyzing 20 variables to determine the overall health of power transformers and diagnose the condition of individual components. This can be followed by improvements in field workforce management, optimizing planning, decreasing reaction time for grid failures, and enhancing productivity factors.

In the future, one can imagine that operational trade-offs between several power stations or within distribution networks will be made automatically by advanced analytics and machine learning algorithms. Where necessary, inspections can be scheduled, with autonomous decisions about whether deploying drones and smart robots is sufficient at first, or whether human intervention is needed right away.

3. AI may unleash market forces on retail electricity markets

Machine learning applications have the power to tailor electricity prices based on the large volume of data currently being provided by the growing number of smart meters and other devices and sensors. In the future, if regulators allow dynamic tariffs, utilities could adopt dynamic pricing based on machine learning that would permit them to protect their margins and reduce customer churn while maximizing their assets. For instance, they could use time-of-day pricing to encourage customers to shift non-essential consumption to earlier in the morning or later in the evening, when demand is lower. Utilities would also be able to use AI to create custom benefits, such as low rates or extra service, in order to hold on to their most valuable, high-volume clients.

Energy consumers also can benefit from AI in the form of detailed real-time insights into their energy consumption and tailored consumption management. For instance, Google-owned Nest's Wi-Fi-enabled thermostat creates a personalized "heating schedule" by monitoring users' habits with a motion sensor to detect when the home is empty and doesn't need to be heated.

4. Matching supply and demand at the local level

Employing AI opens a vista of possibilities for the electricity sector. It may lead to a world where power generation, distribution, and transmission operations are automatically optimized, where the grid is balanced independently of human intervention, where trading and arbitrage decisions are made in nanoseconds at a scale that only machines could tackle, and where end-users never have to worry about searching for a better supplier.

As the price of solar cells and battery storage falls and their popularity rises, it is not inconceivable that one day distributed generation – power generation at the point of consumption – will become the primary source of electricity. If that happens, the grids, with their tens of thousands of new sources of energy and hundreds of thousands of miles of transmission and distribution lines, will become the backup system for industrial plants, office buildings, and residential homes that are now self-sufficient in terms of energy.

Utilities will have to work closely with policymakers to balance their own interests with the lowest economic cost and highest efficiency of resource use. To address this issue, a number of interventions could be explored. These include redefining rate structures for distributed power, creating a more flexible rate structure, such as time-of-use pricing to drive efficiency and demand management, and expanding storage to balance the load and avoid massive spikes in demand. Not all of these changes will be easy. Nor will they be without some discomfort for some industries and individuals. Regulators will be cautious in reviewing time-of-day pricing and other fundamental changes, considering the fraud, mis-selling, and consumer ignorance.

•••

The experience of early adopters and existing case studies demonstrate the potential of AI to transform business processes, shake up entire sectors, increase profits, and create new sources of value. Globally, AI applications are starting to reach maturity, and companies with serious, proactive adoption strategies stand to gain significant competitive advantages. While machine learning and deep learning underpin most opportunities, industries should identify those AI technologies that will bring the most benefits to them and then start to develop their infrastructure, talent, and knowledge as early as possible to catch up on the learning and adoption curves.

Government, developers, and users can act now to realize the full potential of AI in Poland

While AI technology has the potential to fundamentally reshape society, significant uncertainty remains about how it will develop. For firms, governments, and workers, this might suggest a "wait and see" approach. However, we think there is a need for urgent but clear-headed action to respond to the opportunities and risks that are already apparent.

This call for action is particularly relevant for Poland. Although no AI ecosystem exists as yet in Poland, the country has strong capabilities such as talent and numerous IT companies with a global footprint. This gives the country a chance to build a globally recognized AI hub and improve the international position of its companies by developing and implementing AI on a broad base. Below, we discuss in more detail what action the Polish government, firms, and AI developers might consider taking to tap the full potential of AI.

INITIATIVES AT A NATIONAL LEVEL

The impact of AI extends well beyond firms. There are serious implications for government, the workforce, and society. It is important that the government address the potential and the challenges of AI as early as possible. The range of issues is vast, ranging from ethical and equity concerns to the setting of data standards. However, we consider the actions below to be particularly crucial at this initial stage.

1. Nurture local talent

Poland needs AI talent not only to develop new AI technologies but also, perhaps more importantly, to adapt existing technologies bought from tech giants and startups around the world. Academics and IT specialists at startups are a crucial source of talent for data scientist roles at Polish companies.

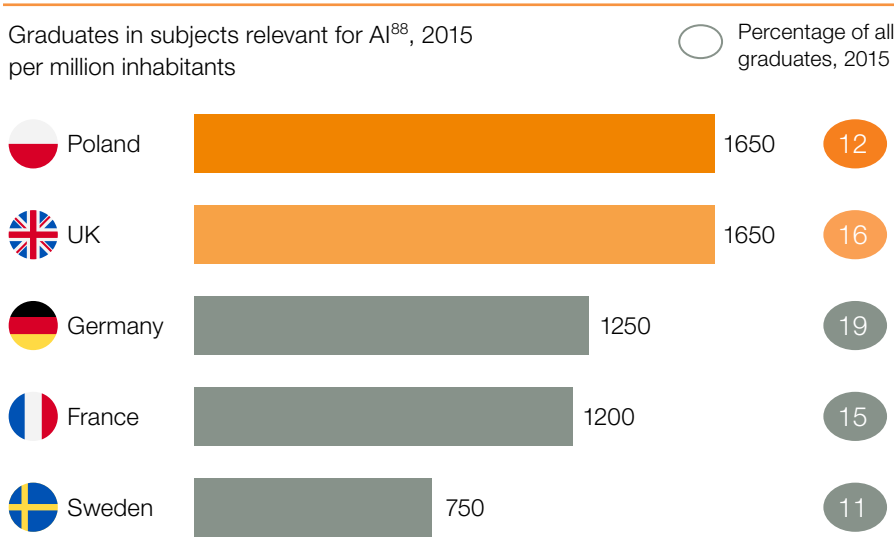
Fortunately, Poland is well positioned to develop its AI talent. According to Eurostat, the country has a large number of science students: 1,650 graduates per million inhabitants in subjects relevant for AI (mathematics, statistics, computer science) in 2015 – the same as the United Kingdom and 38 percent more than in France (Exhibit 8).

Universities usually offer AI as an optional part of master's courses. This is the case at Cornell and Columbia University in New York, for instance. Polish universities could continue to develop strong mathematical and computer science skills in students, adding courses in AI and its applications. They should consider expanding their collaboration with companies and market experts working in the field of AI to ensure that the knowledge passed on to students is truly practical. In addition, research centers located at universities can give top talent and companies a chance to conduct their own research on university campuses, much in the way that MIT has an AI group that strongly cooperates with several global companies.

Polish scientists are highly regarded on the global HR market. In terms of the number of scientific publications, the country ranks fourteenth globally for mathematics and twentieth for computer science[82]. Many of these publications are in journals that are well known to the AI community. Polish teams also regularly win international AI-related competitions, such as the Hello World Open, the CanSat Competition (partly sponsored and run by NASA[83]), and the University Rover Challenge (hosted by the Mars Society[84]). Tech giants use such events for talent scouting. For example, in the 2016 Imagine Cup, organized by Microsoft, the Polish team PSYLLOSOFT, which entered with its automated vision system for the blind, was offered jobs, financial support, and mentoring in the next stages of project development by Microsoft[85].

Another indication that Polish scientific talent is top quality is the fact that many global tech giants set up their R&D and IT centers in Poland. At the beginning of 2017, 748 business service centers, owned by 524 foreign companies, were operating in Poland. One-third of them focus on IT[86], including those belonging to firms such as Volvo (developing new solutions and technologies and providing IT support to the entire company), Opera Software (R&D center in Wrocław), and IBM (IT R&D center in Wrocław). Global companies (such as Samsung[87]) choose Poland mainly thanks to the availability of high-quality IT talent. Most of these centers are not as yet focused on carrying out R&D for AI, but things may be changing in this respect, too, as in the case of Samsung, Intel, and TomTom (see Chapter 1).

Poland's education system is a good starting point from which to develop its AI talent. To do this, a number of steps



SOURCE: EUROSTAT

Exhibit 8

Subjects relevant for AI are as popular in Poland as they are in the United Kingdom, the leading hub for AI in Europe

might be considered. As mentioned above, universities could develop courses in AI and supplement them with opportunities for students to develop practical skills. Government could introduce incentives to attract international talent, such as tax breaks for people who move to Poland to set up AI-related businesses.

Special tech visa quotas are another effective method for attracting talent. The United Kingdom, for example, has the Tech Nation Visa Scheme, which awards up to 200 visas annually, without work sponsorship requirements, to applicants with exceptional talent or promise in the digital space[89]. The Polish government might also consider creating incentives for Polish specialists to stay in the country. Romania has done this by introducing income tax benefits for software programmers, for example[90].

Government action to encourage global companies to set up their AI labs in Poland is also likely to be effective. Later, employees will move on from the labs, either setting up their own new companies or taking with them their knowhow and good practices and helping Polish companies successfully adopt AI. France is a good example of a country that is able to attract global tech giants such as Facebook, which has its AI lab in Paris[91].

France's success is due to at least three factors. First, the availability of high-quality engineering talent. Second, an R&D tax credit program that covers 30 percent of all R&D expenses: it is estimated that French tax incentives mean that an engineer in France costs 50 percent less than in Silicon Valley. And third, a well-developed startup ecosystem: with 40 business incubators, France has become the place for tech giants to scout new talent[92].

2. Prepare the workforce for a lifetime of re-skilling

AI tools promise to change our lives as fundamentally as personal computers did a generation ago. But these gains will be accompanied by losses. AI-powered automation could have a profound impact on jobs and wages. A workforce with specific advanced skills will be required. Apart from the talent needed to develop and adopt AI, Poland needs people who will be able to work with the new solutions and use them in practice.

In some cases, full or partial automation based on AI will displace labor. MGI estimates that 60 percent of all occupations have at least 30 percent technically automatable activities. However, automation will change far more occupations than it will replace – for example, by moving employees up in the value chain to more sophisticated and less routine tasks, and by at least partially automating simple jobs.[93] For instance, when ANZ bank launched robotic process automation in 2013, the aim, apart from cost savings, was to move the employees up in the value chain and away from routine and repetitive jobs[94]. Moreover, many AI applications target non-labor cost savings, as when an AI algorithm reduces a factory's energy use or when AI is used in predictive maintenance. Indeed, less than a fifth of AI adopters in the MGI survey said that their primary driver for adoption was to reduce labor costs. Improving capital efficiency and revenue drivers, such as enhanced product offerings, were cited more often.

Essentially, AI will help grow business and consequently improve employment rates. Although one of the near-term benefits of automation is labor cost reduction, the MGI survey shows that 24 percent of firms that have adopted

AI at scale expect to increase the size of their workforce in response to AI. The reason? They anticipate growth in their business activities overall.

As long-term studies indicate, even if new technologies potentially reduce the number of jobs, they boost productivity over time and as a consequence bring a multitude of new jobs, activities, and new types of work[95]. Thus, a study by McKinsey on the impact of the Internet on the French economy showed that for every job lost, 2.4 new job positions were created[96]. Amazon provides a good example of how increased productivity as a result of AI can affect employment. The company has increased both the size of its workforce and the number of robots working in its warehouses over the last three years[97].

The implication of these changes is clear. Companies, both globally and in Poland, would be well advised to update the skills of their workforces, and individuals need to acquire skills that work with, not against, machines. Overall, demand for employees should grow[98].

For people who have not yet entered the workforce, training in AI should ideally begin early in their educational career. For people already working, re-skilling will be essential. This can take place on the job through professional development programs. For people transitioning between jobs, vocational and adult education programs should be strengthened. Such programs work best when they are short, affordable, closely linked to the job market, and industry-specific.

Poland offers some good examples of how to make vocational training more practical in nature. The Lower Silesian Voivodeship has created the Dolnośląski Klaster Edukacyjny (Lower Silesian Educational Cluster), a partnership between companies, educational institutions, and local government supporting practical education[99]. The region's capital, Wrocław, has 17 "vocational school teams" that cooperate with global companies. The cooperation has led to internships, sponsorships, practical workshops and other forms of support.

In the face of rapidly changing technology, both government and training institutions in Poland might consider doing even more to ensure close alignment between training programs and future jobs. In the future, AI-powered predictive analysis could even be put to use to anticipate future pockets of skill shortages and oversupply.

For people whose abilities do not match the work that needs doing and are not able to be re-skilled, government may have to rethink their models of social support. Various ideas are under consideration globally, including work sharing, negative income taxes, and the introduction of a universal basic income.

3. Encourage broader adoption of AI and build local AI industry

Adoption of AI tends to be concentrated in industries that are fairly digitized and, within those industries, in firms that are already at the digital frontier. The broader adoption of AI in Poland and support for digital technologies, especially in smaller firms, could be important for productivity growth across the economy and for a healthy, competitive market.

AI can drive improvements in labor productivity, which in turn should drive higher wages. Large-scale adoption in a specific sector will ensure more equal growth of wages, rather than pushing up the wages of only those in frontier firms. At the same time, broader adoption can support local ecosystem growth, making it possible to build a strong AI hub.

Poland should focus on building a local AI industry that aspires to a global footprint. The country already has many home-grown IT companies that operate globally or have international clients. For instance, Asseco, which offers comprehensive, proprietary IT solutions, operates in almost all European countries, Israel, the United States, Japan, and Canada[100]. UXPin, which creates tools for designing websites and applications, counts PayPal, HBO, Microsoft, and Sony among its clients[101]. CD Projekt RED, which creates role-playing games, also has a global footprint; the company sold over 25 million copies of The Witcher trilogy globally[102]. For IT companies such as these, AI is the natural next step for growth. If Poland leverages this basis successfully, it could create strong local expertise in AI.

Poland has a good technical and scientific infrastructure in the form of technological hubs, and it should make efforts to strengthen these facilities further still. The technological hub in Lublin, known as the Lubelski Park Naukowo-Technologiczny, helps entrepreneurs launch and manage their businesses and gives them access to 12,500 square meters of functional space and technical infrastructure[103]. The technological hub in Gdynia, the Pomorski Park Naukowo-Technologiczny Gdynia, offers modern offices, bio-technological and electronic laboratories, prototyping, and advice in the area of technology commercialization and external financing for projects[104]. Such technological hubs are important because companies, especially smaller players, need space, access to experts, and cheap computing power – the last of these elements being particularly important for AI. Through its *Horizon 2020*

program, the European Commission recognizes the need for an EU-level policy in high-performance computing (HPC) to optimize national and European investments and make HPC available for small businesses[105].

Government can facilitate the building of a local AI industry not only by strengthening technological hubs but also by developing the general IT infrastructure, such as Internet speeds and quality. Some AI applications such as autonomous vehicles, vital signs monitoring in healthcare, and cyber security will require reliable online data transfer. Poland has plans to develop a 5G network and make high-speed Internet available for everyone[106]. Further progress in this area will boost the adoption of AI.

The critical enabler for creating an ecosystem and boosting the adoption of AI by local industry is the availability of funds. Current EU funding plans envisage giving Poland more than €10 billion for developing innovation in the period to 2020[107]. This gives Poland a unique opportunity to significantly reduce companies' risks, incentivize them to start implementation, build an ecosystem for startups, encourage academics to move into the business world, and incentivize corporate IT specialists to start their own firms. To further boost the AI industry, it would be helpful if EU funding were more industry-specific and available to companies at different stages of development in the form of public-private partnerships and joint investments. The more than €10 billion available from the EU is still well below total R&D spending in leading European countries, so Poland would be well advised to try to use these funds as effectively as possible.

Israel is a good example of how a country can transform itself. Its metamorphosis from an agricultural economy to a high-tech superpower is one of its biggest success stories. Currently, Israel comes only behind the United States and China in terms of the number of its NASDAQ-listed companies[108]. One of the reasons for Israel gaining the reputation of a startup nation is active encouragement from government and private enterprises.

Direct investment and grant programs could be backed up with incentives encouraging companies to adopt technologies. Belgium, for example, offers tax incentives for R&D investment, such as allowing companies to deduct a certain percentage of the net income they derive from qualifying IP assets from their corporate tax base[109]. Similarly, in Australia, investors in qualifying early-stage innovation companies may be eligible for tax incentives in the form of tax offsets equal to 20 percent of the amount invested, up to a maximum of €180,000[110].

4. Ensure training data for algorithms

Access to large pools of data is critical for the development of AI as it enables the development of new AI tools. Opening up public-sector data can spur private-sector innovation. Setting common data standards can also help. In the United States, for example, the Securities and Exchange Commission mandated in 2009 that all public companies must disclose their financial statements in XBRL (extensible business reporting language) format, thereby ensuring that public data is machine readable.

How data availability can positively affect local businesses is shown by the case of Meniga, a FinTech company from Iceland offering Personal Finance Management software and transactional data analyses. Theoretically, Meniga had little chance on the global stage. But everything changed when a local bank allowed it to use its data for training algorithms[111]. Today, Meniga is a global company serving more than 40 million clients[112].

In Poland, setting common data standards, for certain industries at least, may be easier than in some other countries. The healthcare market is overseen by a single body (the National Health Fund, NFZ), unlike, for instance, in the United States, where the market is fragmented. This is important because forecasting the occurrence of diseases, for example, relies on the existence of an integrated healthcare database. Data must be standardized and summarized in the form of records, indicating patients' use of medical devices, physician visits, test results, and the presence of any remote monitoring devices.

Poland also has an opportunity to create a data ecosystem quickly and effectively in the area of electricity transmission and distribution, which features a single grid operator and a small number of distributors controlled by a regulatory body. Launching AI technologies at a country level will require a centralized system that collects detailed data, on the basis of which it is possible to analyze supply and demand and weather factors in real time. To construct such a system, it will be necessary to create a virtual representation of the underlying physical system, including a set of sensors and algorithms that can process and analyze data from these devices. This system would allow companies to react immediately even to small fluctuations in demand. Technology based on AI, using systems for micromanaging power production and transfer, would make it possible to balance the national energy system more efficiently.

Advanced weather-forecasting models can also bring significant value for agriculture, improving cultivation

productivity and reducing crop losses. To make this effort at least regional, a set of weather sensors and detailed weather data collection is required, generating periodical, standardized input relating to crop yields and health.

5. Deploy AI within public institutions

AI has tremendous potential benefits both for the public and the private sector. To realize these benefits, Polish companies need to be able to compete with players from Europe, the United States, and Asia. Without experience in large-scale implementation, they will find this a near-impossible task. The public sector can play a crucial role here. Government and state-owned companies in Poland could act as lead customers for AI technologies. Not only would this likely improve the productivity of the AI industry itself, but the startups from which the government bought its AI solutions would gain references that they could then use to secure their next clients or to apply for funding.

In healthcare, the Polish government could look at international examples of how governments have taken the lead in adopting and developing AI. In France, for example, machine-learning systems are used to forecast admission rates in Parisian hospitals[113]. In the United States, forecasting based on archived in-patient records and patient medical results is also used to identify and mitigate risk groups through preventive care[114].

In the Polish electric utilities industry, almost all companies are at least partially state-owned. Government investment in AI would likely result in greater profitability for those companies. Again, the Polish government can look at experience in other countries. In Germany, for example, there are challenges with predicting energy supply from renewable sources. In response, an AI project has started that is a collaboration between three major grid operators and funded by the Federal Ministry for Economic Affairs and Energy. The aim is to develop load forecasting enabled by machine learning that is specific to the needs of grid operators. This could lead to significant savings[115].

Government and public-sector initiatives related to developing or adopting AI within government can lend credibility to AI technology, encourage local companies to start implementation, and catalyze the growth of the local AI industry both on the demand and the supply side. In the United Kingdom, for example, HMRC (Her Majesty's Revenue and Customs Agency) recently ran a robotic process automation project that automated certain manual operations in the customs process. As a result, the number of times customs advisers have to click their mouse during calls has fallen from 66 to just 10, improving average handling times[116].

6. Resolve ethical, legal, and regulatory issues

AI presents a range of ethical, legal, and regulatory issues. Real-world biases risk being embedded into training data. Since the real world is racist, sexist, and biased in many other ways, real-world data that is fed into algorithms will also have these features—and when AI algorithms learn from biased training data, they internalize the biases, exacerbating the problems[117].

There are also concerns about the algorithms themselves. Whose ethical guidelines will be encoded into them? To what extent should people be able to understand and follow the decision-making process? And who will be responsible for the consequences of decisions made by AI?[118]

Privacy is likewise a concern. Who should have ownership of data, and what safeguards should be used to protect highly sensitive information, such as healthcare records? Organizations leading efforts to tackle these questions include the Partnership on AI, OpenAI, the Foundation for Responsible Robotics, and the Ethics and Governance of Artificial Intelligence Fund.

Poland will likely have to follow regulations set by the European Union. In February 2017, the European Parliament passed a resolution asking the European Commission to submit a proposal for a directive on robotics, stressing the need to enforce ethical standards and clarify liability issues related to, among other things, autonomous vehicles. The resolution also calls on the European Commission to consider giving the most sophisticated autonomous robots the status of "electronic persons"[119].

Poland should take an active part in drawing up the EU regulations. But it is also worth trying, as far as possible, to solve at a local level as many legal and regulatory issues that could block the development of AI as possible. France, for example, is already making such efforts. Last year, it passed the Bill for a Digital Republic, which sets out rules on data protection and the openness of public data. Under the bill, public bodies must publish their databases online and will be required to guarantee the quality and accuracy of reference data, such as the national address database[120].

7. Start the social debate now

The success of AI depends largely on society's approach to it. Persuading citizens to accept new technology is an important task for public institutions. Right now, it is still unclear whether people will accept their data being collected (and maybe sold) in order to train AI, not to mention whether they will accept being diagnosed by AI-facilitated robots in hospitals.

Around the world, the public debate around AI has already begun. In France, for instance, the National

Commission for Information Technology and Liberties (CNIL) is conducting a series of events across the country on behalf of the government to help the French understand what exactly AI means for them[121].

CHALLENGES FOR PROVIDERS OF AI SOLUTIONS

Openness to AI on the part of businesses and the existence of a suitable ecosystem is not enough to ensure the success of AI. The providers themselves would be well advised to offer AI solutions that solve real-world business problems. The McKinsey Global Institute survey highlights the scale of this challenge in the market today. Of the more than 3,000 firms surveyed, 41 percent reported that one of the biggest barriers to their further adopting AI was the uncertain return on investment, while 26 percent reported a lack of relevant AI products on the market.

To close that gap, AI providers would be well advised to develop sector-specific expertise. This means AI developers and engineers should focus more on adapting the technologies to the needs of the business world and the benefits they bring at scale. Experts on the market identify understanding the business case as one of the key success factors for AI providers[122].

In Poland, AI developers are relatively well positioned to address this challenge. We estimate that as many as 90 percent of companies working in the area of AI technology that received venture capital of public-private funding in 2016 are currently developing AI for applications in specific sectors.

It should not be forgotten, however, that meeting market expectations will also require AI developers to work on improving the still imperfect technology. Users become frustrated with machines if the machines cannot understand what they are saying, deliver inaccurate or inappropriate answers, or simply do not live up to the promises made about them. There are no easy answers here, and AI providers would be well advised to take the lead in overcoming this hurdle.

Even the leaders in the industry differ about how best to do this. Thus, in case of personal assistance applications, Amazon focused on error-rate reduction with Alexa[123]. Google took a different approach by managing customer expectations, making clear that it was not an intelligent personal assistant, in order to avoid some of the customer disappointment expressed about Apple's Siri[124].

CHALLENGES FOR FIRMS THAT WANT TO USE AI

While the overall impact of AI to date may be relatively small in many industries, its potential for disruption is high. Globally, we are already seeing examples of how AI-powered new entrants are able to take on incumbents and win. For example, Uber and Lyft have done this in the taxi industry, using AI solutions to optimize routes, tariffs, and deployment of vehicles.

This underscores the need for action now. The existence of an AI ecosystem that facilitates the adoption of AI is not enough in itself. Below, we describe five types of action that Polish companies can take to transform their business models and integrate AI into them.

1. Find the true source of value and build a business case for it

The first step is to establish a solid AI business case and connect it to the firm's strategy. Companies need a realistic view of what AI can and cannot do, which requires a high-level understanding of how AI works and how it differs from conventional technological approaches. On this basis they can make sure that they focus on the most valuable applications for their particular business.

An example of this approach is the use of Kiva robots by Amazon. Among the biggest challenges for retail are rapidly growing volumes and the variety of products, with strong client demand for personalized offers and next-day delivery. The business case for Amazon was clear. The company needed to serve clients faster and offer more products, and simply investing in new warehouse space would not solve the underlying problems.

The solution was AI. Implementing Kiva robots was more than just process automation: The company redesigned the entire warehouse operations by building a model around the idea of robot-human-computer collaboration. In the new system, robots are responsible for moving entire shelves with inventory, storing them closer together and eliminating unneeded space for aisles. People work in pick-and-pack zones, to which entire shelves are delivered by autonomous Kiva robots. Product and shelf allocation is fully controlled by machine-learning algorithms based on purchase patterns (items bought together are located side by side, for example)[125].

2. Build the data ecosystem

Without data, getting the AI engine started is impossible. Business leaders in Poland would be well advised to consider what data they already have access to and where they can obtain additional data relevant for their company's future success. Firms might also try to recognize the different types of data that can potentially give their AI-enabled products a competitive edge, such as customer sentiment or geo-locational real-time event data. Google and Facebook are well-known examples of companies that obtain most of their revenue by using the insights that they derive from the enormous quantities of

data their customers generate on a daily basis when using their services. Similarly, Netflix suggests movies based on users' virtual profiles: it checks what users liked in the past and compares this with choices made by users with similar profiles[126]. All of these steps are possible thanks to an extended data ecosystem, in which customer profiles and preferences are collected and analyzed.

Given the rapidly increasing volume of data coming from sensors, machines, and customer services, companies would also be well advised to work out how to handle massive streams of information. Ideally, they will become fluent in Big Data and AI technology. Clearly defining their business needs will enable them to decide what data to store in its original level of detail and what to bundle, reject, or pre-analyze.

3. Know what – and who – you need

Many businesses that start adopting AI lack experience and internal experts at first. This presents them with a significant challenge. Global companies most often manage by buying knowhow – frequently by acquiring promising startups – or by forming partnerships with leaders in the field of AI.

For example, GE acquired two AI startups in 2016, Bit Stew Systems and Wise.io, both working on analyzing Big Data from industrial devices connected via the Internet of Things. Through these transactions, GE aims to strengthen its AI capabilities[127].

At the same time, internal collaboration within companies is especially important for digital technology such as AI, which often cuts across traditionally separate parts of organizations – from customer service and fulfillment to supply-chain management and financial reporting. The different departments need to learn to work together when implementing AI.

Another key challenge is finding appropriate tools. As with other digital technology, an agile "test and learn" approach is important. Small, fast steps ensure the right focus, for example, through simulation-based pilots that allow companies to quickly test the impact estimated in the business case. Two-speed approaches can help, pushing ahead on newer, more flexible IT architecture while gradually migrating legacy systems. When implementing the Kiva system, for example, Amazon started by evaluating the solution in practice, later acquiring the company, integrating it, and entirely remodeling their warehouse operations around the solution[128].

4. Integrate AI into company's fundamental processes

Once companies have generated insights from pilot projects deploying AI, they should integrate AI into their fundamental business processes. This should allow them to capture the benefits promised in the business case. Integration should be comprehensive. Typically, it will involve changes to processes, such as their automation or comprehensive redesign working with those responsible for the area in question.

Whatever the situation, ensuring a good human-machine interface is crucial. Often, change management and implementation, especially when it impacts what people do within an organization, are many times more challenging than the technical challenges of implementing new solutions. You cannot simply integrate an AI solution in isolation and wait for success. It is necessary to adapt the business processes and train employees to use the new technology[129].

5. Create an open culture and organization

To get the most out of AI long term, companies require an organizational culture that is open to collaboration between humans and machines. Trust is a key enabler here, and humans will need some time to adjust to the paradigm shift. Creating or strengthening an AI-ready culture should be a priority early on. Most organizations will require special training and investment in building up the analytical capabilities of workers, especially mid-level managers, so that they understand how to use the data-driven AI insights and trust them as the basis for making decisions.

The changes to the organization triggered by AI may be significant. Companies should be forthright in addressing employee concerns, if they expect them to help develop and implement AI tools that will change business processes and potentially automate some activities. Today we already know that AI will revolutionize business. Adapting to the new reality will require changes in skills, mindsets, and cultures as we transition into a world where "co-workers" include machines.

CONCLUSION

AI is set to drive profound changes in the global economy. Investment globally has been growing fast since 2013, with tech giants making huge plays on AI technology development and deploying it across their businesses. We are already seeing examples of real-life business benefits for early-adopting firms.

However, the adoption of AI technology remains largely at an experimental stage–not just in Poland, but around the world. The gap between early adopters and the rest is likely to grow. While many companies globally have yet to be convinced of the benefits of AI, frontier firms are charging ahead. Early AI adopters tend to be larger companies with mature digital strategies that display both deep and broad adoption patterns. Their focus on AI is driven by the desire to increase revenue and reduce costs, and they have momentum and support for AI from the top of the company.

It is clear that much can be gained from AI technology. Companies in Poland would be well advised to speed up their digital transformation journey. Companies will need to have the right digital assets and skills in place in order to be able to effectively deploy AI. Poland still has a chance to become a strong hub for AI – if not as a source of cutting-edge solutions, then at least in developing and deploying AI in real business applications.

Endnotes

1. Factiva.
2. Speech by adjunct professor Andrew Ng at the Stanford MSx Future Forum, January 2017.
3. Tractica; Transparency Market Research.
4. "Google achieves AI 'breakthrough' by beating Go champion," *BBC News*, January 27, 2016.
5. William Vorhies, "Artificial general intelligence – the Holy Grail of AI," www.datasciencecentral.com, February 23, 2016.
6. Deep learning is a subfield of machine learning that utilizes many levels of neural networks to carry out the process of machine learning.
7. Timothy B. Lee, "Artificial intelligence is getting more powerful, and it's about to be everywhere," www.vox.com, May 18, 2017.
8. 8 Ophir Tanz, "Can Artificial Intelligence Identify Pictures Better than Humans?" *Entrepreneur*, April 1, 2017.
9. *Artificial Intelligence: The next digital frontier?* McKinsey Global Institute, June 2017.
10. Craig Trudell and Yuki Hagiwara, "Toyota starts $1 billion center to develop cars that don't crash," www.bloomberg.com, November 6, 2015.
11. "IBM invests to lead global internet of things market – shows accelerated client adoption," IBM press release, October 3, 2016.
12. Estimated 2016 spend on developing and deploying AI-based products by the top 35 high-tech and advanced manufacturing companies investing in AI. Estimate based on the ratio of AI spend to total revenue, calculated for a subset of the 35 companies.
13. Venture capital investment estimated for companies primarily focused on AI; private equity investment estimated for companies involved in AI; estimated total value of all mergers and acquisitions in the area of AI; "other" refers to grants and seed-fund investments; figures are based on available data only and assume that all registered deals were completed within the year of transaction.
14. "U.S. companies raising $1 billion or more to fuel artificial intelligence (AI) development: Looking to staff 10,000+ openings, cites new Paysa research," Paysa press release, April 18, 2017.
15. Cade Metz, "Facebook opens a Paris lab as AI research goes global," www.wired.com, June 2, 2015.
16. Salman Podanur, "Following Twitter and Facebook, Google too buys a machine learning setup," www.medianama.com, July 7, 2016.
17. Job offers advertised by Samsung R&D Institute Poland on www.agh.edu.pl.
18. Izabela Biała, "Sztuczna Inteligencja? Także z Gdańska – Intel otworzył nowe centrum," www.targi.agh.edu.pl/edycja-wiosenna/wystawcy-2017/samsung-rd-institute-poland/; Wojciech Kukuła, "Rozmowa z Krzysztofem Miksą z TomTom," flota-online.pl, February 22, 2017.
19. Website of the Amazon Development Center in Gdansk, www.gdansk-amazon.com.
20. "Przyjdź i zacznij coś z nami w Campus Warsaw," Google Blog Polska, November 19, 2015.
21. Adam Sawicki, "Microsoft otwiera w Warszawie inkubator dla startupów. Pomoże im wejść na zagraniczne rynki," mamstartup.pl, March 30, 2017.
22. Anna Bełcik, "Siemens otwiera się na polskie innowacje," www.pb.pl, May 5, 2017.
23. Mariusz Gawrychowski, "VIG zrobi z Polski laboratorium," www.pb.pl, June 20, 2017.
24. Figure for Poland refers to estimated total public/private spend in the form of grants and by venture capital funds on AI-related startups; grants budget equally distributed. Figures for other countries refer to estimated total seed and venture capital investment in AI-related companies.
25. Ingrid Lunden, "Amazon Gets Into Voice Recognition, Buys Ivona Software To Compete Against Apple's Siri," techcrunch.com, January 24, 2013.
26. Ivona website, www.ivona.com.
27. Growbots website, www.growbots.com.
28. Rafał Tomaszewski, "Nethone – polska firma zwalcza fraudy płatnicze za pomocą sztucznej inteligencji," fintek.pl, March 21, 2017.
29. deepsense website, deepsense.ai.
30. Neurosoft website, neurosoft.pl.
31. *Artificial Intelligence: The next digital frontier?* McKinsey Global Institute, June 2017.
32. Figures are estimates of total annual venture capital investment in AI-focused companies, private equity investment in AI-related companies, and M&As by corporations; figures are based on available data only and assume that all registered deals were completed within the year of transaction.
33. Survey results throughout this document are weighted for firm size; "20 precent of firms" indicates firms representing 20 percent of the workforce.
34. The technologies included in survey were natural language processing, natural language generation, speech recognition, machine learning, decision management, virtual agents, robotics process automation, and computer vision.
35. *Artificial Intelligence: The next digital frontier?* McKinsey Global Institute, June 2017.
36. The MGI Digitization Index is GDP-weighted average of Europe and United States.
37. Kevin Zhu, Kenneth L. Kraemer, and Sean Xu, "The process of innovation assimilation by firms in different countries: A technology diffusion perspective on e-business," *Management Science*, volume 52, number 10, October 2006; Chris Forman, Avi Goldfarb, and Shane Greenstein, "The geographic dispersion of commercial Internet use," in Lorrie Faith Cranor and Steven S. Wildman, eds., *Rethinking rights and regulations: Institutional responses to new communication technologies*, MIT Press, 2003.
38. Sanjeev Dewan, Dale Ganley, and Kenneth L. Kraemer, "Complementarities in the diffusion of personal computers and the internet: Implications for the global digital divide," *Information Systems Research*, volume 21, number 5, December 2010.
39. Eugene Kim, "Amazon's $775 million deal for robotics company Kiva is starting to look really smart," www.businessinsider.com, June 15, 2016.
40. Operating profit margin for selected sectors as a share of revenues, for continuing operations and before exceptional items.
41. Firms that use Big Data and cloud services say that their strategic response to AI is one of the following: "Disrupting our industry using AI technology is at the core of our strategy," "We have changed our longer-term corporate strategy to address the threat or opportunity of disruption by AI," or "We have developed a coordinated plan to respond to the threat or opportunity of AI but have not changed our longer-term corporate strategy." Based on the McKinsey Global Institute survey on the adoption and use of AI, with responses from around 3,000 C-level executives of at least AI-aware companies from the United States, Canada, China, Japan, South Korea, the United Kingdom, France, Germany, Italy, and Sweden.
42. In terms of GVA in 2014; Eurostat National accounts aggregates by industry (up to NACE A*64).
43. Eurostat: National accounts employment data by industry.
44. *Digital Poles – Consumers in a time of e-revolution*, McKinsey & Company, September 2016.
45. *Artificial Intelligence: The next digital frontier?* McKinsey Global Institute, June 2017.
46. Euromonitor International Retailing Edition 2016.
47. United Nations Statistics Division, data for 2015.
48. "How Germany's Otto uses artificial intelligence," The Economist, April 12, 2017.
49. "Rynek powierzchni magazynowych w Polsce w 2016 r.", www.magazyny.pl, February 10, 2017.
50. *Artificial Intelligence: The next digital frontier?* McKinsey Global Institute, June 2017.
51. Description of Amazon Go on www.amazon.com.
52. Staples website, www.staples.com.
53. Andrew Gebhart, "Google Home vs. Amazon Echo, round 2: Google strikes back," www.cnet.com, May 18, 2017.
54. Biran Heater, "Amazon's new Echo Look has a built-in camera for style selfies," techcrunch.com, April 26, 2017.
55. *Wskaźniki makroekonomiczne*, GUS, initial estimates for 2016.
56. *Nakłady i wyniki przemysłu,* GUS, number refers to average paid employment; data for 2016.

57. *5 opportunities for Poland,* McKinsey & Company and Forbes report, 2015.
58. Anja Weber, "Siemens-SupplyOn Suppliers Day: Collectively driving digitalization," www.supplyon.com, May 12, 2017.
59. "The World's First Smart Factory To Introduce Artificial Intelligence," www.posco.com, February 17, 2017.
60. "Artificial Intelligence: Quality Prediction of Chemical Products in the Production Process," iot.do, September 17, 2016.
61. Luke Upton, "The digital railway gathers pace as SNCF enlist IBM's Watson supercomputer," www.smartrailworld.com, February 21, 2017.
62. OECD Health Statistics 2015.
63. Euro Health Consumer Index 2016.
64. *GUS: Prognoza ludności na lata 2014-2050* (opracowana w 2014 r.).
65. *Artificial Intelligence: The next digital frontier?* McKinsey Global Institute, June 2017.
66. "Camden's CCG's analysis of the scale of opportunity for reducing non-elective admissions," in *Better Care Fund, Appendix B—Defining Our Focus and Ambitions*, Camden Clinical Commissioning Group, September 2014; Alicia O'Cathain et al., "A system-wide approach to explaining variation in potentially avoidable emergency admissions: National ecological study," *BMJ Quality and Safety*, volume 23, issue 1, January 2014.
67. McKinsey analysis, based on OECD health statistics 2015.
68. OECD health statistics 2015.
69. Bertalan Meskó, "Top artificial intelligence companies in healthcare to keep an eye on," medicalfuturist.com, February 2, 2017.
70. *The age of analytics: Competing in a data-driven world*, McKinsey Global Institute, December 2016.
71. McKinsey analysis based on OECD health statistics 2015.
72. *The age of analytics: Competing in a data-driven world*, McKinsey Global Institute, December 2016; *A future that works: Automation, employment, and productivity*, McKinsey Global Institute, January 2017.
73. *The age of analytics: Competing in a data-driven world*, McKinsey Global Institute, December 2016.
74. McKinsey analysis based on OECD health statistics 2015.
75. *6th Benchmarking Report on the Quality of Electricity and Gas Supply*, CEER, 2016; data for 2014.
76. West Pomeranian, Pomeranian, Warmian-Masurian, Kuyavian-Pomeranian, and Podlaskie Voivodeships.
77. *2014 smart grid system report*, US Department of Energy, August 2014.
78. *Statystyka elektroenergetyki polskiej, Agencja Rynku Energii 2015*; data from 2015 and 2016 annual reports of PGE, Tauron, Energa, and Enea.
79. Energinet.
80. "GE launches the next evolution of wind energy making renewables more efficient, economic: The digital wind farm," General Electric press release, May 19, 2015.
81. *6th Benchmarking Report on the Quality of Electricity and Gas Supply*, CEER, 2016; data for 2014.
82. Thomson Innovation Scientific Literature, number of publications in the fields of computer science and mathematics in the period 2013-16.
83. CanSat competition website, www.cansat.competition.
84. University Rover Challenge website, urc.marssociety.org.
85. Anna Klimczuk, "Microsoft Research inwestuje w projekt dla niewidomych autorstwa polskich studentów," Microsoft press release, August 3, 2016.
86. *Business Services Sector in Poland 2017*, ABSL.
87. Andrzej Maciejewski, "Centrum R&D Samsunga w Polsce będzie głównym ośrodkiem rozwoju systemu Bada," Computerworld, March 1, 2011.
88. Includes graduates of bachelor, master, doctoral or equivalent degrees in mathematics, statistics, and information & communications.
89. "Tech Nation Visa Scheme: High demand as scheme enters fourth year," Tech City UK blog, April 13, 2017.
90. "Romania expands tax incentives for software programmers," Romania Insider, December 29, 2016.
91. Section on Facebook AI Research (FAIR) on research.fb.com.
92. "A booming startup ecosystem", La French Tech, May 2017.
93. *A future that works: Automation, employment, and productivity*, McKinsey Global Institute, January 2017.
94. Paul Smith, "Rise of the machines as ANZ brings in robot workers to do the 'boring' jobs," Australian Financial Review, August 24, 2015.
95. *A future that works: Automation, employment, and productivity*, McKinsey Global Institute, January 2017.
96. *A future that works: Automation, employment, and productivity*, McKinsey Global Institute, January 2017.
97. Sarah Kessler, "The optimist's guide to the robot apocalypse," qz.com, March 9, 2017.
98. *Digital America: A tale of the haves and have-mores*, McKinsey Global Institute, December 2015.
99. Information about the Lower Silesian Educational Cluster from the website of the Legnica Special Economic Zone, lsse.eu.
100. Asseco website, asseco.com.
101. UXPin website, www.uxpin.com.
102. CD projekt 2016, summary of results; 2CD Projekt press release; March 30, 2017.
103. Lublin Science and Technology Park website, lpnt.pl.
104. Pomeranian Science and Technology Park website, ppnt.pl.
105. Discussion of strategy for high-performance computing (HPC) in the framework of Horizon 2020, European Commission website.
106. Press relase on the Ministry of Digital Affairs signing an agreement for a 5G Strategy for Poland, Ministry of Digital Affairs website, June 29, 2017.
107. Total funds relating to the Smart Growth Operational Program 2014-2020 (*Program Operacyjny Inteligentny Rozwój 2014-2020*) and the Operational Program Digital Poland for 2014-2020 (*Program Operacyjny Polska Cyfrowa 2014-2020*), Portal Innowacji, September 22, 2014.
108. Richard Behar, "Backed By Big Wheels, A Boston Incubator Hooks Up Young Israelis And Palestinians To Launch Startups," Forbes, March 21, 2017
109. Robert Sledz, "Belgium Enacts Patent Box Incentive Regime," Thomson Reuters, February 28, 2017.
110. "Tax incentives for early stage investors," Australian Taxation Office website, August 2, 2017.
111. Eugeniusz Twaróg, "mBank wchodzi w start-upy," Puls Biznesu, February 16, 2017.
112. Meniga website, www.meniga.com.
113. Bernard Marr, "Big Data in Healthcare: Paris Hospitals predict Admission Rates using Machine Learning," www.forbes.com, December 13, 2016.
114. Steve Curd, "Healthcare Analytics: Analytics and Machine Learning," analytics-magazine.org, July/August 2016.
115. Quirin Schiermeier, "Germany enlists machine learning to boost renewables revolution," www.nature.com, July 13, 2016.
116. Mark Holl, "Robotics and people make a great combination…," Her Majesty's Revenue and Customs blog, September 22, 2016.
117. *The age of analytics: Competing in a data-driven world*, McKinsey Global Institute, December 2016.
118. See, for example, *Statement on algorithmic transparency and accountability*, Association for Computing Machinery US Public Policy Council, January 2017.
119. Civil-law rules on robotics, *European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics* (2015/2103(INL)).
120. "The Digital Bill," www.gouvernement.fr, January 26, 2016.
121. "Public debate on algorithms, artificial intelligence and ethics: the upcoming high points," Commission Nationale de l'Informatique et des Liberté, June 7, 2017.
122. Panel session at the Startup Grind conference "How AI Startups Must Compete with Google," Dr. Fei-Fei Li (Google Cloud) and Mike Abbott (KPCB), published on www.youtube.com.
123. Jordan Novet, "Amazon has reduced Alexa's mistakes in completing tasks by a factor of 2," venturebeat.com, July 13, 2016.
124. Farhad Manjoo, "Siri is a gimmick and a tease but Google voice search is getting close to fulfilling Apple's broken promise," www.slate.com, November 15, 2012.
125. Bloomberg interview with Dave Clark, Amazon Senior VP, Worldwide Operations, published on www.youtube.com, December 2, 2014.
126. Kris Hammond, "The A.I. ecosystem," Computerworld, May 11, 2015.
127. "GE acquires two artificial intelligence startups," Reuters, November 15, 2016.
128. "Amazon Unveils its Eighth Generation Fulfillment Center," Business Wire, December 1, 2014.
129. "Implementation of artificial intelligence requires fundamental changes in business processes," AI Conference, April 26, 2017.