Artificial Intelligence in Africa: Economic Development Potential and Challenges to Overcome

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Acronyms

AFD: French Development Agency
AV: Autonomous Vehicles
BATX: Baidu, Alibaba, Tencent, Xiaomi (major Chinese tech companies)
ETS: Educational Testing Services
IMF: International Monetary Fund
AI: Artificial Intelligence
AGI: Artificial General Intelligence
OAI: Organoid Artificial Intelligence
IDC: International Data Corporation
MOOC: Massive Open Online Courses
NAIIO: National Artificial Intelligence Initiative Office (United States)
ILO: International Labor Organization
UN: United Nations
PASANDAD: Accelerated Food and Nutrition Security and Sustainable Agricultural Development Program
GDP: Gross Domestic Product
PNDA: National Agricultural Development Plan
PNDES: National Economic and Social Development Plan
PNIASA: National Agricultural Investment and Food Security Program
TFP: Total Factor Productivity
PwC: PricewaterhouseCooppers
SMS: Short Message Service
AU: African Union
UNCTAD: United Nations Conference on Trade and Development
UNESCO: United Nations Educational, Scientific and Cultural Organization
**Abstract**

This report delves deeply into the issues related to artificial intelligence (AI), with a focus on its potential for socio-economic transformation in Africa. After tracing the origins and various typologies of AI, in-depth analyses are conducted on its impact on employment globally and the disparities between developed and emerging countries. Special attention is given to key sectors such as healthcare, automotive, and finance, which are particularly vulnerable to AI disruptions.

The dossier then examines the prospects for the evolution of AI, discussing the technical and scientific challenges to achieving true general artificial intelligence. It also addresses the promising but controversial emergence of organoid artificial intelligence, cultivating biological neural networks and raising thorny philosophical and ethical questions.

The section devoted to Africa provides an overview of the continental AI landscape, highlighting its immense economic potential estimated at nearly $1.5 trillion in GDP contribution by 2030. However, challenges in terms of infrastructure, skills, and regulation are analyzed, calling for massive and coordinated investments to develop a competitive AI ecosystem.

Concrete case studies illustrate innovative applications of AI in various strategic sectors such as healthcare, agriculture, education, or financial services. Finally, recommendations are made for Africa to become a major player in sovereign, ethical, and responsible AI, as a driver of sustainable development.
1. **A massive impact on employment is expected.** According to an IMF study, nearly 40% of jobs worldwide will be affected by the effects of AI, with 60% of jobs affected in wealthy countries, 40% in emerging countries, and only 26% in low-income countries like those in Africa, which risks exacerbating inequalities.

2. **Entire sectors are threatened by automation.** A McKinsey study in South Africa estimates that by 2030, the retail sector could lose 334,000 jobs, administration 309,000 jobs, industry 231,000 jobs, transportation 186,000 jobs, agriculture 87,000 jobs, and real estate 20,000 jobs due to AI.

3. **AI represents an opportunity for job creation.** Although raising concerns about job destruction, AI also offers the opportunity to create new professions, as highlighted in an IMF report addressing the demographic challenge of creating 20 million jobs per year in Africa over the next 20 years.

4. **Colossal economic potential for Africa.** According to PwC, AI could contribute nearly $1.5 billion to African GDP by 2030, transforming key sectors such as health, agriculture and education.

5. **Africa lags behind in technological readiness.** The 2019 Government AI Readiness Index painted a bleak picture of the African continent, with no African country included among the 50 most innovative countries in AI, highlighting the lack of strategies and investments.

6. **Funding for African AI startups is stalling.** According to a recent analysis, funding for tech startups in Africa is expected to see a sharp slowdown in 2023, with an overall 46% drop in funding expected, despite growth in 2022.

7. **Digital infrastructure challenges persist.** Africa faces significant infrastructure challenges for AI, with limited access to high-speed internet and very few powerful data centers, less than 100 on the continent according to the Global IA Index 2023.

8. **A regulatory and ethical framework is necessary.** On the regulatory front, Africa is in the early stages of developing legal and ethical frameworks for AI, with 19 countries reporting an absence of legal frameworks according to UNESCO.
10. **A glaring deficit of specialized skills.** According to UNESCO, 26 African countries report lacking the means to address the ethical implications of AI, reflecting a significant deficit of specialist skills on the continent.

11. **Risks of a new form of digital colonization.** According to Seydina Ndiaye, UN expert, “the biggest threat is colonization by AI” with a risk of dependence on solutions from foreign multinationals and a plundering of African talents and data.

12. **AI raises deep philosophical questions.** The emergence of organoid AI, cultivating biological neural networks, raises the dizzying question of the potential consciousness of these “mini-brains” and calls into question the boundary between human and machine.

13. **Ethical governance of AI is crucial.** Faced with the unprecedented challenges posed by AI, it is crucial to anticipate potential abuses and to draw clear ethical red lines, within a thoughtful and collectively controlled framework.

14. **AI must remain at the service of humans.** The challenge is to build an ethical and inclusive AI, which increases our capabilities instead of enslaving us, creative and diverse, like human intelligence.

15. **Africa can become a leader in responsible AI.** With its youth and diversity, Africa has the opportunity to chart an original path towards inclusive AI.
Preface

Artificial intelligence (AI) is revolutionizing our societies and economies at dizzying speed. Its dazzling progress opens up perspectives that are as exciting as they are worrying for the future of humanity. At the heart of this technological revolution, Africa intends to take its full place and seize the immense opportunities offered by AI for its development.

"AI, a new global economic paradigm"

AI is emerging as the new paradigm of the global economy. According to a PwC study, it could contribute $15.7 trillion to global GDP by 2030, including nearly $1.5 trillion for Africa. Key sectors such as health, agriculture, finance or education could be profoundly transformed by AI-based innovations.

But for Africa to fully benefit from this revolution, it will need to overcome several major challenges. The lack of infrastructure, skills and appropriate regulatory frameworks still hinders the deployment of these technologies on the continent. Concerted action by governments, businesses, researchers and civil society will be essential to create an ecosystem conducive to the development of inclusive and beneficial AI for all Africans because the potential of AI for the development of Africa is huge.

Beyond economic gains, it offers formidable levers to address the major social and environmental challenges of the continent, from combating poverty to adapting to climate change and access to health and education. Provided that it is used for the common good and not for the benefit of a few.

"The specter of a new technological colonization of Africa"

But be careful, if Africa misses this AI turning point, it risks remaining permanently on the margins of the global economy. Without local control of these technologies, the continent is exposed to a new form of technological colonization by the global AI giants. Its talents and data could be captured by these foreign multinationals, reproducing neocolonial patterns of domination.

The stakes are therefore high. It is about Africa's digital sovereignty and its place in the new world order that is emerging.

This study sheds precious light on these crucial issues. May it fuel the debate and inspire action so that Africa becomes a major player and not just a spectator of the ongoing and irreversible AI revolution!
1 Introduction
L’intelligence artificielle (IA) fascine autant qu’elle inquiète. Ses progrès fulgurants, portés par la puissance de calcul exponentielle des ordinateurs et l’abondance des données, ouvrent des perspectives vertigineuses. Traduction automatique, conduite autonome, diagnostic médical... Les pouvoirs s’enchaînent, repoussant les limites de ce que l’on croyait l’apanage de l’intelligence humaine.

"If tomorrow our creations escaped our control?"

But AI also raises legitimate concerns. The specter of machine domination, long confined to science fiction, seems to be drawing closer. James Cameron’s Terminator, that cyborg assassin sent from the future by the Skynet AI to annihilate humanity, crystallizes our deepest fears. What if tomorrow, our creations were to escape our control?

This threat seems less and less fanciful as AI gains autonomy, capable of learning and reasoning. The emergence of a "super artificial intelligence" surpassing humans is seriously considered by many experts.

Among the most alarming scenarios is that of an organoid AI, no longer based on silicon chips but on biological neurons. These "mini-brains" cultivated in the laboratory from stem cells could endow machines with unprecedented computing power and cognitive capabilities, far beyond current AI. Enough to give body to our worst nightmares...

Should we then give in to panic?

No, provided we keep control of our destiny. It is crucial to steer the development of AI in a direction that benefits humanity. This requires a massive research effort, but also a broad public debate on the purposes we want to assign to it. Ethics must be at the heart of its design.

When used properly, AI can become humanity's best ally in tackling the immense challenges of our time, from climate change to health, education or the fight against poverty. It is up to us to build this virtuous AI and chart a course in which machines sublimate human intelligence instead of replacing it. The future of our species depends on it.

Artificial Intelligence (AI) represents the ability of machines to mimic human intelligence, a constantly evolving concept catalyzed by technological advances, the exploitation of massive data, and the continuous refinement of algorithms.

In a context of exponential growth, AI has emerged as a crucial field, redefining our understanding of intelligence and its multiple applications, from medicine to finance, to scientific research.

This study is committed to providing a comprehensive overview of AI, starting with the definition of the concept. We will delve into its historical origins, from ancient developments to the formalization of the concept in the 20th century, highlighting notable figures such as Alan Turing, John McCarthy, Marvin Minsky, among others. Following this trajectory, we will explore the different typologies of AI, from weak to strong AI, encompassing approaches such as expert systems, machine learning, artificial neural networks, and many others.

At the heart of our approach, a specific section will focus on AI in Africa, addressing its state of play, its potential for economic development, and its contribution to the structural transformation of the continent. We will rely on various sources, ranging from strategic analysis to detailed reports on the digital economy in Africa, to nourish this reflection.
Finally, our exploration will move toward the limits and dangers of AI, discussing the current capabilities and challenges of AI systems, addressing issues related to model interpretation, bias, ethics, and sketching possible dystopian scenarios.

Our ultimate goal is to provide a holistic view of issues related to AI, encouraging in-depth reflection on its growing role and responsible use in our society.

In summary, this file aims to draw up a complete map of AI, exploring its origins, its evolutions, its impacts, and its prospects, while highlighting the key role of AI in Africa to stimulate economic development and promote positive structural transformation.

In a proactive approach, we will seek to understand the challenges of AI and reflect on how it can be used responsibly and ethically for the benefit of our society.
2 Foundations of the Rapid Rise of Artificial Intelligence
Artificial intelligence has been experiencing a spectacular development in recent years, propelled by the convergence of several key factors. To understand the roots of this rapid rise, it is essential to deeply explore the technological pillars that have made this revolution possible: exponential computing power, the abundance of massive data, and the continuous improvement of algorithms.

These remarkable advances are not the result of chance, but are part of a broader context, shaped by economic, societal, and regulatory forces that have created a fertile ground for the emergence of AI. The enthusiasm of companies for these technologies, the evolution of consumer expectations, and government initiatives have played a decisive role in catalyzing the large-scale adoption of artificial intelligence.

In the following sections, we will decipher the foundations of AI’s rise by exploring, on the one hand, the winning technological trinity formed by computing power, big data, and sophisticated algorithms, and on the other hand, the supportive ecosystem that has favored the rapid deployment of these disruptive innovations. This in-depth analysis will allow us to better understand the driving forces behind this major technological revolution and grasp its full scope.

2.1 The three pillars of the rise of artificial intelligence:

The advent of artificial intelligence (AI) relies on the convergence of three key elements: technological advancements, the abundance of massive data, and the refinement of algorithms.

First, the rapid progress made in computer processing and storage capabilities laid the essential groundwork for the rise of AI.

“Big data is the second pillar of AI.

The exponential growth in processing power of processors and the emergence of “cloud computing” have enabled the management of ever-increasing volumes of data, paving the way for machine learning. Indeed, these massive amounts of data constitute the second pillar of AI. The explosion of big data, fueled by the proliferation of connected objects, the digitalization of society, and the ubiquity of the Internet, has provided researchers with mountains of information to train and refine AI models.

“Algorithms are indeed the third ingredient in the recipe for AI success.

From images to sounds to texts, this profusion of data has fueled ever more efficient algorithms. Because algorithms are indeed the third ingredient in the recipe for AI success. Major advances in their design, such as deep learning based on multi-layer neural networks, have increased the capabilities of machines to learn on their own from data. By freeing themselves from rigid rule-by-rule programming, these algorithms have achieved unequalled levels of performance in complex tasks such as visual recognition or language processing.

It is the synergistic combination of these three elements - computing power, big data and advanced algorithms - which has propelled artificial intelligence to the forefront of the technological scene, opening up dizzying prospects for applications in all fields.
2.2 Context of the emergence of AI: Technological advances, big data, and algorithms have contributed to its development.

The emergence of Artificial Intelligence (AI) is deeply embedded in a context marked by significant technological advancements, the management of massive data, and the refinement of algorithms. These converging elements have played a crucial role in the rapid and evolutionary development of AI, propelling this discipline to the forefront of major transformations in our era. Specifically, technological advancements include the following pillars:

➢ **Technological Advancements:** The rapid evolution of computing capabilities has been one of the fundamental pillars of the rise of AI. Continuous progress in computing power has enabled the swift and efficient processing of complex data, thereby providing a fertile ground for the deployment of sophisticated algorithmic models. Emerging technologies, such as cloud computing, have also provided a robust infrastructure for executing data-intensive tasks, thus fueling the growth of AI.

➢ **Big Data:** Another major catalyst has been the increasing availability of large data sets. AI, particularly machine learning, relies heavily on access to massive amounts of information to train and refine models. The explosion of data from various sources, such as social media, IoT (Internet of Things) sensors, and online databases, has created a rich and diverse reservoir fueling the ever-evolving AI.

➢ **Sophisticated Algorithms:** The improvement of algorithms constitutes the third pillar of the emerging AI context. Advances in algorithm design, from symbolic logic to data-driven methods, have enabled AI systems to become more adaptive, capable of learning and autonomous reasoning. The introduction of deep learning, based on artificial neural networks, has notably played a major role in improving the performance of AI, enabling previously unseen levels of complexity and sophistication.
3 Genesis of Artificial Intelligence
3.1 Origins and history of AI

In China, the philosopher Mozi (5th century BC) described a machine capable of deciding and reasoning.

Reflections on the creation of intelligent artificial entities are ancient. Indeed, since Antiquity, philosophers and sages have imagined machines capable of reasoning, making decisions and solving problems.

In China, the philosopher Mozi (5th century BC) described a machine capable of deciding and reasoning. In India, the sage Patanjali (2nd century BC) wrote a treatise on logic that describes a machine capable of solving mathematical problems.

These examples attest to the fascination of humans for artificial intelligence. They show that the idea of creating machines capable of thinking and acting like humans is an ancient tradition dating back thousands of years.

The myths and legends of humanity are also full of examples of artificial creatures endowed with remarkable intelligence and autonomy.

Over the last few centuries, tangible progress has been made in the realization of these abstract concepts. Ada Lovelace, considered the first computer programmer, developed ideas on programming an analytical machine in the 19th century. Her work had a major influence on the development of AI.

3.2 The Precursors of AI

The 20th century witnessed the emergence of the precursors of AI. Alan Turing, a pioneer of computer science and computational thinking, is considered the father of AI. He laid the theoretical foundations of the discipline, notably with his paper "Computing Machinery and Intelligence" (1950), in which he defined the Turing test, a criterion for evaluating the intelligence of a machine.

John McCarthy, an American computer scientist, is often considered the first to have used the term "artificial intelligence". He organized the Dartmouth conference in 1956, which is considered the starting point of modern AI.

Marvin Minsky, an American computer scientist, was a pioneer of research in computer vision and artificial intelligence. He founded the MIT Artificial Intelligence Laboratory, one of the most prestigious AI laboratories in the world.

3.3 The Major Milestones in the Development of AI

The evolution of AI has centered around two main approaches: symbolic logic and machine learning.

3.3.1 Symbolic logic

The earliest attempts at AI were based on explicit logical rules. This approach had some success in areas such as chess and the traveling salesman problem.

✓ Chess: In 1997: Deep Blue, a computer developed by IBM, beat Garry Kasparov, then world chess champion.

✓ Traveling Salesman Problem: This problem involves finding the shortest path to visit a series of cities. Symbolic logic methods were able to solve problems of up to 80 cities in size.

3.3.2 Machine Learning

The rise of modern computing has enabled the emergence of methods for learning from data. This revolutionary approach, called machine learning, gives machines the ability...
to learn autonomously, without having to be explicitly programmed.

Medical diagnosis has greatly benefited from this. Machine learning algorithms now assist doctors in making accurate diagnoses for various pathologies.

Translation has also been transformed by these systems. They now allow texts to be translated from one language to another with remarkable fluency.

Finally, machine learning is at the heart of autonomous driving.

However, fully autonomous vehicles capable of traveling on any road completely autonomously are not yet a reality today. Current systems only work on certain types of well-mapped roads and in favorable weather conditions. They always require human supervision, with a driver having to be able to regain control at any time.

Despite these limitations, machine learning opens up promising prospects for gradually improving vehicle autonomy in controlled environments, performing certain tasks previously reserved for humans.
4 Types of Artificial Intelligence
Artificial intelligence (AI) is a vast and constantly evolving field, encompassing various approaches and techniques. This chapter explores the different existing AI typologies and categories, without presenting them as complementary or exclusive to each other. Rather, it offers a comprehensive overview of this rich and diverse landscape.

We will begin with the fundamental distinction between weak AI and strong AI. Then, we will examine different AI approaches such as expert systems, machine learning, artificial neural networks, symbolic AI, intelligent agents, and computer vision. These techniques are described as distinct categories that are part of the range of existing AI methods, without indicating whether they are complementary or mutually exclusive.

By exploring this diversity of approaches, we will gain an in-depth understanding of the capabilities, limitations, and future evolution prospects of these revolutionary technologies. This overview will help us better grasp their potential impact across various sectors, as well as the technical and ethical challenges to be addressed in the years to come, which have largely contributed to its development.

4.1 Weak AI vs Strong AI

AI can be classified into two main categories: weak AI and strong AI.

Weak AI: Weak AI focuses on developing specialized systems designed to excel at specific and limited tasks. These systems are tailored for particular domains such as speech recognition, computer vision, machine translation, or strategic games like chess or Go. These applications are characterized by clear rules and well-defined contexts, allowing weak AI systems to achieve performance levels often superior to humans in specialized tasks.

Examples of Weak AI:

- Voice assistants like Siri, Alexa or Google Assistant, ChatGPT. They are specialized in limited tasks such as answering questions, providing weather information or controlling home devices.

Strong AI: In contrast, strong AI aims to create systems with general intelligence, making them capable of handling a wide variety of tasks and learning autonomously from diverse experiences. These hypothetical systems would be able to generalize knowledge from one domain to another, reason abstractly, and even understand the world in a way similar to humans. The ultimate goal of strong AI is to create machines with consciousness and a deep understanding of their surrounding environment.

Examples of Strong:

- An AI system with general intelligence comparable or superior to humans, capable of abstract reasoning, self-learning and adapting to multiple domains like a human would.

We can deduce that weak AI specializes in efficiency and performance in specific tasks, while strong AI seeks to reproduce a form of general intelligence comparable to that of humans.

This dichotomy reflects the various aspirations of research in artificial intelligence and influences the strategic directions in the development of this technology, also raising ethical and philosophical questions regarding the creation of machines with an intelligence similar or even superior to that of the man.
4.2 Expert Systems and Fuzzy Logic
Expert systems use explicit rules to make decisions, simulating human expertise in a specific domain. Expert systems are often used in areas such as medical diagnosis, finance, and predictive maintenance. Fuzzy logic allows handling uncertainty and improving in situations where information is incomplete or contradictory. Fuzzy logic is often used in applications such as image recognition, speech recognition, and risk management.

4.3 Machine Learning
Machine learning is a field of study in artificial intelligence that is based on mathematical and statistical approaches to give computers the ability to "learn" from data, that is, to improve their performance in solving tasks without being explicitly programmed for each one.

Machine learning is a powerful approach that is used in many different applications, such as image recognition, speech recognition, time series prediction, and fraud detection.

4.4 Artificial Neural Networks
Inspired by the functioning of the human brain, artificial neural networks use search and learning algorithms to process complex and imprecise data. They are capable of learning from experiences and adapting to new situations. Artificial neural networks are widely used in applications such as image recognition, speech recognition, machine translation, and fraud detection.

4.5 Symbolic AI and Automated Reasoning
Symbolic AI uses symbols and logic to make decisions. Symbolic AI is often used in areas such as planning, programming, and problem-solving. Automated reasoning focuses on optimal decision-making in dynamic and unpredictable environments. Automated reasoning is often used in areas such as finance, logistics, and cybersecurity.

4.6 Intelligent agents
Intelligent agents are computer programs capable of perceiving and acting autonomously in a complex environment to achieve specific goals. They combine machine learning and logical reasoning to make optimal decisions for a given situation. Autonomous vehicles or virtual personal assistants are examples of intelligent agent applications.

4.7 Computer vision
Computer vision is a branch of AI that aims to equip machines with visual analysis capabilities similar to those of humans, or even better. It combines image processing and deep learning techniques to recognize shapes, faces or objects. Applications such as content moderation or autonomous driving rely on artificial vision.

AI offers many opportunities for the future, and different approaches to AI, such as machine learning, neural networks, and symbolic AI, can be used to address complex and evolving problems. Investment in this area is considerable, and governments and businesses are seeking to drive its expansion while ensuring responsible and ethical use of this technology.
5 The impact of artificial intelligence (AI) on employment
5.1 The Impact of Artificial Intelligence on Employment

Automation of 300 Million Full-Time Jobs

Faced with the rapid rise of generative artificial intelligence (AI), crucial questions are emerging about the future of work. According to a report by Goldman Sachs, this technological evolution could lead to the automation of 300 million full-time jobs, mainly in developed countries. This forecast is all the more concerning as Figure 1 indicates that about two-thirds of jobs in the United States are likely to be affected to some degree by AI automation.

Figure 1 Two-Thirds of Current Occupations Could be Partially Automated by AI. (Source Gold Sachs 2023)
In this context, research conducted by the University of Pennsylvania and OpenAI brings an important nuance by identifying that some skilled workers in the tertiary sector, with incomes up to $80,000 per year, are particularly vulnerable to these changes.

This vulnerability within the service sector highlights the broad scope of AI’s impact, which is not limited to production but also extends to skilled professions traditionally considered less exposed to automation.

14% of employees globally may need a career change

In parallel, Forbes reports that a joint study by MIT and Boston University predicts that AI could replace up to two million workers in the manufacturing sector by 2025, confirming AI’s profound impact on jobs traditionally based on physical labor.

In addition to these observations, a study by the McKinsey Global Institute projects that by 2030, at least 14% of employees globally may need to change careers due to digitization, robotics, and advances in AI.

AI is becoming a powerful driver of transformation in the labor market

Combining the perspectives of these different reports, it is evident that AI is becoming a powerful driver of transformation in the labor market, affecting not only jobs traditionally considered automatable, but also those requiring advanced cognitive skills. The impact is expected to be uneven across different sectors, with significant implications for workforce training, skills development, and business strategies to adapt to this new era of intelligent automation.

This projection highlights the urgency of addressing the challenges posed by AI, not only in terms of job losses but also in terms of the need to retrain and upskill the workforce for future competencies.

18% of global work could be automated

5.2 Global Disparities in Work Automation: Perspectives from Developed and Emerging Markets

Figure 2 from the Goldman Sachs report, indicating that 18% of global work could be automated, highlights disparities between developed markets (DM) and emerging markets (EM). This difference could be due to higher wage levels and advanced technological infrastructure in DMs, making automation more cost-effective and easier to integrate. For EMs, although the impact is lower, a trend towards automation remains present, suggesting a global shift towards more automated economies. The adoption of automation in DMs could create competitive pressure on EMs to keep pace, despite distinct challenges related to their economic structure and level of technological development.
5.3 Sectors Specifically Vulnerable to AI

The PwC report highlights that sectors such as healthcare, automotive, and financial services are particularly vulnerable to the impact of AI. The integration of AI in these domains could lead to a major transformation, significantly improving the efficiency and personalization of these services.

5.3.1 Healthcare: The Rise of Medical

Artificial intelligence is rapidly transforming the healthcare sector. According to a 2021 McKinsey study, the medical AI market is expected to grow from $6.9 billion in 2021 to $62.4 billion in 2030.

➢ Tangible Clinical Benefits

A recent meta-analysis in The Lancet (Liu et al., 2022) confirmed the very high accuracy of AI algorithms for breast cancer screening from medical imaging. In some cases, the accuracy even exceeds that of expert physician.

➢ Increasing Adoption in Healthcare Organizations:

According to the "AI in Healthcare" report by Oxford Insights (2022), more than 50% of healthcare decision-makers have already adopted at least one AI technology. And 86% plan to invest more in AI over the next 5 years. IT departments are at the forefront of supporting this AI transformation of health information systems.

Challenges to Overcome:

However, obstacles remain to be overcome regarding the reliability of algorithms, cybersecurity or the interoperability of systems. Regulations are also evolving to frame these high-risk AI innovations.

5.3.2 Automotive industry

AI, an accelerator of the automobile industry
The automotive sector is undergoing a radical transformation, driven by spectacular advances in the fields of artificial intelligence (AI) and deep learning. This evolution is rooted in the increasing ability of AI systems to process, analyze, and learn from vast amounts of data, paving the way for unprecedented innovations in vehicle design, manufacturing, and usage.

$1.6 trillion per year by 2030

Onboard AI is reinventing driving:
According to a McKinsey study, global revenues related to autonomous vehicles (AVs) in urban areas could reach $1.6 trillion per year by 2030. This is more than twice the combined revenues of Ford, General Motors, Toyota, and Volkswagen in 2017.

$800 billion per year in 2030

Immense societal benefits:

Also according to McKinsey, in the United States, if AVs were fully adopted, the savings for society would exceed $800 billion per year in 2030, broken down as follows (Figure 3):

- **Approximately $400 billion** due to improved road safety and fewer accidents
- **Over $120 billion** through productive time gained by workers during their commutes
- **$250 billion** related to the conversion of parking spaces into more productive real estate properties

![Figure 3: Estimation des bénéfices économiques annuels des véhicules autonomes aux États-Unis (Mds $)](image-url)

1Environmental benefits are proportionately small (<$4 billion) and barely visible in the chart.
Source: US Federal Highway Administration; McKinsey analysis
5.3.3 Financial Services: AI, the Future Norm of Financial

The integration of artificial intelligence (AI) in the banking sector marks a decisive turning point, redefining traditional operational models. Figure 4 from the McKinsey report titled "Building the AI Bank of the Future" shows that the potential of AI in the banking sector is considerable, with an estimated annual added value of around $1 trillion.

This analysis details that the value generated by AI is divided between traditional analytics and advanced AI, influencing various areas such as marketing, sales, risk management, finance, IT operations, human resources, among others.

This breakdown illustrates the significant impact of AI on improving banking processes and enriching the customer experience, while fostering revenue growth and cost reduction.

Figure 4: Estimated annual economic benefits of autonomous vehicles in the United States ($ billion)

Potential annual value of AI and analytics for global banking could reach as high as $1 trillion.

Total potential annual value, $ billion

<table>
<thead>
<tr>
<th></th>
<th>Traditional AI and analytics</th>
<th>Advanced AI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>660.9</td>
<td>361.5</td>
</tr>
<tr>
<td>1,022.4 (15.4% of sales)</td>
<td></td>
<td></td>
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% of value driven by advanced AI, by function

- Finance and IT: 8.0
- Other operations: $2.4 B
- Marketing and sales: 624.8
- Risk: 372.9
- HR: 14.2

Complex regulatory challenges

However, this massive deployment of AI raises questions about the transparency and control of algorithm risks in the highly regulated finance sector. Regulators therefore have a key role to play in ensuring the ethical and responsible use of these technologies.

If they meet these challenges, there is no doubt that AI could become the norm in the financial services industry in the years to come.

5.4 Displacement and job creation

The adoption of technologies without human intervention will lead to the obsolescence of some positions, but at the same time, new job opportunities will emerge thanks to changes in productivity and consumer demand arising from AI.

Entirely new jobs, which would not have existed without AI, will be created.

5.4.1 Potentially significant automation of work tasks

“In the United States, 46% of tasks are in the administrative field and 44% in the legal field

According to the Goldman Sachs report, "up to a quarter of current work tasks could be automated, affecting sectors like administrative support and law. Indeed, the Goldman Sachs study estimates that in the United States, 46% of tasks in the administrative field and 44% in the legal field could be automated (figure 5).

In Europe, the areas most concerned are administrative (45%), legal (34%), technicians (31%) and senior executives (29%).

Figure 5: A quarter of current work tasks could be automated (source the Goldman Sachs report 2023)
5.4.2 Mixed Impact on Employment

A recent study from Goldman Sachs estimates that if generative artificial intelligence like ChatGPT develops as promised, it could replace 7% of U.S. jobs. However, 63% of jobs would rather be supplemented than replaced by AI. (Figure 6)

By analyzing 900 American professions, economists estimated the share of tasks that can be automated by AI. They assume that a job with 50% or more automatable tasks will be replaced, while a job with 10 to 49% automatable tasks will instead be supplemented by AI.

Thus, the study predicts the complete replacement of 7% of American jobs, especially in the legal and administrative fields where 46% and 44% of tasks are considered automatable. Conversely, construction (6% of automatable tasks) and maintenance (4%) will be little affected.

The majority of jobs (63%) will see AI as a complement, making it possible to increase employee productivity on certain tasks. According to Goldman Sachs, generative AI could increase American labor productivity by 1.5 points per year for 10 years.

Although the final impact depends on the capabilities and pace of AI adoption, this study highlights its enormous economic potential if it develops as promised.

Figure 6: Impact on professions and increase in productivity in all other areas (source: the Goldman Sachs report 2023)
6 Impacts and economic issues of AI
6.1 PwC methodology for estimating the economic impact of AI

In its 2023 report entitled "Sizing the prize", the consulting firm PwC sought to estimate the potential economic value of artificial intelligence by 2030. To do this, PwC used a two-step approach.

The first step consisted of a bottom-up analysis, evaluating nearly 300 concrete use cases of AI across different economic sectors. This analysis was based on an "AI impact index" to measure the potential of the technology to improve dimensions such as personalization, quality or speed.

The second step was a top-down economic modeling, exploiting the use cases analyzed previously. Econometric models and data such as KLEMS enabled PwC to estimate the impact of AI adoption in 2030 on productivity and consumer demand, across geographies and industries.

$15.7 trillion to global GDP in 2030

6.2 Main results of the PwC study

This two-step methodology led PwC to establish a scenario in which AI could contribute up to $15.7 trillion to global GDP in 2030, representing additional economic growth of 14% compared to today. (Figure 7) The majority of the gains would be captured by:

- **China:** +26% of GDP thanks to productivity gains from AI in industry
- **North America:** +14.5% of GDP

But AI would also lead to job destruction linked to automation. Fortunately, new jobs requiring skills in data science, IT development or AI project management would emerge.

**Opportunities to seize quickly**

Companies must quickly assess the vulnerability of their business model to AI disruption. The winners will be those who know how to develop the talents and technological capabilities to innovate.

Consumer confidence will also be crucial. The transparency of algorithms and the ethical management of data will be essential to avoid possible biases and abuses.
6.3 GAIN BY REGION

6.3.1 En China:

The integration of artificial intelligence into various economic sectors in China represents a major opportunity for its economy.

According to McKinsey's "The Next Frontier for AI in China" report, released in June 2022. The strategic adoption of AI in key industries like automotive, logistics, manufacturing, enterprise software and Health could generate $600 billion in annual economic value for China by 2030. (Figure 8)

Sectors with high potential:
The sectors identified as having the highest potential for value creation thanks to AI are:

- Automotive, transport and logistics: 64%
- Manufacturing: 19%
- Business software: 13%
- Health: 4: 4%
According to the Diplomat’s article “Why AI Is the New Frontier in China-US Competition”, published in August 2022, China clearly shows its desire to become the world leader in AI by 2030.

Its official strategy published in 2017 by the Council of State is divided into 3 stages:

- **2020**: Major breakthrough in fundamental research in AI and participation in the development of international standards
- **2025**: AI as the main driver of Chinese economic growth
- **2030**: Global leadership in the AI sector

To achieve this, significant public and private investments are being made in AI research and companies. China is also banking on the abundance of its data and its native technological champions (BATX)\(^1\) to catch up with the United States.

$1 trillion in the US economy by 2033

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\(^1\) BATX is an acronym which designates 4 large Chinese technology companies: Baidu: search engine, Chinese equivalent of Google; Alibaba: e-commerce platform, equivalent of Amazon; Tencent: internet services company (messaging, social networks, etc.) and Xiaomi: manufacturer of smartphones and connected objects
Generative artificial intelligence (AI) is expected to have a major economic impact in the United States in the coming years. According to a study by Cognizant and Oxford Economics, generative AI could inject **$1 trillion into the US economy by 2033**

As part of a forward-looking analysis of the impact of generative artificial intelligence (generative AI) on the US economy and labor market, three scenarios were developed to assess potential changes in productivity total factors (PTF)\(^2\) and repercussions on employment. (Figure 9)

- **Low scenario:** envisages a modest increase in TFP, leading to an increase of +1.7 percentage points in GDP. This scenario assumes limited adoption of generative AI, with incremental improvements in production processes and little disruption to existing jobs.

- **Central scenario:** projects a more significant progression, with an increase of +2.9 points in TFP, reflecting a more widespread adoption of generative AI. This medium integration would lead to significant productivity gains, affecting a wide range of sectors and substantially changing the employment landscape.

- **High scenario:** represents an optimistic case where enterprise adoption of generative AI reaches its full potential, resulting in a +3.5 point increase in TFP. This scenario suggests deep and widespread changes in modes of production and a major reorganization of the labor market, driven by disruptive innovations and maximum efficiency.

Each scenario highlights the potential implications of generative AI on the U.S. economy, from improving productivity to transforming jobs, emphasizing the need for policymakers, businesses, and workers to prepare for challenges and opportunities of this emerging technological era.

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\(^2\)Total Factor Productivity (TFP) is a measure of the efficiency with which an economy or business uses its factors of production (labor, capital, etc.) to produce goods and services. It assesses the overall efficiency of use of production factors and the contribution of technological progress and other factors to economic growth.
6.3.3 The United States in pole position

According to Stanford University's 2023 AI Index Report, the United States is the country best positioned to benefit from AI, ahead of China and the United Kingdom. (Figure 10)

Several factors explain this leading position:

- Massive investments in AI research: $248 billion between 2013 and 2022
- Dynamic ecosystem of startups specializing in AI
- Skilled workforce in new technologies
- Regulatory framework still flexible
Artificial intelligence (AI) is at the heart of a major economic transformation in Europe, with significant impacts expected in the years to come. The European Commission has highlighted in its coordinated plan the critical importance of AI for the growth of various sectors, thereby positioning Europe on the path to substantial technological advancement.

6.3.4 In Europe

At the heart of this evolution, France presents itself as an interesting case study, reflecting both the challenges and opportunities associated with the adoption of AI. A survey carried out by Cisco in November 2023 reveals that only 4% of French companies are fully prepared to integrate AI solutions, ranking France among the bottom three countries in Europe in terms of AI readiness.

However, according to France Digitale, 59% of French companies have already implemented or are developing an AI adoption strategy, and 21% have increased their investments in this sector.

6.3.4.1 France faces the AI Challenge

6.3.4.2 Investments in AI and Economic Growth

“32 billion euros in 2023

These investments are crucial for the European dynamic around AI. The IDC 2023 report indicates that European spending on AI is expected to reach €32 billion in 2023, with annual growth of
Key sectors include banking, professional services, retail, manufacturing and telecommunications, which together account for 60% of AI spending.

6.3.4.3 EU Engagement in AI Development

The European Union is playing a leading role in this development, with annual investments of one billion euros planned through the Horizon Europe and Digital Europe programs. In particular, demonstrating a strong commitment from the public sector.

The Attractiveness of AI Startups in Europe

Despite an uncertain global economic context, European startups specializing in AI continue to attract significant funding, according to a report from France Digitale. This positive trend is crucial for development and innovation in the field.

Strategies for European Leadership in AI

The European Commission has also recognized the importance of closing the AI skills gap, improving SMEs’ access to advanced technologies, and putting in place balanced and protective regulation. In December 2023, Europe adopted its first regulatory framework on AI, marking an important step towards global leadership.

6.3.4.4 Economic Potential of AI for France and Europe

"European spending on AI expected to reach 99 billion euros to the French economy by 2030"

At the same time, a study by AWS and Strand Partners predicts that AI could contribute €99 billion to the French economy by 2030, as part of the Commission’s "Digital Decade" initiative. European. The goal is for 75% of European businesses to have adopted AI by 2030, potentially adding €3.4 trillion to the European economy, through accelerated adoption of AI technologies.

AI is seen as an engine of economic growth and progress. It could inject up to $16 trillion into the Asian economy by 2030, boosting productivity and growth.

However, AI is also likely to automate a number of tasks, which could impact employment in various sectors. In China, for example, the AI market is now worth nearly 27 billion Swiss francs (CHF), and a quarter of the country’s jobs could be replaced by AI within twenty years.

6.3.5 In Africa

Adoption of AI could add nearly $150 billion to the continent’s GDP by 2030. Many applications of AI are already emerging in key sectors such as health, agriculture and services financial (see chapter devoted to Africa).

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6.1 Supporting public policies

Some countries have already started to put in place policies to support the employment transformation brought about by AI. In France, the government announced an investment plan of 1.5 billion euros in AI by 2022, aiming to stimulate the startup ecosystem and support professional retraining. In the United States, the government created the National Artificial Intelligence Initiative Office (NAIIO) to coordinate the federal government’s AI efforts.

“Train 100 million people in the skills required by AI.”

In China, the government launched the "Made in China 2025" program which aims to make China a world leader in AI, including training 100 million people in the skills required by AI. These policies are first measures that must be supplemented by other initiatives to support the transformation of employment caused by AI.

6.2 Prospects for changes in the quantity and quality of jobs

According to the report, generative AI is expected to have a greater impact on the nature and content of jobs than on their total number. By automating certain repetitive or routine tasks, AI will allow workers to focus on higher value-added activities requiring cognitive and social skills that are difficult to automate.

However, the extent of this complementation or substitution of tasks will vary considerably between sectors and professions. The report identifies office work as the job category most exposed to generative AI, with nearly a quarter of tasks considered high exposure and more than half of tasks having a medium level of exposure.

Conversely, manual jobs, technical professions and creative professions would be less impacted initially, with AI still struggling to reproduce complex physical tasks or calling on human imagination and creativity.

The report also underlines that if generative AI destroys certain jobs, it will also create new ones, particularly in the areas of the design and development of these technologies, their maintenance, but also their ethical and regulatory framework.

Finally, the ILO insisted on the need to support this transition with massive training and retraining policies, so that workers can acquire the skills required to benefit from generative AI rather than suffer from it.

Overall, while generative AI is not expected to cause a net destruction of jobs, it will profoundly transform the content and nature of many professions, requiring significant adaptation efforts from workers, businesses and public authorities.

6.3 Most exposed job categories

Still according to the ILO report, Office work is the category most exposed to artificial intelligence technologies, with almost a quarter of tasks considered very exposed and more than half of tasks presenting a level of medium exposure.

According to a study carried out in France in 2023, 52% of those questioned considered that progress in artificial intelligence represented more of a risk than an opportunity for their jobs. Rather than an
advancement likely to increase their productivity, reduce their workload or create new professional prospects, a majority of respondents perceived the development of AI as a potential threat to the sustainability of their jobs. These figures and facts highlight the potential impact of AI on global employment, as well as workers’ perceptions of the technology.

Additionally, the latest contributions to AI and internal audit highlight the growing importance of trust in AI. According to Quantmetry, the AI market is growing exponentially, but with this evolution comes an increase in scandals and risks associated with uncontrolled use of AI. This trend highlights the need for trusted AI governance and the performance of internal AI audits to ensure responsible and ethical use of this technology.

Additionally, the guidelines for conducting an internal audit engagement emphasize the importance of developing and documenting a work program to achieve the engagement objectives, which is essential for assessing the impact of AI on employment.¹

¹ Grant Thornton La place de l’IA dans les pratiques d’audit 2022
7  AI development perspectives
We are currently experiencing a pivotal period in the history of humanity, marked by a profound and accelerated transformation of our society under the effect of digitalization. Artificial intelligence (AI) and robotics are at the heart of this technological revolution which is attracting growing interest.

China wants to become the world leader in AI by 2030

This enthusiasm for AI can be perceived in different ways, whether with fear as expressed by Vladimir Putin by affirming that "whoever dominates AI will dominate the world", with ambition as shown by China's desire to become the world leader in AI by 2030, or even wisely as Pope Francis recommends by calling for these technological advances to be directed towards human development and the common good.5

AI indeed offers immense opportunities to improve our lives, but also carries risks that should not be overlooked, such as the possibility of malicious use or domination of humans by algorithms. But beyond this current excitement, what are the longer-term prospects for development towards which AI is heading?

7.1 Towards an increasingly "general" Artificial Intelligence

Today, the majority of AI systems developed are "narrow" or specialized artificial intelligences, efficient in a specific domain but lacking flexibility and broader abstraction capabilities. The stated objective of many researchers and companies is now to move towards artificial general intelligence (AGI) or "Artificial General Intelligence" (AGI) in English.

An AGI would be a system with general cognitive abilities comparable to or superior to those of humans: reasoning, planning, problem solving, transfer learning, social interaction, etc. The advent of a true AGI would thus mark a decisive paradigm shift in AI.

Many technical and scientific challenges remain to be met to achieve this, in particular the detailed understanding of neural mechanisms, the optimal software and hardware architecture, and the automatic acquisition of knowledge. But several experts consider the AGI to be a realistic goal, if not inevitable in the very long term.

7.2 The rise of organoid AI, a new frontier

Beyond advances in algorithms, AI could experience a real revolution thanks to the emergence of a new field of research called "organoid intelligence" (OI). The idea is to use laboratory-grown brain organoids as biological "hardware" to develop computers that are much more powerful and energy efficient than silicon-based systems.

Brain organoids are 3D cultures of stem cells that mimic the development and certain functions of the human brain. Although small, they contain neurons capable of organizing themselves into complex networks. Researchers have already shown that organoids can learn to play simple video games like Pong.

5 https://institut-europia.eu/une-renaissance-numerique-avec-lia/
IO would make it possible to study the cognitive aspects of neurological disorders and contribute to drug testing such as for Autism...

Ultimately, OI could make it possible to create revolutionary “biocomputers”, combining the computing power and plasticity of the biological brain with the programmability and scalability of computer systems. This would open up immense prospects in terms of speed, energy efficiency and learning capabilities, particularly in medicine.

Indeed, Professor Thomas Hartung of John Hopkins University (JHU) said that IO would enable the study of cognitive aspects of neurological disorders and contribute to the testing of drugs for neurodevelopmental disorders and neurodegeneration such as autism. Figure 11 shows a symbolic image of a Biocomputers powered by human brain cells.

Figure 11: Symbolic image of one of the biocomputers powered by human brain cells

The rise of artificial intelligence (AI) in recent years has been spectacular, with the emergence of powerful language models like GPT-3 or generative AI like DALL-E. However, despite their prowess, these systems remain very energy intensive compared to the human brain. A supercomputer like Frontier consumes 21 megawatts to match the performance of a brain that requires only 20 watts.

Figure 12 highlights a striking face-to-face between two titans of intelligence: the human brain and supercomputers, represented here by Frontier, one of the most powerful in the world.

<table>
<thead>
<tr>
<th>Frontier supercomputer (June 2020)</th>
<th>Human brain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed 1.102 exaFLOPS</td>
<td>~1 exaFLOPS (estimate)</td>
</tr>
<tr>
<td>Power requirements 21 MW</td>
<td>10-30 W</td>
</tr>
<tr>
<td>Dimensions 600 m² (7,300 sq ft)</td>
<td>1.3-1.4 kg (2.9-3.1 lb)</td>
</tr>
<tr>
<td>Cost $600 million</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Cabling 145 km (90 miles)</td>
<td>850,000 km (530,000 miles) of axons and dendrites</td>
</tr>
<tr>
<td>Memory 75 TB’s read; 35 TB’s write; 15 billion IOPS flash storage system, along with the 700 PB Orion site-wide Lustre file system</td>
<td>2.5 PB (petabyte)</td>
</tr>
<tr>
<td>Storage 58 billion transistors</td>
<td>125 trillion synapses, which can store 4.7 bits of information each</td>
</tr>
</tbody>
</table>

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8 After artificial intelligence, organoid intelligence - Le Temps
To overcome these limits, researchers are exploring a radically new path: organoid intelligence (IO). The idea is to use cerebral organoids as material support, that is to say 3D cellular structures cultivated in the laboratory from stem cells and imitating the organization of the brain. Figure 13 below shows a promising integrated 3D microfluidic system for culturing brain organoids. This system offers a valuable tool for brain research and could contribute to new advances in the field of neurology.

It should be noted that the culture of cerebral organoids in 3D offers a more precise and more physiological model of the human brain than the culture in 2D. This allows for more precise and meaningful research into brain development, neurodegenerative diseases and the effects of medications. Connected to electrodes and controlled by algorithms, these “mini-brains” could make it possible to create “biocomputers” combining the power and plasticity of biological neural networks with the programmability of computing.
Ultimately, IO could revolutionize many fields such as robotics, medicine or human-machine interfaces. However, there is still a long way to go. It will be necessary to overcome numerous technical challenges such as the scaling of organoids, their vascularization or the interpretation of their electrical activity.\(^\text{10}\)

The development of IO also raises complex ethical questions, in particular on the moral status to be granted to these organoids if they were to develop a form of consciousness. An “integrated ethics” approach, involving researchers, philosophers and citizens, will be essential to guide this research.

### 7.3 AI at the service of global challenges

Faced with the urgency of climate change and the collapse of biodiversity, AI appears to be a valuable tool to meet the immense environmental challenges of our time. From climate modeling to optimizing cities and power grids to monitoring ecosystems, the applications of AI for sustainability are countless.

Machine learning techniques make it possible, for example, to improve weather and climate forecasts, optimize the management of renewable energies, detect deforestation using satellite imagery, or even discover new materials for energy storage or carbon capture.

AI can also help make our food systems more sustainable and resilient, for example by optimizing irrigation and the use of agricultural inputs, improving crop yields, or developing alternative plant-based proteins.

Coupled with robotics, AI also promises major advances in cleaning up oceans, soils and the atmosphere polluted by human activities. Drones and autonomous underwater robots could thus locate and collect plastic waste much more efficiently than current methods.

However, the deployment of AI for sustainability will need to be done thoughtfully and responsibly. In particular, it will be necessary to ensure that AI systems do not reproduce existing biases and inequalities, that they respect the privacy and security of citizens, and that their environmental footprint (energy consumption, use of rare metals, etc.) remains limited.

**In summary**

Artificial intelligence is set to progress in multiple directions in the decades to come, from the advent of general AI to the development of organoid AI, including machines with increased creative capabilities and an integration of ethics from the design of systems.

If these prospects are exciting and bring immense opportunities for humanity, they also raise numerous technical, ethical and

\(^{10}\) [https://www.anthropotechnie.com/organoides-neuronaux-quelle-ethique/](https://www.anthropotechnie.com/organoides-neuronaux-quelle-ethique/)  
societal challenges that we will have to take up collectively. The stakes are high: it is nothing more and nothing less than shaping the future of our species and our planet in symbiosis with artificial intelligence that is trustworthy and beneficial for all.

To achieve this, close cooperation between researchers, public decision-makers, businesses and citizens will be more necessary than ever. We will need to demonstrate anticipation, vigilance and responsibility to guide the development of AI in a desirable direction. The choices we make in the years to come will have major and lasting repercussions. It's up to us to guide them towards a desirable future.
Philosophical and ethical issues of AI
8.1 Does AI call into question human singularity?

The rapid rise of artificial intelligence raises fundamental questions about the very nature of intelligence and the specificity of the human mind. With machines capable of learning, reasoning and now creating, the boundary between the artificial and the natural is becoming blurred.

Should AI be seen as a mere reproduction of human cognitive processes? Or rather the emergence of a radically new form of intelligence, surpassing our abilities in certain areas? The singularity of the human, long considered self-evident, is being called into question.

Some experts, like the philosopher Nick Bostrom, do not rule out that an artificial superintelligence could eventually surpass us in most cognitive tasks, relegating humanity to the rank of an inferior species. A scenario that revives the old fear of machines dominating their creators.

Others, on the contrary, like the neurobiologist Henri Korn, see AI as an opportunity for a fruitful symbiosis between humans and machines. A hybrid intelligence, where the complementary strengths of each would mutually reinforce each other to give rise to unprecedented capabilities.

This debate harks back to age-old philosophical questions about the nature of mind and consciousness. Artificial intelligence, by reproducing certain cognitive processes, challenges the idea of a human exception based on rationality. It forces us to rethink our relationship to otherness and technology.

8.2 The question of consciousness of Al organoids

Beyond conventional AI based on algorithms, the emergence of organoid artificial intelligence (AOI) raises dizzying metaphysical questions. By cultivating networks of biological neurons derived from stem cells, scientists are attempting to reproduce brain architecture to endow machines with unprecedented cognitive capacities.

But what would happen if these organic “mini-brains” were to develop their own form of consciousness, sensitivity or intentionality? Should we then recognize them as having a particular moral status, or even rights?

The possibility of such consciousness is debated. Some experts consider this scenario highly improbable, arguing that consciousness emerges from highly complex neural processes that will be very difficult to reproduce in vitro.

Others do not rule out this possibility, provided that the organoids reach sufficient size and complexity. Neuroscientist Anil Seth believes that beyond a certain threshold, “there is no reason to think that a brain organoid could not develop a form of primary consciousness”

If such a consciousness were to emerge, however primitive it may be, it would raise thorny ethical questions. What moral status should be given to these organoids? Should we recognize their rights? Or on the contrary consider them as simple biological artifacts, devoid of any form of sensitivity?
8.3 Repenser Rethinking the boundary between human and machine

Beyond the debate on consciousness, the advent of CAE questions more broadly the boundary between humans and machines, which is becoming increasingly tenuous and shifting. With these “artificial brains” cultivated from human cells, this limit is blurred.

Should we consider these organoids as hybrid beings, halfway between human and artificial? Or like a new form of life, radically different from the two? Will the classic criteria of humanity (consciousness, emotions, free will, etc.) still be effective in the face of these creations?

These questions go beyond the framework of IAO to embrace all emerging biotechnologies (genomic editing, human-machine hybridization, etc.) which are reshaping our definition of humanity. They force us to rethink in depth our relationship to otherness and technology.

The philosopher Donna Haraway thus calls for going beyond traditional dualities (nature/culture, human/machine) to embrace new forms of “cyborg” existence, mixing the organic and the artificial. A major ontological upheaval which will require redefining our categories of thought.

8.4 Supervising AI through ethics and regulations

Faced with these unprecedented challenges, it is crucial to anticipate potential abuses now and to draw clear ethical red lines. The development of CAE, like any disruptive technology, must not be done blindly but within a thoughtful and collectively controlled framework.

This involves establishing a broad democratic debate, bringing together citizens, experts, political decision-makers and industrialists. It will be necessary to define together the desirable purposes of the IAO, the acceptable or prohibited uses, and the safeguards to be put in place in terms of security, surveillance and protection of fundamental human rights.

An ethics-by-design approach, integrating these considerations from the design of CAE systems, will be essential. Mechanisms for human control, explainability of decisions and emergency shutdown must also be provided to guarantee our control over these technologies.

On a regulatory level, new legislation specific to AI will have to be developed, as the European Union did with its 2023 AI regulation. The objective will be to regulate risky uses while promoting innovation in this strategic area

8.5 Towards a new humanism in the age of AI?

Finally, the stakes are high: it is a question of channeling the progress of IAO in a direction beneficial to humanity. By establishing a robust ethical and regulatory framework now, we will be able to exploit its immense potential while guarding against its excesses. It is up to us to collectively write this new humanism in the era of organoid artificial intelligence. A humanism open to otherness, but also determined to preserve the integrity and dignity of the human condition.
The risk would be to see the emergence of a dehumanized society, where AI would supplant human judgment in crucial choices concerning us (employment, credit, health, etc.). Not to mention the security abuses of generalized surveillance by opaque algorithms.

For AI to remain progress, we must maintain control of its development. This requires a massive education effort to give everyone the keys to understanding these technologies. And through a broad democratic debate to collectively define the purposes that we want to assign to AI.

The challenge is to build an ethical and inclusive AI, serving human flourishing and the common good. An AI that augments our capabilities instead of enslaving us. A creative and diverse AI, reflecting human intelligence in all its richness.

It is at this price that we can make the advent of AI a historic opportunity to build a better world, where digital technology is finally reconciled with humans.
9 Impacts of AI in Africa and Challenges to Address
Artificial intelligence (AI) represents both a major opportunity for economic and social development for the African continent, as well as a major challenge in terms of infrastructure, skills and ethical and regulatory frameworks.

According to a study by PwC, AI could contribute nearly 1.5 billion dollars to African GDP by 2030. Many key sectors such as health, agriculture or education could benefit from AI-based innovations. However, the continent is lagging behind in terms of technological readiness and qualified human capital.

The objective of this chapter is therefore to analyze in depth the current state of the AI landscape in Africa, highlighting both the potential for socio-economic transformation and the obstacles to overcome. We will look at emerging pan-African initiatives as well as national AI strategies.

Particular attention will be paid to ethical issues and the importance of establishing regulatory frameworks adapted to African realities. This is to ensure equitable and responsible integration of AI technologies, serving the sustainable development of the continent.

Concrete recommendations will be made to address the technical, human and institutional challenges that still hinder the massive deployment of AI in Africa.

9.1 Economic impacts of AI

9.1.1 The Impact of Artificial Intelligence on Employment in Africa: Threats and Opportunities

According to a report from the International Monetary Fund (IMF), nearly 40% of jobs worldwide will be impacted by the effects of AI. However, this impact will be unevenly distributed depending on the level of development of the countries. While 60% of jobs will be affected in rich countries, this rate will only reach 40% in emerging countries and only 26% in low-income countries like those in Africa. Indeed, many African countries have neither the infrastructure nor the skilled workforce to take full advantage of the opportunities offered by AI, which risks worsening inequalities with more advanced countries over time.11

Nonetheless, with the right investments in digital infrastructure and human capital, AI could help Africa reduce skills shortages in key sectors like health and education, and improve productivity and competitiveness.12

9.1.1.1 The most exposed sectors and professions

A McKinsey & Company study on South Africa estimates that by 2030, retail could lose 334,000 jobs, administration and government 309,000, manufacturing 231,000, transportation 186,000, agriculture 87,000 and real estate 20,000 jobs. However, the same study highlights that few types of jobs are fully automatable. In functions related to data processing for


example, such as payroll or transaction agents, only 72% of activities could be automated.

Conversely, certain agricultural professions such as agricultural engineers, agricultural teachers and technicians are particularly threatened by AI which could generate text for them.

9.1.1.2 Jobs threatened vs created by AI in Africa

Although the advent of artificial intelligence raises fears of massive job destruction, it also represents an opportunity to create new professional opportunities on the African continent. As Betelhem Dessie, founder of iCog in Ethiopia, points out, AI could contribute to the emergence of dynamic businesses in various sectors, having a positive impact on the African economy. This technology should also facilitate inclusion by improving access to healthcare, education and financial services.

"Governments must create 20 million jobs per year over the next 20 years."

A report from the International Monetary Fund highlights the demographic challenge Africa will face, forcing governments to create 20 million jobs per year over the next 20 years. Artificial intelligence could help meet this challenge by encouraging the emergence of new areas of activity.

Estimates vary on the extent of the coming upheavals in the labor market. A 2023 World Economic Forum study predicts the loss of 83 million jobs globally by 2027, offset by the creation of 69 million new job opportunities, resulting in a net loss of 14 million jobs.

"The disappearance of 3.3 million existing jobs by 2030 in South Africa,"

In South Africa, the McKinsey & Company firm estimates that AI will cause the disappearance of 3.3 million existing jobs by 2030, but will at the same time allow the creation of 4.5 million new positions, a net gain substantial 1.2 million jobs.

These new professional opportunities would be mainly concentrated in the sectors of technology, health (with 570,000 additional jobs), construction (261,000 jobs) as well as other emerging services.

"Artificial intelligence could increase global GDP by 14% by 2030"

9.1.2 Potential contribution of AI to African GDP

According to a study by PricewaterhouseCoopers, artificial intelligence could increase global GDP by 14% by 2030, or approximately $115.7 trillion. This could make AI the biggest business opportunity in the global economy. The report also estimates that AI could increase the GDP of Africa, Oceania and other Asian markets by 5.6%, or approximately $1.2 trillion.

"No African country is among the top 50 for AI innovation."

Africa could therefore benefit from significant economic benefits. Nonetheless, the 2019 Government AI Readiness Index painted a bleak picture of the African
continent. Currently, no African country is among the top 50 for AI innovation.

Only 12 of 54 African countries are in the top 100 for AI innovation and development. The top 5 African countries are Kenya, Tunisia, Mauritius, South Africa and Ghana. These countries well reflect documented developments in AI technology.

9.1.3 The development of the AI ecosystem in Africa

The AI industry in Africa is still emerging compared to the United States, Europe and Asia. However, this has not discouraged some of the continent's most innovative startups from developing solutions, proving the promising potential of AI-based technologies for the African economy.

"South Africa leads the continent in AI adoption"

Many African countries, with emerging AI startup scenes, have seen various public and private stakeholders come together at a pan-African level to enhance capacity-building efforts and establish an environment conducive to the growth of the AI community across the region.

South Africa leads the continent in AI adoption, with a robust ecosystem. It is estimated that more than 100 companies in South Africa are integrating AI solutions into their existing operations or developing new solutions using AI.

The top 5 African countries in the 2022 Global AI Government Readiness Index are Mauritius, Egypt, South Africa, Tunisia and Morocco. The high ranking of these countries is explained by their good performance in the “Government” pillar of the index. This pillar assesses the efforts made by governments in terms of strategies, investments, training and regulations to prepare for the adoption of artificial intelligence in their country.

The high scores obtained by Mauritius, Egypt, South Africa, Tunisia and Morocco in this “Government” pillar reflect the initiatives put in place by their respective governments to develop an ecosystem favorable to AI, which allows them to rank among the best prepared countries in Africa in this area.

The emergence of an AI ecosystem in Africa, as well as the establishment of several AI research hubs across the continent, is driving the development of AI industries in Africa.

9.1.4 Case study of innovative African AI startups

The African start-up ecosystem is experiencing significant growth, particularly in the field of artificial intelligence (AI). We will focus on innovative African AI startups, examining the number of startups, the level of investment,

9.1.5 Funding for African startups at half mast in 2022

According to an analysis recently published in The Big Deal newsletter, financing for technology startups in Africa is expected to see a significant slowdown in 2023 after several years of sustained growth. Africa as a whole raised around $5 billion in 2022, twice as much as in 2021. But the trend is expected to reverse this year with an overall 46% drop in funding, falling to $2.7 billion, dollars according to forecasts. However,
this development hides strong regional disparities as shown in Figure 13.

### Figure 13: Regional disparities in funding

![From Western Africa’s dominance to four balanced blocks](image)

<table>
<thead>
<tr>
<th>Region</th>
<th>Funding Raised 2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Africa</td>
<td>$880m</td>
</tr>
<tr>
<td>Western Africa</td>
<td>$780m</td>
</tr>
<tr>
<td>Southern Africa</td>
<td>$380m</td>
</tr>
<tr>
<td>Northern Africa</td>
<td>$340m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Equity</th>
<th>Debt</th>
<th>Inception</th>
</tr>
</thead>
<tbody>
<tr>
<td>2023</td>
<td>$1.4b</td>
<td>35%</td>
<td>65%</td>
<td>31%</td>
</tr>
<tr>
<td>2022</td>
<td>$1.6b</td>
<td>36%</td>
<td>64%</td>
<td>30%</td>
</tr>
</tbody>
</table>

#### 9.1.5.1 East Africa

East Africa has risen to the top spot among African regions in terms of startup investment in 2023, according to the latest figures. The region attracted $880 million in funding raised by startups last year.

This represents a 31% share of total venture capital investments on the African continent. East Africa thus overtakes West Africa, which occupied first place in 2022.

This performance is driven by some very large fundraisings, such as those from startups Sun King and M-Kopa, which alone total nearly $500 million. Apart from these two exceptional rounds, few other startups have managed to raise more than $100 million in the region.

Despite this first place in the ranking, investments in East Africa still fell by 29% compared to 2022. And more than half of the funds raised in the region (56%) were in the form of debt.

East Africa therefore achieves a very good performance in 2023, but its leadership remains fragile in the face of the vitality of the West African ecosystem.

#### 9.1.5.2 North Africa

For the first time, North Africa has risen to second place among the most attractive African regions for startup investments in 2023. Tech companies in the region raised...
$670 million last year, a decrease of 39% compared to 2022.

This performance is driven above all by the startup MNT-Halan, alone responsible for more than half a billion dollars raised in the region. And that amount doesn't include the value of InstaDeep and Expensya's IPOs, which exceed $500 million between them.

9.1.5.3 Southern Africa
Southern Africa comes third among African regions for funds raised by startups in 2023, with a total raised of $460 million. Unlike other regions of the continent, it experienced moderate growth of 6% compared to 2022.

No startup has achieved a mega-raise of more than $100 million. The 3 main operations (Planet42, TymeBank and E4) total around a third of investments in the area, a much smaller share than in other regions.

This reflects a more diverse and balanced entrepreneurial ecosystem than elsewhere on the continent. Many startups raise more modest funds, between $1 and $10 million.

Although no star startup is driving growth, southern Africa is showing some resilience. Its positive growth contrasts with the clear slowdown observed in the rest of Africa.

9.1.5.4 West Africa
Leader at the bottom for investments in startups.

West African startups only raised $600 million, 2.6 times less than in 2022

West Africa experienced a brutal fall in 2023. After dominating the ranking of African regions for funds raised by startups for 3 of the last 4 years, it tumbled to fifth and last place on the podium in 2023.

**West African startups have only raised $600 million, or 2.6 times less than in 2022.** However, with 191 startups having managed to raise more than $100,000, the region represents 39% of the continental total on this criterion.

But the amounts raised individually remain low: only 23% of funds went to mega-raisings of more than $100 million. The rest is atomized between multiple small operations.

This clear decline in West Africa can be explained by an ecosystem that is still young and fragmented. The region has many startups but few leaders capable of attracting hundreds of millions of dollars on their own.

9.1.5.5 Central Africa
A sham growth for startups in Central Africa, which is the only region on the continent to have experienced strong growth in funds raised by its startups in 2023: +33% compared to 2022, going from 51 to 68 millions of dollars

"Central Africa represents only 3%"

A sham growth for startups in Central Africa, which is the only region on the continent to have experienced strong growth in funds raised by its startups in 2023: +33% compared to 2022, going from 51 to 68 millions of dollars.
However, this figure hides a less rosy reality: Central Africa represents only 3% of total investments in African startups (figure 15). The amounts raised are out of proportion with neighboring regions.

For comparison, $68 million is barely more than a single mega-lift can bring in in other parts of Africa. Far behind the hundreds of millions, even billions, raised elsewhere. This sham growth shows that the entrepreneurial ecosystem in Central Africa remains in its infancy. Very few startups manage to raise significant funds to develop.

International investors are only beginning to show interest in this long-neglected region. But for the moment, Central Africa remains far behind its neighbors in terms of attractiveness for startups.

The figure below provides a comparison between each region of Africa which highlights the lack of attraction of Central Africa.

Source: Author of the report based on the Big Deal 2023 report

**INVESTISSEMENTS (M$) PAR RÉGION**

- Afrique du Nord: 670; 25%
- Afrique Centrale: 68; 3%
- Afrique de l'Ouest: 600; 22%
- Afrique Australe: 460; 17%
- Afrique de l'Est: 880; 33%

9.1.6 Investments in startups: Africa versus the rest of the world

According to data from the Partech Africa Fund, venture capital investments in Africa reached $6.5 billion in 2022, an increase of 8% compared to 2021 (Partech, 2023). A level which may seem modest but which testifies to the resilience of the continent in a difficult economic environment.

**A stark contrast to the rest of the world**

Globally, venture capital investments collapsed by 35% in 2022 according to figures from Crunchbase, falling to $415
billion after record levels reached during the pandemic (The Big Deal, 2023).

This dropout is particularly marked in the main entrepreneurial ecosystems such as Silicon Valley (-38% investments), or in regions such as Latin America (-49%). Only Southeast Asia shows relative stability (+5%) (Crunchbase, 2023).

Africa therefore appears to be a zone of resilience, relatively spared from the brutal correction hitting global venture capital markets.

**Structural explanatory factors**

This contrast finds its origin in several structural factors specific to the African continent, according to analysts such as the priority given to "essential" solutions rather than "comfort" products by African startups (access to energy, health, fintech basic...) according to (The Big Deal, 2023).

If these specificities have protected Africa from the global shock in 2022, they could also constitute obstacles to the emergence of future technological leaders of continental or global dimension in the years to come.

Indeed, by focusing mainly on basic solutions meeting essential needs (access to energy, health, basic fintech, etc.), African startups risk missing opportunities to develop disruptive innovations with high growth potential and global reach.

Additionally, this focus on local niche markets and relatively basic solutions could limit the ability of African startups to achieve continental or global scale, in terms of users, revenue and ambitions.

Furthermore, the specificities of the African market (low purchasing power, limited infrastructure, etc.) could lock startups into economic models that are not very scalable and difficult to transpose to other more technologically mature regions.

Finally, the focus on basic needs could slow down investments in research and development of cutting-edge technologies, essential to rise to the level of global technological giants.

In short, although this "essential" approach may have protected African startups in the short term, it risks confining them to a form of dependence on local markets and preventing them from reaching a truly continental or global dimension in the long term. Thus slowing down the emergence of future major African tech leaders.

**Africa represented only 1.2% of global startup funding flows in 2022**

Africa, poor relation of startup financing

According to data from CB Insights' State of Venture 2022 report, Africa represented only 1.2% of global startup funding flows in 2022, or $4.8 billion. A very low figure compared to Africa's share in global GDP (2.5-3%) and especially in the world population (17%). If we aligned funding with demographics, the continent would have had to raise no less than 70 billion dollars last year.

However, the dynamic is positive. Africa was the only region to see its fundraising increase in 2022 (+5%), (Figure 15) while all other geographic areas showed double-digit declines. A sign of this resilience, the
gap with Latin America has narrowed considerably, going from 16 billion dollars in 2021 to 6.5 billion in 2022.

Certainly, in absolute terms, there is still a long way to go before African startups capture funding aligned with the demographic weight of the continent. But the trajectory seems well and truly underway.

Figure 15: Percentage of funds raised by African Startups

9.1.7 Infrastructural challenges facing Africa

9.1.7.1 Connectivity and access to the internet: a major obstacle
As Africa finds itself at a crucial juncture in its digital development, it is essential to take a close look at the infrastructure and regulatory framework associated with artificial intelligence (AI). These elements play a fundamental role in establishing an ecosystem conducive to the emergence and adoption of AI on the continent. Before diving into the specific challenges and opportunities related to these aspects, it is important to understand the current situation regarding digital infrastructure in Africa.

9.1.7.2 Shortage of powerful data centers on the continent
Africa faces significant infrastructure challenges for artificial intelligence (AI) development, including limited access to electricity and high-speed internet, as reported by the World Bank in 2019. Only nearly 42% of Africa's population will have access to the internet in 2024, according to Statista. The high cost of internet services...
and low purchasing power also hinder the adoption of technologies such as AI, according to UNCTAD in 2021.

“Less than 100 data centers in Africa, only 1.3% of the global total.

Furthermore, the African continent has very few powerful data centers, essential for the operation of AI systems. According to the Africa Interconnect 2023 report, there are currently fewer than 100 data centers in Africa, or only 1.3% of the global total (Figure 16).”

Figure 16 Data centers in Africa (Source: https://baxtel.com/map)
Half of these data centers are in South Africa. The number of sub-Saharan African countries with access to a carrier-neutral data center increased from 16 in 2021 to 24 in 2022. The countries with the most installed and planned data centers are South Africa, Nigeria and Kenya.

The Africa Interconnect 2023 report analyzes the growth in the number of data centers in Africa over three years. It shows that the number of open, carrier-independent data centers increased from 20 to 27 in one year. However, some of these new data centers have modest power (between 1 and 1.5 MW), delaying the full development of larger capacities in the future.

![Figure 17: Growth in the number of data centers in Africa over three years (Source: Africa Interconnect 2023)](image)

Despite the current limited number of data centers in Africa, significant investments are planned in the coming years ($5 and $6 billion) to develop more data center infrastructure, particularly in Nigeria, South Africa and the Kenya. The number of existing data centers increased from 20 to 50, and the number of planned data centers increased from 15 to 68.

South Africa still represents more than 90% of installed capacity in the region. However, with the construction of larger data centers in other countries such as Kenya, the supply dynamics are changing. Taken together, Nigeria, South Africa and Kenya have both the most installed and planned capacity.
9.1.7.2.1 Mapping data infrastructures in Africa

South Africa, Nigeria and Kenya are the three main hubs of data center development in Africa (figure 18). South Africa clearly stands out with no less than 19 centers, ahead of Nigeria which has 14 and Kenya brings up the rear with 9 data centers.

An interesting point to note is the contrast between Nigeria and Kenya. While Nigeria has a much larger economy, Kenya has built an extremely solid regional connectivity model. This allows it to benefit from privileged access to the market of 300 million consumers represented by the East African Community.

Thus, despite a modest economic size compared to Nigeria, Kenya takes advantage of its advanced digital hub to irrigate the entire East African region.

9.1.7.3 State of play of AI regulation in Africa

The state of regulation of artificial intelligence (AI) in Africa is a complex and evolving topic, reflecting both the opportunities and challenges that this technology presents for the continent. AI offers promising prospects for economic development, improved health services, education, agriculture, and natural resource management. However, it also raises ethical and safety issues, and requires adequate regulation to maximize its benefits while minimizing potential risks.

9.1.7.3.1 Initiatives and Regulatory Frameworks

Africa, as a whole, is still in the early stages of developing AI-specific regulatory frameworks. However, some countries...
have started to take initiatives to regulate the development and use of AI, focusing on ethics, security, and the creation of standards.

- **The African Union (AU)** has not yet established a continental regulatory framework specific to AI, but it recognizes the importance of the technology for the development of the continent. The AU has launched several initiatives to promote technological innovation, including AI, such as the African Union Strategy for the Information Society (African Action Plan for the Digital Economy). (African Union Digital Transformation Strategy)

- **Senegal** has been identified as a country taking steps to make AI a national priority as part of its digital transformation. The country was mentioned in an Oxford Insights report for its readiness to accelerate AI adoption

- **Egypt, South Africa, and Tunisia** are also cited for their progress in preparing for AI adoption. These countries have made significant progress in less than three years, indicating a growing commitment to the development and regulation of AI

### 9.1.7.3.2 AfCFTA opportunity for adoption of common AI standards and regulations

The African Continental Free Trade Area (AfCFTA) represents a unique opportunity for Africa to harmonize regulatory frameworks and standards related to artificial intelligence (AI) across the continent.

In the context of pan-African economic integration targeted by the AfCFTA, the adoption of common AI standards and regulations would be crucial for:

- Facilitate the harmonious development of the AI ecosystem on a continental scale, avoiding regulatory fragmentation.
- Promote the free flow of data, services and AI talent between member countries.
- Attract foreign investment by providing a stable and unified legal framework for AI.
- Protect African consumers and citizens with ethical and shared security standards.

Thus, the AfCFTA could constitute an ideal platform to initiate a pan-African dialogue and develop a common strategy on AI regulation, involving all member countries. This would allow Africa to speak with one voice on these crucial global issues.

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13. Source: Developments and Future of AI in Africa (worldbank.org)
14. Source: Machine Ethics and African Identities: Perspectives on Artificial Intelligence in Africa Munich Personal RePEc Archive (uni-muenchen.de)
15. Source: Artificial intelligence for cybersecurity in Africa: What should we expect? | Africa Cybersecurity Magazine
9.1.7.4 Challenges and Opportunities

Challenges of regulating AI in Africa include the lack of digital infrastructure, the need for AI skills and training, and the need for regional and continental cooperation to develop coherent policies.

No African nation is among the global top 50 for AI in 2023

9.1.7.5 The absence of Africa in AI governance

Currently, Africa is largely absent from international bodies overseeing and regulating the development of artificial intelligence. During the Bletchley Park summit in November 2023, bringing together politicians, tech giants and global experts to define a common approach on AI, no African country participated in the signing of “the Bletchley declaration”.

This absence concerns UN Secretary General Antonio Guterres, who fears that “AI will exacerbate the already growing inequalities between countries”. He underlines that no African nation is among the world’s top 50 for AI in 2023. An observation which pushed the UN to create an Advisory Council on AI of 38 experts, including 6 Africans like Ms. Seydina Ndiaye of Senegal, to represent the voice of the continent.

9.1.7.6 Risk of new form of digital colonization

According to Seydina Mme Ndiaye, UN expert, “the biggest threat is colonization by AI”. Without local mastery of this technology, African countries risk depending on solutions developed by Western multinationals, with models based on data not contextualized to African realities.

This new neocolonial form would lead to a plundering of the continent’s talents and data. Young people trained locally would be hired by these multinationals, while African data would be captured and exploited by these same companies.

The expert also fears that Africa will become a field for hazardous experiments, combining AI with other emerging technologies such as biotechnology or nanotechnology, in the absence of adequate regulations.

To avoid these scenarios, Seydina Ndiaye insists on the urgent need for Africa to master AI in order to preserve digital sovereignty.

On the other hand, AI presents significant opportunities for Africa, particularly in the areas of health, education, agriculture, and resource management. The adoption of AI can help overcome some of the continent’s most pressing development challenges.

Outlook

To maximize the benefits of AI while minimizing the risks, African countries must work to develop regulatory frameworks that encourage innovation while protecting the rights and security of citizens. This includes setting ethical standards, promoting transparency, and ensuring AI systems are inclusive and equitable.
In summary, although Africa is still in the early stages of regulating AI, there is growing recognition of its potential for the development of the continent. Ongoing initiatives and discussions around the regulation of AI in Africa indicate a desire to seize these opportunities while addressing the ethical and security challenges that this technology presents.

9.1.8 Training and education issues

Skills and research gap

In 2021, UNESCO initiated an in-depth assessment of artificial intelligence (AI) needs in Africa, targeting the identification of deficits and prospects for the sector. This approach aims to draw up a precise assessment and make recommendations to boost African capacities in AI. Faced with the adoption and implementation of AI, African countries face significant obstacles, despite the considerable benefits of this technology for economic and social development.

According to the results of the UNESCO survey of 32 countries, the main obstacles include a glaring lack of specialized skills, insufficient technological infrastructure and inadequate legislative and ethical frameworks (Figure 19).

“0.77% of citations in "The AI Journal 2023" were attributed to sub-Saharan Africa

According to this survey, 19 countries report a notable absence of legal frameworks to respond to the challenges posed by AI, as well as a significant lack of human resources to address the legal implications.

Figure 19 : Pedagogical resources for teaching AI 5source Unesco 2022)
This skills gap also extends to the ethics area, where 26 countries report not having the necessary means to address the ethical implications of AI, leaving only 6 countries (Figure 20) reporting that they have the skills required for this task (the Angola, Congo, Equatorial Guinea, Madagascar, Sudan and Togo).

Figure 20: Skills needed to meet the ethical challenges of AI

<table>
<thead>
<tr>
<th>Skills needed to meet the ethical challenges of AI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pas de déficit de compétences humaines</td>
</tr>
<tr>
<td>Important déficit de compétences humaines</td>
</tr>
</tbody>
</table>

9.1.8.1 Low research capacity;

Of particular concern is the research capacity in the field of AI in Africa. The AI Index Report 2023 shows that only 0.77% of citations in The AI Journal were attributed to sub-Saharan Africa, highlighting a considerable gap in contribution to global AI research. Research capacity in the field of AI in Africa is particularly worrying.
In summary
These challenges have direct implications for the ability of African countries to harness the potential of AI. Insufficient technological infrastructure and specialized skills severely limit opportunities for innovation and economic development. Likewise, the absence of adequate legislative and ethical frameworks jeopardizes the governance and responsible use of AI, posing risks in terms of security, privacy, and equity.

To overcome these obstacles, concerted action from governments, educational institutions, and private sector actors is essential. It is crucial to invest in strengthening technology infrastructure, develop targeted educational programs to address the skills gap, and develop robust legislative and ethical frameworks that will guide the adoption and use of AI in Africa in a fair and secure manner.
10 Africa areas of use of AI in Africa
In this chapter, we will explore various real-world examples of successful applications of artificial intelligence (AI) across different sectors in Africa. These use cases illustrate the opportunities offered by AI to solve challenges specific to the African continent and improve the lives of populations. The information presented is taken from several sources (see bottom of page).

10.1 AI as a transversal technology

Artificial intelligence (AI) holds considerable potential to improve communication with disadvantaged communities and populations. For example, AI-powered voice recognition can allow people to use helplines in their native languages. For example, an illiterate farmer in Rwanda could speak in Kinyarwanda, his native language, to get crucial advice on improved farming methods. With approximately 2,000 native languages spoken in Africa, voice interaction patterns in these languages can reach large populations previously excluded due to language barriers.

10.1.1 Case study

Realizing the potential mentioned above, the example of the Rwandan start-up Digital Umuganda illustrates the concrete exploitation of AI for communication with disadvantaged populations. Indeed, the latter collects voice data in Kinyarwanda. This data is available on the Mozilla Common Voice platform and can be used to develop AI-driven voice interaction models in Kinyarwanda. Digital Umuganda is notably developing a text-to-speech model that reads government publications and announcements to visually impaired or illiterate people.

10.2 AI for agriculture

Agriculture is a key sector in Africa, employing over 65% of the workforce and contributing 32% of gross domestic product (GDP) AI could play an important role across the agricultural value chain, from financing smallholder farmers, to production by analyzing and predicting diseases and pests, facilitating the creation of cooperatives and promoting better price control.

10.2.1 Case study

On the continent there are several use cases and best practices, such as Zenvus, a Nigerian agricultural data start-up, or Ujuzikilimo, a big data platform. In the area of credit, examples like FarmDrive and Agrospaces are cited for supporting African farmers with live price data.

Another good practice mentioned is the Sowing APP, a solution deployed in the Indian state of Andhra Pradesh to optimize sowing based on weather forecasts, soil and other indicators. This initiative was carried

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19 https://digitalumuganda.com/
out in collaboration between the government of Andhra Pradesh, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Microsoft, and resulted in an increase in average yield by 30% per hectare.

10.3 AI for education

The education sector is currently experiencing a major transformation with the proliferation of free content accessible on MOOC platforms such as Coursera, Atingi, Khan Academy or Smart Africa Digital Academy. At the same time, the growing demand for digital skills is favoring the emergence of disruptive initiatives such as University 42 in California or Molengeek in Belgium, offering free, high-quality digital education to disadvantaged populations.

Artificial intelligence (AI) can greatly contribute to the efficiency and accessibility of education, including language learning, intelligent tutoring, student support through continuous assessments or automated grading, virtual learning companions or personalized course recommendations. It can also support teachers with automatic test generators, plagiarism detection or the recommendation of open educational resources.

10.3.1 Case study

Several concrete use cases are mentioned, such as Jill Watson, an AI teaching assistant developed by Georgia Tech University based on the IBM Watson platform, or the essay grading technology used in around 60,000 schools in China to analyze the logic and meaning of the text and evaluate the overall quality of the work.

Other notable examples include Educational Testing Services (ETS) e-rater for grading and feedback on student essays, as well as M-Shule, an SMS-based learning platform in Kenya that leverages the AI to track and analyze student performance.

10.4 AI for health

Artificial intelligence (AI) is set to play a key role in the digital transformation of the healthcare sector. It can greatly support medical professionals, improve diagnostics and detection using computer vision applied to medical imaging, and facilitate access to care via chatbots in local languages or automated analyzes from photos taken with a smartphone.

10.4.1 Case study

Several concrete use cases are highlighted, such as Babyl in Rwanda, a digital healthcare provider that collaborates with the national health system to make care
more affordable. Babyl Rwanda leverages AI and machine learning to provide medical advice and arrange appointments through mobile applications.

Among the relevant initiatives, the Data Science & AI Summit for Health in Africa is cited as an excellent example for promoting the use of AI in health, developing the necessary human skills and attracting investments in this strategic sector.

10.5 AI for financial services

Artificial intelligence (AI) holds considerable potential to transform access to financial services in Africa, changing the way Africans access banking, save, invest and insure themselves. Leading financial institutions have demonstrated proactivity and innovation in developing new business models that address the region's specific challenges, such as low levels of banking penetration and widespread use of cash.

10.5.1 Case study

Several concrete use cases are highlighted, such as Zenith Bank Plc in Nigeria, which launched several digital solutions allowing more convenient and secure transactions, or ALAT, the first fully digital bank in Africa, launched in 2017 by Wema Bank in Nigeria and targeting young people.

Strider, a South African fintech providing platforms that banks and financial institutions can quickly adopt to offer financial services to their customers, is also cited.

10.6 AI for energy, transportation and climate change

Artificial intelligence (AI) can greatly contribute to more efficient management of natural resources and the environment in various key industries, including energy and transportation. In the energy sector, AI enables better management of supply and demand through smart grid systems, and optimizes renewable energy solutions.

The adoption of AI is widespread in the financial services sector, with emblematic examples like the German bank N26 which built its business model entirely around this technology.

AI roles include automating and improving the efficiency of operations, reducing fraud and money laundering risks, optimizing user experience, and expanding accessibility with voice channels or automated translations.

Source: https://www.journaldunet.com/intelligence-artificielle/1494883-l-ia-est-en-train-de-revolutionner-la-gestion-d-actifs-des-banques-francaises/

Source: https://www.lebigdata.fr/comment-lia-va-contribuer-a-la-lutte-contre-le-changement-climatique
In transportation, it improves the safety, efficiency and sustainability of the movement of goods and people, enabling better traffic prediction, real-time journey planning and, in the future, autonomous vehicle technologies.

### 10.6.1 Case study

Several use cases of AI for smart energy management are highlighted, such as supply and demand prediction, decentralized energy networks, and optimization of renewable assets. In transportation, AI is widely used in consumer applications such as Waze or Google Maps but can also be scaled for commercial and organizational use, offering tools for traffic optimization, traffic prediction, demand and logistics planning.

When it comes to climate change, notable initiatives are mentioned, such as climatechange.ai, a global community of experts and scientists dedicated to combating global warming, or Microsoft’s AI for Earth, which has generated solutions like Zamba Cloud, a free and open source AI solution to support biodiversity.

*These use cases illustrate the potential of AI to address the challenges specific to the African continent and improve the lives of populations, while providing opportunities for economic and social development.*

### 10.7 AI in Mining

Artificial Intelligence (AI) has revolutionized the mining industry in Africa, providing innovative solutions to various challenges. In the South African mining industry, for example, advanced systems leveraging drones and AI have been deployed to optimize operations.

TOMRA Kumba uses a smart sorting system that employs drones for tasks such as drilling and dropping explosives, while at Exxaro’s Grootegeluk coal mine, drones are used for topographical surveys, helping to increased production through improved efficiency.

### 10.7.1 Practical Cases: The Use of Drones for Mining

The integration of drones and AI has revolutionized mining operations in Africa, automating crucial processes and improving worker safety. Rocketmine, a Johannesburg-based start-up, has introduced innovative solutions in several African countries. As an example, Rocketmine replaced manual mining surveys, traditionally carried out by planes every two weeks, with surveys carried out by drones. This approach, using AI to analyze collected data, provides a much higher frequency of data collection, thereby improving the accuracy of mining operations. This technology has also been successfully deployed in hard-to-access mining areas, such as Exxaro’s Grootegeluk mine in Limpopo, helping to increase the efficiency and safety of mining operations in Africa.
11 Conclusion
Artificial intelligence is poised to become the new paradigm of the global economy. According to projections, it could contribute nearly $1,500 billion to African GDP by 2030, by profoundly transforming key sectors such as health, agriculture, finance and education.

Many startups and innovative initiatives are emerging on the continent to exploit the potential of AI to meet African challenges. Whether to improve medical diagnostics, optimize agricultural yields, democratize access to financial services or personalize learning, promising use cases are multiplying.

However, Africa still lags behind in terms of its AI ecosystem compared to other regions in the world. The lack of digital infrastructure, specialized skills and appropriate regulatory and ethical frameworks hinders the large-scale deployment of these technologies.

Only 12 African countries appear in the global top 100 of the index preparing governments for AI. Investments in African AI startups remain marginal on an international scale. And African research in AI is struggling to make its mark in the global academic landscape.

For Africa to fully benefit from the AI revolution, coordinated mobilization of all stakeholders will be essential. States, businesses, universities and civil society will have to join forces to create favorable conditions for the emergence of a dynamic and inclusive AI ecosystem on the continent.

The stakes are high. It is about Africa’s capacity to be an actor and not a simple spectator of this major technological disruption. Without local mastery of AI, the continent is exposed to a new form of digital colonization and plundering of its talents and data by foreign technological giants.

But by taking up the challenge of AI, Africa has a card to play in becoming a world leader in ethical and responsible artificial intelligence, in the service of human development. With its creative youth, its cultural diversity and its values of solidarity, Africa can chart an original path towards inclusive and sustainable AI.

The global economy is on the cusp of a major paradigm shift, catalyzed by the meteoric rise of artificial intelligence. At a crossroads, the African continent cannot afford to miss this crucial meeting with History. If it fails to master this disruptive technology, it risks finding itself relegated to the rank of simple consumer, or even a hazardous testing ground for the new masters of the global economic game that will be the AI giants.

But if it manages to build a sovereign, ethical AI adapted to its development challenges, Africa could on the contrary emerge as a leading player in this new technological and economic situation. It would then have tremendous leverage to address the immense challenges it faces, from the fight against poverty to adaptation to climate change, including access to health and education for all.

To achieve this, proactive and coordinated action is urgently needed. It is vital to invest massively in infrastructure, training and research to create a competitive and inclusive AI ecosystem on a continent-wide
scale. And to put in place robust regulatory and ethical frameworks to guarantee trustworthy AI, serving the common good.

Africa has all the cards in hand to become a global beacon of diverse, creative and responsible artificial intelligence. It is up to governments, businesses, researchers and civil society to mobilize collectively to meet the challenge of an AI made in Africa, a vector of emancipation and shared progress for future generations.
12 Recommandations
In view of the analyzes in this report, we make the following recommendations to make AI a development engine for Africa:

### For African governments

1. Develop ambitious national AI strategies, with quantified objectives, dedicated funding and governance at the highest level of government. Draw inspiration from good practices from the most advanced countries.

2. Invest massively in digital infrastructure to democratize access to broadband connectivity and cloud computing. Develop a dense network of data centers.

3. Launch major training programs for AI professions to fill the skills gap. Integrate AI into curricula.

4. Establish regulatory and ethical frameworks for trustworthy AI (laws, regulatory authorities, ethical guidelines).

5. Support the development of African AI technological champions through targeted industrial policies.

6. Promote a pan-African approach to AI by strengthening cooperation between countries.

7. Put AI at the service of the SDGs and priority challenges (health, education, agriculture, climate).

### For universities and research

8. Integrate AI into school and university curricula.

9. Stimulate African research in AI with more funding. Create centers of excellence in AI. Encourage regional and diaspora collaborations.

### For the private sector

10. Boost the AI startup ecosystem by facilitating their access to financing, data and markets. Create dedicated incubators/accelerators.

11. Encourage the emergence of African AI champions and strategic alliances between stakeholders.

12. Establish South-South cooperation, particularly with India and China, for technology transfers.

### For civil society

13. Involve civil society in the development of ethical guidelines on AI.

**For Pan-African Bodies**

15. Promote the pan-African approach: pool resources, good practices, speak with a united voice.

16. Create an African AI Observatory to map actors/initiatives and formulate recommendations.
Appendix Literature Review

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