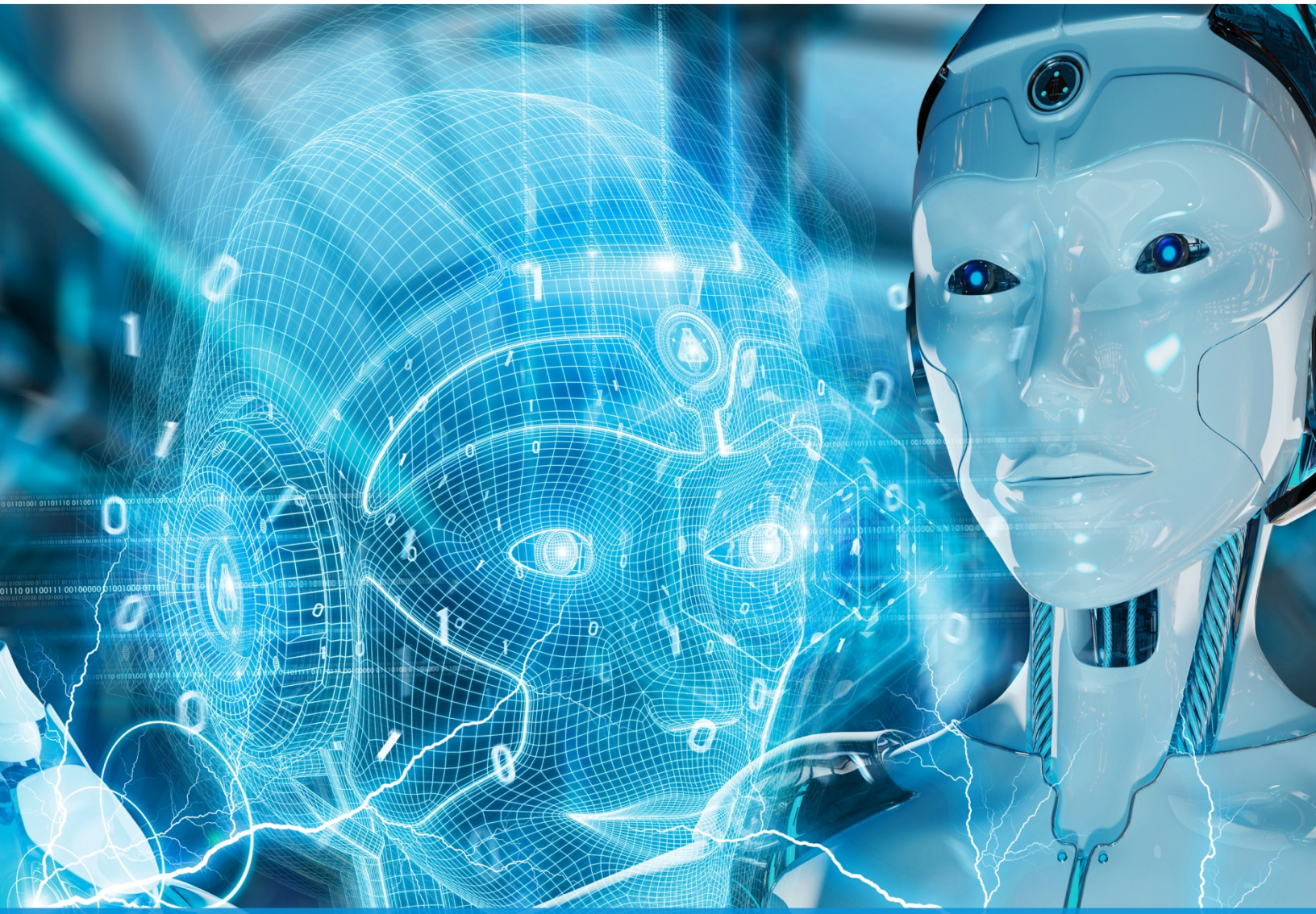
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

International Trade Centre



Empowering SMEs through 4IR Technologies

ARTIFICIAL INTELLIGENCE

Disclaimer

UNIDO Director General Foreword

It gives me the greatest of pleasure to introduce this publication that shares practical recommendations for the adoption and application of Artificial Intelligence (AI) by Small and Medium Enterprises (SMEs) in Developing Countries. It is developed by UNIDO in cooperation with the United Nations' High-Level Committee on Programmes (HLCP) Inter-Agency Working Group on Artificial Intelligence (IAWG). This document fills a void where knowledge products around artificial intelligence and SMEs have tended to use high-income countries as their reference point.

While this focus drawing on the experience of high-income countries is understandable given that the bulk of technological infrastructure and innovation currently resides in advanced economies, such an approach overlooks the distinct and important challenges faced by SMES in developing and emerging economies, most notably with respect to financing, acquisition of appropriate technology, the digital divide, infrastructural issues, knowledge gaps and a lack of skills. Such unresolved issues should concern us all, given that SMEs are estimated to make up to 60 per cent of employment in manufacturing within developing countries.

Moreover, AI is rapidly becoming a technological application with far reaching overspills and consequences for sustainable development through inclusive and sustainable industrial development (ISID). Of the 169 Targets of the 2030 Agenda for Sustainable Development, as many as 134 targets can be impacted positively through AI. For example, AI can be harnessed successfully to make manufacturing more efficient, safer, and greener, through circular economy, resource-efficient and cleaner production techniques.

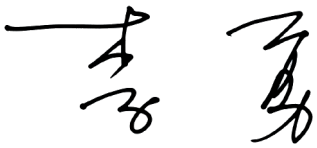
As AI grows exponentially, it is also creating enormous caches of data globally. The World Economic Forum estimates that by 2025, 463 exabytes of data will be created daily worldwide. This unprecedented flow of data comes with considerable downside risks and challenges, such as the growing digital divide; the proliferation of hate speech, demagoguery, deep fake technology and fake news; cybersecurity issues; and challenges to data protection and ethics.

The gender divide is also prominent within the data and AI sectors, with women accounting for just 26 per cent of professionals in this occupational category. The ongoing COVID-19 pandemic is also playing a role in accelerating digitalization in a globally uneven fashion, with high-technology sectors (e.g. computing, electronics, automotive) growing markedly faster than lower technology sectors (e.g. wood products, textiles, and agro-food).

UNIDO is dedicating its expertise and resources to contribute to the tackling of digital transformation challenges of its Member States. Policy guidance forms a major strand of the outputs, most notably through its nascent UNIDO Fourth Industrial Revolution (4IR) Strategic Framework and UNIDO Knowledge Hub. As part of this work, we are planning to develop a toolkit that will provide further practical guidance to support the implementation of AI by the SME sector in developing countries. This work will complement the other knowledge products in the realm of digital transformation that the Organization has produced over the last few months, which includes a methodology for the use of blockchain in agro-industrial value chains, and our flagship publication the Industrial Development Report 2022.

I see these efforts as the beginning of the implementation of a robust conceptual framework for an inclusive, gender-responsive and sustainable 4IR. A framework that will inform and underpin the development of specific national, regional and global programmes to support the Decade of Action as we explore the acceleration of solutions towards the 2030 Agenda for Sustainable Development.

I am confident that this pioneering publication will provide insightful and practical information to policymakers, private industry practitioners, and the research community in the years to come.



Li Yong
Director General
United Nations Industrial Development Organization

ITU Secretary-General Foreword

We live in times of accelerated digital transformation amid an unprecedented global pandemic that has shown us how we can accelerate progress towards connecting all humanity when we work with businesses, large and small, across all sectors and borders.
ITU, as the UN specialized agency for information and communication technologies (ICTs), has worked with its private sector members to bring the benefits of technological progress to all for over 150 years. And today, we spare no effort in supporting and fostering the growth of small and innovative players in the ICT sector to help them take the industry forward in fields ranging from AI to 5G.

ITU has introduced reduced membership fees for SMEs to encourage greater participation in our activities. As a result, I am proud that the ITU's SME community is growing and taking an active part in the development of international standards on emerging technologies and initiatives, such as the AI for Good Innovation factory, ITU Digital World, ITU Incubators programme, ITU's International Centre of Digital Innovation (I-Codi), to name a few.

SMEs are the engine of the digital economy. They have the power to bring about social and economic development unlike any other. As we look to recovery from the COVID-19 pandemic, I believe they will help ensure that local needs for new digital services are met in all corners of the world.

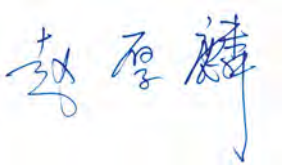
However, SMEs and entrepreneurs face specific challenges – in particular an urgent need to develop local skilled talent, access to new markets and sectors, and investment. Sharing existing policies, initiatives, programs and best practices in support of SMEs is more important than ever, especially in the development and adoption of emerging technologies. I commend UNIDO for developing practical recommendations for the adoption and application of AI by SMEs in developing countries, and for giving ITU an opportunity to contribute to this valuable resource. ITU and UNIDO are working together on several projects, from promoting smart sustainable cities to implementing 5G on the African continent. Our two organizations are united in our resolve to support the growth of SMEs, help all countries advance their industrialization efforts, and bridge the digital divide.

The UN Secretary-General has called on all of us to redouble efforts to achieve universal connectivity with affordable services by 2030. It is a huge challenge, one that would be difficult to achieve without the help and engagement of SMEs.

I believe that tech SMEs everywhere are central to efforts to achieving the levels of connectivity and digital transformation needed to drive economic growth, jobs and innovation in the development and adoption of emerging technologies such as AI and many others.

These emerging technologies are pushing the boundaries of the possible, playing a key role in accelerating progress on the United Nations Sustainable Development Goals and tackling the world's most pressing challenges.

ITU is committed to continuing to work with UNIDO and other partners inside and outside the UN system to harness these technologies as a source for good and for everyone – so that together we can turn today's digital revolution into a development revolution for all.



Houlin Zhao
Secretary-General
International Telecommunication Union

ITC Executive Director Foreword

In the world of yesterday, most small businesses could get by with some simple statistics, such as sales records. These times are over. Change now happens at digital speed. Data-driven firms can quickly detect and exploit market opportunities that allow them to outperform the rest. In the world of today, data provide a competitive edge. As the availability of data increases, firms must find ways to translate them into actionable insights. Artificial intelligence is one such tool. It is profoundly changing all aspects of our lives, from the movies we watch to the products we buy. And as widespread as these technologies may be, they can be largely traced back to a small group of wealthy countries.

International organizations have a role to play to promote the use of artificial intelligence in the developing world. To do so, they must make use of such tools themselves. This is why the International Trade Centre (ITC) recently joined the United Nation's Inter-Agency Working Group on Artificial Intelligence –a forum where UN agencies discuss and exchange experiences on uses of artificial intelligence in the context of their work.

ITC uses artificial intelligence in its trade strategy programme, for instance, to extract policy-relevant insights from vast amounts of text data. As a newcomer to the space of artificial intelligence, ITC has adopted a "test and learn" approach. One early valuable lesson has been that sophistication can wait. In the beginning it is essential to keep things simple and focus on identifying relevant but tractable problems where artificial intelligence can bring a direct benefit. As the proverb goes "A journey of a thousand miles begins with a single step". Trivially simple proof of concepts that save some time, help with repetitive tasks, or provide new insights to an area of our work can quickly add value and make a big difference.

Technologies based on artificial intelligence can support organizations fulfil their mandates, as they can help scale technical cooperation and reach more beneficiaries. But developing production-level tools and applications requires resources. Technical expertise, data preparation and cloud computing can be costly. Making smart resource allocation decisions, cost-sharing schemes and donor involvement will be instrumental to spread the adoption of artificial intelligence to small businesses in developing countries.

This publication presents a pathway to the adoption and application of artificial intelligence. What is critical, however, is that it does so by taking into consideration the special and often challenging circumstances faced by small firms in developing countries.
I hope the case studies and technical recommendations will inspire new ideas and help spread the use of artificial intelligence. ITC looks forward to cooperating with UNIDO, other international organizations and donors towards developing pragmatic tools that can support small businesses succeed in our data-driven world.

Pamela Coke-Hamilton
Executive Director
International Trade Centre

Acknowledgements

The publication was prepared by the UNIDO in cooperation with the International Telecommunications Union (ITU), and the International Trade Center (ITC). Furthermore, private sector entities such as Siemens A.G., Aizon, and Okra Technologies contributed with their experience in the field.

The publication was prepared under coordination of Mr. Alejandro Rivera-Rojas based on the work of Mr. Ashraf Abushady, Mr. Allan Bachenheimer. It benefited from valuable contributions and constructive comments of UNIDO colleagues: Mr. Marco Kamiya, Mr. Fernando Santiago Rodriguez, Mr. Farrukh Alimdjanov, Mr. Stephan Kratzsch, Mr. Brian Portelli, Mr. Anatoly Balonev, Ms. Sibilla Sartori, Mr. Alberto Medina Islas, and Ms. Rebeca Gallardo-Gomez, and Mr. Darren Gleeson.

UNIDO extends its appreciation to all those who directly contributed and provided feedback, Mr. Preetam Maloor (ITU), Ms. Clare Stark (UNESCO), Mr. Alberto Amurgo Pacheco (ITC); Mr. Toni Manzano (Aizon), and Ms. Loubna Bouarfa (Okra Technologies).

Executive Summary

AI has been attributed with one of the most significant disruptive effects in the global economy. It comprises a set of widely different technologies, broadly defined and grouped as self-learning, adaptive systems. With applications extending across a wide range of fields and sectors and new technological advances, AI's possibilities seem to be boundless. However, AI's adoption has also raised concerns related to security, reliability, privacy, and data governance, as it has brought important challenges and risks such as ensuring data availability and the unintentional transfer of human bias into AI systems. The above makes an open ethical debate about AI indispensable and the need to adhere to ethical values and principles crucial, as outlined in UNESCO's Ethics of AI Recommendation. [1]

The present publication is oriented to improve the competitiveness and sustainability of Small and Medium Enterprises (SMEs), particularly those in developing countries, by promoting their innovation and digitalization. The analyses and recommendations presented in this publication highlight the significance of AI for business amidst the ongoing digital transformation, raise awareness about the opportunities of AI for adding value across the different business functions and production areas of a company and provide practical recommendations for the adoption and application of AI. SMEs in developing countries face several challenges for improving their automation level and advancing their adoption of AI. However, the available knowledge and tools are frequently not tailored to the needs and context of SMEs in developing countries. Additionally, the assistance offered tends not to be practical. Therefore, the information contained in this publication, structured in six chapters, aims to provide concrete solutions, which are easily understandable and applicable.

Chapter 1 introduces fundamental concepts associated with AI. While machine learning (ML) is concerned with computers learning to think and behave without human involvement, deep learning involves computers utilizing structures modelled on the human brain. It addresses a common misconception about AI being synonymous with automation by arguing that AI goes beyond simple tasks by progressively developing an individual decision-making system that emulates human behaviour.

Chapter 2 provides an overview on how decreasing costs of hardware and software, raising computational power, new market trends, the development of new market niches, advances

[1] UNESCO, *Recommendations on the Ethics of Artificial Intelligence* (2021)

in regulation and standardization, national support mechanisms and the impact of COVID-19 on the global economy are driving the adoption of AI forward.

Chapter 3 discusses how SMEs' adoption of AI-based solutions can be constrained by insufficient business infrastructure and standardization processes, limited know-how and financial resources, and skilled workforce shortages. In addition, a limited number or absence of well-equipped local technology partners, inadequate policies and regulatory frameworks, as well as ethical, social, and cultural concerns may also hinder this process. Chapter 4 maintains that as business models change, SMEs from developing countries can have the advantage of creating better data for a value-based economy and using it for evidence-based testing and early access to novel products and services. In addition, thanks to the emergence of existing tools, libraries and frameworks, new service providers offer pre-built and out-of-the-box AI solutions, giving rise to Artificial Intelligence as a Service (AIaaS) and improving its overall affordability.

Chapter 5 proposes a five-staged approach aiming to guide SMEs in their pathway to AI adoption. First, conducting a self-assessment of processes and AI readiness. Second, establishing a legal framework, committing resources, and setting up the standards for developing an AI strategy. Third, showing an adequate data governance standard to manage digital data. Fourth, embracing an AI data-driven decision making and finally creating a Proof of Concept (PoC) and conducting a pilot application. It also emphasizes that a successful AI strategy needs to consider carefully that: i) AI cannot solve all problems, ii) over training an algorithm and over delineating thresholds on datasets are likely to produce generalization errors with a direct impact on performance and iii) piloting an AI system requires several models for addressing the different contexts in which they would be employed.

Chapter 6 explores the strengths, weaknesses, opportunities, and threats of AI across strategic sectors and examines a selection of case studies supported by UNIDO and other partner organizations, detailing the role of AI, the impact generated for SMEs and general results obtained. It underlines that AI is no longer restricted to large companies and aims to lead and encourage companies to take determined but informed steps for integrating AI in their operations. The information, guidelines and practical recommendations discussed in the present publication will be complemented by the publication of a toolkit which will aim to provide practical tools to SMEs, oriented towards concrete solutions, which are easily understandable and applicable.

Contents

UNIDO Director General Foreword 3
ITU Secretary-General Foreword 5
ITC Executive Director Foreword 7
Acknowledgements 9
Executive Summary 11
List of Acronyms 15
List of Figures 18
List of Tables 19
Preamble 21
Chapter 1: Introduction to AI 23
1.1 General definition of AI 25
1.2 Fundamentals of the technology 26
1.3 Potential limitations to the adoption of AI 27
1.4 The Humans behind the keyboard, *the CAPTCHA story* 30
1.5 Risks and how to deal with it 30
1.6 What is Not AI 32
1.7 How can AI support SMEs? 33
Chapter 2: 'Drivers' of the adoption and application of AI 37
2.1 Innovation ecosystem 39
2.1 AI National Strategies and Support Mechanisms 40
2.2 Technology advances 43
2.3 Competitiveness and market dynamics 45
2.4 Regulations and Standards 49
2.5 Health and safety and cybersecurity 51

Chapter 3: Barriers that SMEs in Developing Countries face in adopting and applying AI 55

3.1 Finance and financial sustainability 56

3.2 Skills development, gender imbalance, capital-skill complementarity 59

3.3 Infrastructure and process standardization 61

3.4 Partnerships 63

3.5 Ethical concerns within the adoption of AI 64

3.6 Regulations and Standards 67

3.7 Social and Cultural barriers 68

3.8 How to mitigate the effect of barriers in the AI applications in SMEs 68

Chapter 4: Benefits of the adoption and application of AI 71

4.1 Economic benefits 72

4.2 Social considerations 74

4.3 Environmental considerations 76

Chapter 5: Pathway to the Adoption of AI 78

5.1 Introduction 79

5.2 First Phase: AI Transformation Framework 80

5.3 Second Phase: Build your AI Strategy, standards, and processes 86

5.4 Third Phase: Data governance standards 90

5.5 Fourth Phase: The risk of doing nothing (embrace AI Data-Driven Decision Making) 91

5.6 Fifth Phase: Piloting your first project 93

Chapter 6: From Theory to Practice 97

6.1 Potential Applications of AI across different productive sectors and processes 99

6.2 Selected UN cases of success 104

6.3 Selected private-sector cases of success 120

Conclusions and Recommendations 126

Glossary 128

References 136

List of Acronyms

4IR	Fourth Industrial Revolution
ADRs	Adverse Drug Reactions
AEs	Adverse Events
AGI	Artificial General Intelligence
AGIs	Above Guideline Increases
AI	Artificial Intelligence
AIaaS	Artificial Intelligence as a Service
ANI	Artificial Narrow Intelligence
ANN	Artificial Neural Network
ANSI	American National Standards Institute
API	Active Pharmaceutical Ingredient
ASI	Artificial Super Intelligence
AVs	Autonomous Vehicles
AWS	Amazon Web Services
BDVA	Big Data Value Assessment
CPPs	Critical Process Parameters
CPV	Continued Process Verification
DDI	Data Driven Innovation
DL	Deep Learning
DR	Drug Repurposing
DTA	Directorate of Digitalization, Technology and Agri-Business (UNIDO)
DTI	Department of Digitalization, Technology and Innovation (UNIDO)
EC	European Commission
EEA	European Economic Area
EHR	Electronic Health Record
EP	European Parliament
EU	European Union

FDA	Federal Drug Administration (United States)
GCP	Google Cloud Platform
GDPR	General Data Protection Regulation
GIN	Global Innovation Network
GMP	Good Manufacturing Practices
HMIs	Human-Machine Interfaces
IBM	Watson International Business Machines Corporation
IEEE	Institute of Electrical and Electronics Engineers
IEC	International Electrotechnical Commission
IR	Industrial Revolution
IoT	Internet of Things
ISO	International Standards Organization
IT	Information Technology
ITC	International Trade Centre
ITU	International Telecommunication Union
JTC	Joint Technical Committee
LDCs	Less Developed Countries
MES	Manufacturing Execution Systems
ML	Machine Learning
NGGP	National Green Growth Plan
OCR	Optical Character Recognition
OEMs	Original Equipment Manufacturer
PD	Process Design
PDA	Parenteral Drug Association
PDD	Public Domain Data
PoC	Proof of Concept
PPM	Part per million
PPQV	Process Performance Qualification and Validation

QbD	Quality by Design
QSAR	Quantitative structure-activity relationships
R&D	Research and Development
ROI	Return on Investment
SDGs	Sustainable Development Goals
SME	Small and Medium Enterprises
STP	Science and Technology Park
UNESCO	United Nations Educational Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
UN	United Nations
VDMA	German Mechanical Engineering Industry Association
WEF	World Economic Forum
XAI	Explainable AI

List of Figures

Figure 1	Difference between AI, ML and DL.	p.
Figure 2	COVID Impact on enterprises' AI strategies.	p.
Figure 3	Number of AI policy initiatives	p.
Figure 4	Estimated number of AI Start-Ups	p.
Figure 5	Cost to train a Neural Network	p.
Figure 6	Where will the value gains come from with AI?	p.
Figure 7	Why did you choose an AI solution?	p.
Figure 8	Share of men and women by professional cluster globally	p.
Figure 9	Pathway to AI Adoption	p.
Figure 10	Process towards AI Transformation	p.
Figure 11	IMPULS Readiness Model	p.
Figure 12	Microsoft AI Maturity Model	p.
Figure 13	8 Steps AI Maturity guide	p.
Figure 14	Build your AI Strategy, standards, and processes	p.
Figure 15	Example of an AI business model canvas by C. Lomas	p.
Figure 16	Example of a filled in AI business model canvas by C. Lomas	p.
Figure 17	Data Governance for AI	p.
Figure 18	Decision Making Model	p.
Figure 19	5 Step approach to AI project development	p.
Figure 20	From PoC to Production	p.

List of Tables

Table 1	Main areas of support for AI policies	p.
Table 2	Summary of AI barriers	p.
Table 3	SWOT analysis of the agro industry	p.
Table 4	SWOT analysis of the automotive industry	p.
Table 5	SWOT analysis of the creative industry	p.

Preamble

The present publication is the result of a joint effort of UNIDO, ITU, and ITC, and it represents a contribution to the work stream of the **United Nations Inter-Agency Working Group on Artificial Intelligence (IAWG-AI)**, established in October 2020. It also benefitted from the extensive experience of private sector partners, including Siemens A.G., Aizon, and Okra.

The UN IAWG-AI, co-led by ITU and UNESCO, is aware of the transformative power Artificial Intelligence has to advance sustainable development. Its mission focuses on enhancing UN system-wide policy coherence and programmatic coordination, and to promote the adoption and use of AI to accelerate progress towards the achieving of SDGs.

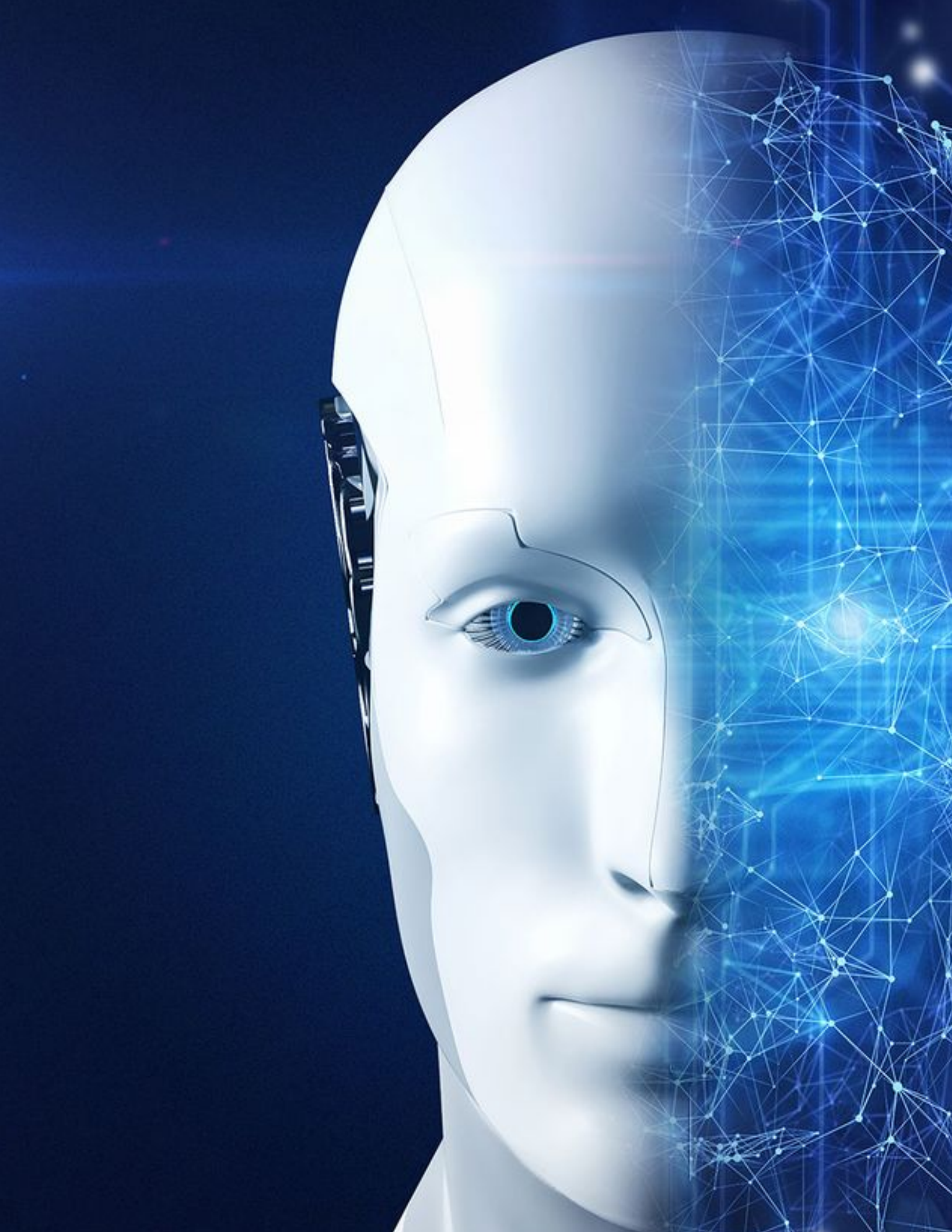
The UN System-wide Strategy on AI Capacity-building (approved by the UN Chief Executive Board in 2019) recognized the importance of supporting sustainable and robust local AI technology innovation and entrepreneurship for public good in developing countries. A subsequent gap analysis carried out by ITU recommended a more collaborative system-wide effort on supporting SMEs – including identifying requirements that would be specific to AI businesses, compiling guidelines on conducting legal and policy assessments, and developing clear frameworks and guidance for Member States. This publication is a significant step in this direction.

The main aim of this work is to provide guidance to both SMEs located in developing countries, and business development services institutions, to facilitate the adoption and application of AI in their respective contexts. AI has the potential to promote SMEs' competitiveness and sustainability, both for improving services and manufacturing. The latter, in particular, would benefit from newer types of automation using AI, which learn and make predictions from data.

This initiative stems from the awareness that SMEs in developing countries deal with specific barriers, which impede them from growing. Initial research found that, at present, existing tools and publications on AI addressed to the SME sector are often not tailored to the needs of SMEs in developing countries or lack a practical perspective from their standpoint.

Considering the above, the ''Practical Recommendations for the Adoption and Application of Artificial Intelligence'' will be also complemented by a **Toolkit**, aiming at providing practical tools to SMEs, oriented towards concrete solutions, easily understandable and applicable. This contributes to supporting SMEs in their path towards a Covid-19 recovery. Indeed, the COVID-19 pandemic has demonstrated the importance of advanced technologies to sustain economic and social activities in times of crisis.

From a programmatic perspective, UNIDO is currently designing its **4IR Strategic Framework** that will guide the Organization's efforts to support its Member States in transitioning to the 4IR. As part of this strategic vision, AI is a key technology that UNIDO endeavours to further promote in Member States and this publication takes stock of UNIDO's AI activities to- date. In light of the disruptive power of Fourth Industrial Revolution technologies, this publication represents the first effort of a **series of works addressing advanced technologies**. UNIDO, in line with its Medium-Term Programme Framework (MTPF) 2022-2025, through the Directorate for Digitalization, Technology and Agri-Business, is committed to promoting the use of several advanced technologies in a multitude of sectors and contexts, as a way to promote inclusive and sustainable industrial development.



Introduction to AI

1.1 General definition of AI 25
1.2 Fundamentals of the technology 26
1.3 Potential limitations to the adoption of AI 27
1.4 The Humans behind the keyboard, *the CAPTCHA story* 30
1.5 Risks and how to deal with it 30
1.6 What is Not AI 32
1.7 How can AI support SMEs? 33

Chapter 1: Introduction to AI

1.1 GENERAL DEFINITION OF AI

The term Artificial Intelligence (AI) is commonly associated with the field of research and development in computational disciplines. However, due to its interdisciplinary use it can be assigned different definitions.[2] Depending on the discipline, AI tends to be characterized in terms of a) technologies, techniques, or approaches (e.g., a neural network approach to machine translation); purpose (facial recognition, image recognition), functions (e.g., the ability to understand language, recognize pictures, solve problems, and learn) or agents or machines or algorithms (e.g., robots, self-driving cars).

AI can be understood as "*a branch of computer science concerned with the study of mechanisms of intelligent human behaviour*"[3], as well as the "*property of an IT system to exhibit human-like intelligent behaviour*"[4]. On the other hand, AI can be also defined as "*[...] technologies that complement human abilities in seeing, hearing, analysing, deciding, and acting*"[5] and politics as "*the ability of a machine to display human-like capabilities such as reasoning, learning, planning and creativity*"[6].

Within the context of this publication, the term "Artificial Intelligence" will be used to signify technologies under the following definition, adapted from ITU's "AI For Good" initiative description, June 2021.[7] AI comprises a set of widely different technologies, which can be broadly defined and grouped together as 'self-learning, adaptive systems'. The above working definition will be employed, making specific references to further sub-fields of AI for discussing examples and facilitating explanations.

It is important to note that AI is further classified into artificial narrow intelligence (ANI), artificial general intelligence (AGI) and artificial super intelligence (ASI). ANI is the most common form of AI, usually programmed for specific problem or software solutions. Font recognition, service bots and brake assistants are common examples. ANI is the only AI concept that finds application in the real world.[8] Figure 1

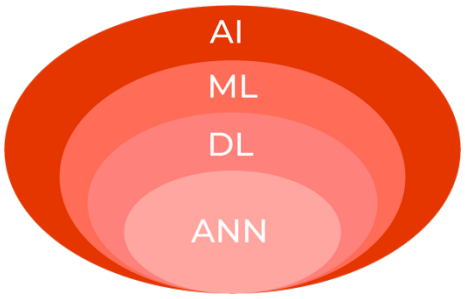
[2] The American computer scientist John McCarthy, who coined the term in 1955 as part of a research project, can be considered the pioneer of the term. See McCarthy, J. et al., A proposal for the Dartmouth summer research project on artificial intelligence (1955).
[3] Wichert A., *Encyclopaedia of Neuroscience: Artificial Intelligence* (2021)
[4] Bitkom V., *Artificial intelligence Economic significance, social challenges, human responsibility* (2017)
[5] Microsoft, *Microsoft explains: What is artificial intelligence? Definition & Functions of AI* (2020)
[6] EP, *What is artificial intelligence and how is it used?* (2020)
[7] See: aiforgood.itu.int/
[8] Wang P., Goertzel B., *Introduction: Aspects of artificial general intelligence* (2007)

illustrates, in a simplified manner, the difference and relation between the introduced subtypes of AI.

The AGI concept can be compared to human intelligence, as they are not limited to a specific task area; they can think abstractly, solve problems, grasp complex ideas, and learn from experience. Although this form of AI was just theory until recently, nowadays it is a reality, as renowned scientists assume that this form of AI could fully emulate human abilities sooner or later.[9]

ASI is the evolution of AGI that outperforms humans in all disciplines, including emotional intelligence. Since the effects of such a machine or technology are factually unimaginable, the term (technical) singularity is often used in this context, due to the impossibility for humans to determine the event horizon and make statements about the future.[10]

Figure 1: Difference between AI, ML and DL.



Source: Holzinger, A. et.al. (2018)[11]

1.2 FUNDAMENTALS OF THE TECHNOLOGY

As a sub-field of AI, the so-called machine learning (ML) is a specific AI mechanism often used in narrow AI. The academic literature defines ML as „*a subset of artificial intelligence in the field of computer science that often uses statistical techniques to give computers the ability to "learn" (i.e., progressively improve performance on a specific task) with data, without being explicitly programmed*"[12]. Simply put, ML enables IT systems to recognize patterns

[9] Cellan-Jones R., *Stephen Hawking warns artificial intelligence could end mankind* (2014)
[10] Barrett A. M., Baum S. D., *A model of pathways to artificial superintelligence catastrophe for risk and decision analysis,* Journal of Experimental & Theoretical Artificial Intelligence, *29*(2), 397-414 (2017).
[11] Holzinger A. et.al, *Current Advances, Trends and Challenges of Machine Learning and Knowledge Extraction: From Machine Learning to Explainable AI* (2018)
[12] Ongsulee P. et. al, *Big data, predictive analytics and machine learning* (2018)

and regularities on streaming data based on learnings from historical data and algorithms, and to develop solutions from them without being bound by strictly static program instructions. The insights gained from the data can be generalized and used for new problem solutions or for the analysis of previously unknown data. Moreover, ML (unlike data mining) can also be unsupervised[13] and used to learn and create basic behavioural profiles for different entities and then use them to identify comprehensive clusters and informative anomalies.[14] In practice, ML is used for knowledge extraction, for making predictions and calculating probabilities for certain events, and for autonomous adaptation to developments and optimisation of processes based on recognised patterns.

Deep Learning (DL), as a subfield of ML, is a specific method of information processing and is at the heart of recent advances in AI. Whereas Machine learning is about computers being able to think and act with less human intervention; deep learning is about computers learning to think using structures modelled on the human brain. In the scientific literature, DL is often referred to its subfield artificial neural network (ANN).[15] The multilayer artificial neural network of DL works with mathematical probability and is theoretically inspired by our human brain, which has many neurons and synaptic connections and can have neurons with multiple connections to other neurons. DL is mainly used for face, object, or speech recognition.[16]

The present publication addresses AI in general, but focuses on ANI, the most common form of AI with practical applications. Other subtypes of AI, such as AGI and ASI are not discussed extensively since they might only be relevant for a reduced number of SMEs. Although the acronym AI will be mainly used in this paper, references and distinctions will continue to be made between AI, ML and DL for describing and explaining examples.

1.2 POTENTIAL LIMITATIONS TO THE ADOPTION OF AI

AI has been attributed with one of the highest potential and disruptive effect in the global economy and society in general. AI applications seem to be extending beyond an almost unlimited array of fields and sectors. The number of related companies, patent applications and publications continuously grows every year. However,

[13] To read more about four main classifications: supervised, unsupervised, semi-supervised, and reinforcement learning, see: Portugal I., Alencar P., Cowan D., *The Use of Machine Learning – Algorithms in Recommender Systems: A Systematic Review* (2018)

[14] Ibid.

[15] Wilson B., *The machine learning dictionary* (2012)

[16] Microsoft, *Microsoft explains: What is Deep Learning? Definition & Functions of DL* (2020)

while the potential of AI cannot be neglected, there are important considerations that can limit the suitability, functionality, and the relevance of AI. This section describes three of the most relevant ones for the purposes of this publication: availability of data, explainability of results, and overall cost.

Availability of Data

The effectiveness of decision models and prediction algorithms relies on the data input that is used for their training and improvement. The data available today is mostly collected for different purposes than training an ML algorithm, and therefore it mostly lacks the key variables to decision making. For instance, in healthcare most data available is collected for transactional purposes such as claims data or medical record datasets. In many sectors, the data available today is not ideal, if the data used fails to capture the key variables impacting a process this can be detrimental to the accuracy and even functionality of AI. For example, vibration measurements of a piece of machinery would be not enough for an AI system to provide precise predictive maintenance alerts. Additional data such as temperature and revolutions per minute are required to strengthen the robustness of the predictive models and algorithms. In other words, AI demands not only data in the right amounts, but also in the right quality and quantity to avoid overfitting. A good example to illustrate the danger of poor quality data can be seen is in the case of Microsoft AI Chatbot "Tay" which was intended as an AI experiment in conversational understanding. However, Microsoft used Twitter feeds as the training data for the chat bot and it took less than 16 hours for Twitter to corrupt the chatbot and turn it into a racist, offensive, and hostile bot, to the extent that Microsoft had to shut it down[17].

Explainability of results

Many industries – especially evidence-based industries such as healthcare, education and the legal industry – are not satisfied with receiving only the final results, but would rather require an understanding of why the AI model has recommended a given action. For example, in the healthcare sector and life sciences in general, the concept of a Black box system cannot be accepted, the explanation of why the AI model has predicted an illness is as crucial as the diagnosis itself.

[17] Microsoft, *Microsoft explains: What is Deep Learning? Definition & Functions of DL* (2020)

In evidence-based sectors, understanding the reason behind a result is sometimes more important than the result itself.

In fact, a new branch of AI is now growing for specifically such requirement, it is called Explainable AI (XAI) and it is AI in which the results of the solution can be explained and understood by humans.

The aim of XAI is to explain what has been done, what is done right now, what will be done next and unveil the information the actions are based on[18] These characteristics make it possible: (i) to confirm existing knowledge; (ii) to challenge existing knowledge; and (iii) to generate new assumptions.[19]

Explainability is a concept that references the need to fully understand, document and keep traceability of the logic, decision methodology, data sets and data sources used in preparing and executing AI systems to produce the expected output, whatever it is (recommendations, predictions, clusters, decisions, patterns, etc.). Advanced explaianbility of AI systems also means making a distinction between correlation and causation variables. Identifying confounding variables that are causing an illness is much more important than identifying the markers that are correlating with the illness. Explanability means answering the "why" question: why an AI recommendation should be followed by the human in charge.

Overall Cost

The cost of AI continues to represent a major challenge for many businesses, in particular for small companies. The initial investment required to develop and for the acquisition of the system demands a significant amount of resources associated with data extraction and transformation, maintenance, and operation. To put it in perspective, AI tends to demand greater resources than IoT and Cloud Computing. Cost can be considered to be a limiting factor for many companies since it holds a direct relation to functionality and algorithm processing performance (e.g. tailored-made vs. pre-built solutions and computing power and amount of training needed). However, as it will be further elaborated in Chapter 3, the benefits can overweight the benefits.

[18] Gunning D., et al. *XAI-Explainable artificial intelligence*, Science Robotics (2019)

[19] Rieg T., Frick J.; Baumgartl H., Buettner R., *Demonstration of the potential of white-box machine learning approaches to gain insights from cardiovascular disease electrocardiograms* (2020)

1.3 THE HUMANS BEHIND THE KEYBOARD, *THE CAPTCHA STORY*

As described in section 1.3, one of the crucial elements in implementing a successful AI model is the presence of a good training dataset. The quality of that training dataset depends mainly on the humans behind the keyboard who define what is correct and what is false. The more data used for the training dataset and the wider the range the better the model would be able to learn and excel. One of the very success stories for mass training AI models was the use of CAPTCHA by Google in training their AI Optical Character Recognition (OCR) modules to correctly interpret difficult text found in old books[20].

Completely Automated Public Turing Tests to tell Computers & Humans Apart (CATPCHA) is a program that was designed to protect of websites from bots through a series of tests that only humans can solve. The tests and methods employed underwent significant changes to cope with the raising capabilities of AI. Computers were unable to distinguish differences in the forms of characters, separate words and characters where whitespaces were not present, and separate characters based on context when CAPTCHA was first implemented in 1997. Currently, AI has evolved to be able to process not only characters but also images and sounds, which has in turn forced companies to abandon text and audio CAPTCHAs, thus demanding more complex images sets. On the other hand, there has been developments of tests that are becoming increasingly difficult for humans to solve, while for machines the task could only require a fraction of a second. For example, Amazon developed (and patented) a system that arguably can be only solved by computers.

1.4 RISKS AND HOW TO DEAL WITH IT

Given the emerging force of AI in all areas of the public sphere, understood as the interface between politics, the economy, and the cultural world, and that the actual scale of AI potential exceeds human imagination, there is little sensibility of the full scale of risks of AI[21]. Knowledge about data fed into AI systems, about the operation of algorithmic models, up to knowledge about the interactions between humans and machines, is low. Nevertheless, risks can arise both around elements which enable AI – such as data difficulties, technological problems and security issues – as well as risks related to the algorithms and human-machine

[20] Rao L., *Google Acquires reCaptcha To Power Scanning For Google Books And Google News* (2009)
[21] Habermas J.*The structural transformation of the public sphere: An inquiry into a category of bourgeois society*, MIT Press (1991)

interactions that are central to the operation of AI itself. [22] Many private sector entities confirm that AI offers many opportunities for development[23], but that *"(it) also comes with far-reaching implications for the economy, politics, mobility, healthcare, security and the environment."*[24]

First and foremost, AI raises concerns around personal data protection. Invasion of privacy, discrimination, accidents, and the manipulation of political systems are among the most visible consequences. McKinsey[25], for example, sees the increasing amount of unstructured data from sources such as the internet, social media, mobile devices, sensors and the Internet of Things (IoT) as complicating the accurate use of data and posing a major threat to privacy regulations. To counteract data insecurity, some institutions, such as the European Union (EU) are attempting to address the issue through legislation. For instance, the EU adopted on 14 April 2016 the General Data Protection Regulation (GDPR), aiming at creating more consistent protection of consumer and personal data across EU nations.[26]

In addition to significant challenges for companies, ranging from reputational damage and lost revenue to regulatory repercussions, criminal investigations and weakened public trust, the risks also run to catastrophic scenarios that may involve human fatalities and threats to national security. At the same time, existing ML technology could enable a high degree of automation in labour-intensive activities such as satellite imagery analysis and cyber defence, which represents a significant potential threat to national security.[27]

Because ML systems learn from historical data, it also captures human biases in its learning. Despite the efforts to prevent it, during the development of AI systems humanbias can be unintentionally transferred to the system. The advantage of applying AI is that now we can measure this bias and find ways to eliminate it. There are many ways that the bias of AI systems can be reduced, such as balancing the data before training an AI system, using diverse teams in building the AI systems and using advanced testing to detect bias of the trained AI system. However, in the non-AI world, it is hard to measure bias, such as gender or ethical bias; we have a great opportunity with AI to reduce bias in our society.

[22] McKinsey, *Confronting the risks of artificial intelligence* (2019)
[23] Research by the McKinsey Global Institute shows that AI could add USD 13 trillion a year in global economic output by 2030, see McKinsey Global Institute, *Notes from the AI frontier – modeling the impact of AI on the world economy* (2018).
[24] Allianz, *The Rise of Artificial Intelligence: Future Outlook and Emerging Risks* (2018)
[25] McKinsey, *Confronting the risks of artificial intelligence* (2019)
[26] Global Partnership on Artificial Intelligence (GPAI), *The Role of Data in AI - Report for the Data Governance Working Group of the Global Partnership of AI* (2020)
[27] Allen G., Chan T., *Artificial Intelligence and National Security* (2017)

However, we have seen examples where AI inherited human bias for example, one study revealed that the Google's Ads tool targeted a lower number of advertisements of high-paid positions to women than to men.[28] Inclination towards discriminatory behaviors on the grounds of gender, race, sexual orientation, or social class can make their way into the system when the model is discussed (e.g., the problem is addressed by prioritizing profit over any other considerations or when the model is learning from historical data that already contains bias), data is collected (e.g. data selected miss to adequately represent all groups and sub-groups of individuals). Although current research is oriented towards identifying and mitigating bias to prevent AI to exacerbate existing inequalities, it can be said that it continues to be a potential factor limiting the broad adoption of AI.

In academia, addressing ethical disputes and dealing with dilemma scenarios (where AI-driven algorithms, e.g., in the widespread adoption of self-driving autonomous vehicles (AVs), promises to drastically reduce the number of traffic accidents, but at the same time must inevitably be involved in accidents because AVs must choose the lesser of two evils in some situations) is a prevalent and debated topic when it comes to the increased use of AI in everyday life.[29]

In summary, as soon as AGI applications find their way into the real world, the risks and benefits will emerge in the short or long term. A basic prerequisite for the sustainable use of AI is therefore transparency, especially to ensure tamper-proofing, predictability and, above all, trust. This needs to be ensured at the earliest stage (by the programmer and the technology provider) so that the algorithm's decision paths are comprehensible and thus the responsible use of AI and its benefits can be guaranteed. It can be said that all the ways to prevent or mitigate negative impacts of AI are at the core of any progress in its diffusion and implementation. Especially in the case of self-learning and self-assessing technologies in business, industry, (non-)government institutions and research, it is essential that the technology is guided by its human counterparts. Finally, the increasing use of AI necessitates an open ethical debate in society and underlines the importance of increased research and development on internet governance issues.

1.5 WHAT IS NOT AI

In roughing out definitions of AI, developers are also becoming more settled on what it is not. A critical differentiator between AI and non-AI systems is what might be called machine independence. "Where AI is oriented around specific tasks, AGI seeks

[28] Datta A., Tschantz M. C., Datta A., *Automated experiments on ad privacy settings. Privacy Enhancing Technologies* (2015)

[29] Bonnefon J.-F., et.al., *Autonomous Vehicles Need Experimental Ethics: Are We Ready for Utilitarian Cars?* (2015)

general cognitive abilities," according to a recent report by JASON, an independent group of scientists that advises the US federal government on science and technology questions.[30] The JASON report defined two kinds of artificial intelligence: AI, or the ability of computers to perform specific tasks that humans do with their brains, and the AI subset of AGI that refers to general cognitive abilities and "seeks to build machines that can successfully perform any task that a human might do."[31]

The most common misconception about AI is that it is synonymous with automation. In fact, the only shared elements between AI and automation are their reliance on data and their goal of streamlining convenience[32]. To liken AI to automation beyond those commonalities is to ignore the key capacities of an AI system. While automated systems must be "*manually*" configured to execute monotonous, repetitive tasks, AI systems are independently adaptive once they have data to process, meaning that they "*learn*" as they go without continuous monitoring. AI leverages aspects of automation, but it goes beyond simple execution of tasks by learning to making decisions on its own, mimicking human behaviour.

AI's ability to surpass human intelligence can be misrepresented and exaggerated as eventually developing the means to gain control over human society. Although it can be manipulated by people with ill will, AI doesn't possess organic, malicious intent of its own. As with any new science or theory, the danger remains with the humans behind these applications, not with the technology itself. AI is a process of collecting data, sorting it, and learning from what is stored, enabling computers to perform tasks that normally require human intelligence. The key is that AI mimics human intelligence in a systematic way. This means there must be some type of planning, learning, problem-solving, knowledge representation, motion and manipulation, as well as sociable skills and creativity to a lesser extent. Simmering AI down to its fundamental elements is about understanding the importance of data and how we can train machines to synthesize, analyze and act on data as a human being could.

Automation in manufacturing and in business has been used for a long time, however, until recently automation was limited to a few applications and was almost always set as a rule-based process ''If the

1.6 HOW CAN AI SUPPORT SMES?

The uses of Artificial intelligence in Business and in Manufacturing are manifold.

[30] Potember R., Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD, Mitre Corp Mclean (2017)

[31] Ibid.

32 Glidden J., *Understanding What Artificial Intelligence Is, And What It's Not*, Forbes Business Council, Forbes (2021)

condition is met, then do something, otherwise do something else''. Newer types of automation using AI, which learn and make predictions from data and are not Rule Based processes, now have a role in every stage of business and production.[33]

Industrial Research. A compelling example comes from Boeing[34], which recently wished to mass-produce 3D-printed metal parts for jets. However, most useful metal alloys are not printable because the different powder grains do not arrange well. Boeing thus turned to an AI system belonging to Citrine Informatics. The AI trawled through decades of experiments, scanning 10 million possible recipes for alloy powders. The company wrote software so the AI could even scan data from old reference books and handwritten notebooks. A process of materials discovery that usually takes years was shortened to days[35].

Business Intelligence. In a world where the average SME generates large amounts of data daily, unless some insight can be driven from it, the data on its own does not hold much value. This is where AI helps aid data analysis, exploration, find patterns and make predictions. There are quite a few tools today that involve the use of artificial intelligence in business intelligence. Popular tools include Microsoft Power BI that helps companies get key analytics to know which strategies and decisions have great influence on business metrics[36].

Product Design. AI-driven design software, combined with 3D printing, are set to revolutionize industrial design. Such software generates vast numbers of potential designs. Over many cycles, less suitable designs are discarded and better versions retained and refined. Using such a system, an aircraft bulwark partition incorporated in Airbus' A320 aircraft was stronger than the partition it replaced, but 45 % lighter[37].

[33] Nolan A., *Artificial intelligence, its diffusion and uses in manufacturing*, Going Digital Toolkit Note, No. 12 (2021)
[34] Wilson, G. *Boeing reduces lead time and saves money by 3d printing aircraft parts*, Manufacturing Global (2020)
[35] Chen S., *The AI company that helps Boeing cook new metals for jets*, Science, American Association for the Advancement of Science, Washington DC (2017)
[36] Microsoft. *Use AI Insights in Power BI Desktop* (2021)
[37] Airbus, *Pioneering bionic 3D printing*, Airbus Newsroom (2016)

Personalized and Targeted Marketing. The key to growing company revenue requires knowing what the consumer wants and knowing what to market to each consumer and when to market. Presize.ai uses computer vision to 3D-model a user's body, from which it can determine a shopper's body measurements. Based on this, it can provide sizing and style recommendations to the customer.[38]

Process control. So-called 'digital twins' are computer models of a machine, or system of machines, based on real-time data from sensors in real machinery. Aided by AI, the computer models help to monitor production, optimize key parameters, and predict maintenance needs.[39]

Natural Language Processing. With advancements in natural language processing, companies can now use AI to generate automated business reports without human supervision and carry out sentiment analysis to understand a customer's perception of their brand from various online comments, tweets, etc., about the company. Through sentiment analysis, companies can constantly understand the perception of people on their products and services. This helps to improve the quality of services and personalized product offerings. For example, a fashion brand may deploy AI-based services to generate its intended customer experiences. A smart social community bot may be deployed as part of its customer engagement strategies to drive on-demand and trending conversations that align with the identity of its target consumers.[40]

Supply chain management. BMW has set a goal of knowing the real-time status of all major production equipment at each company producing key components for its vehicles. Information of this sort can extend upstream to the supply of production inputs and downstream to distribution and retail. AI can help to integrate and improve supply chains, for instance by predicting fluctuations in customer demand and efficiently scheduling distribution.[41]

[38] Presize, Die perfekte Kleidergröße im E-Commerce – 100% digital (2021)
[39] Beck, R., Digital Twins and AI: Transforming Industrial Operations. Reliable Plant, Noria Corporation (2021)
[40] Jeffery O., *Consumer Perception in The Age of AI* (2021)
[41] Pathak R., *How BMW uses Artificial Intelligence (AI)?* (2021)

Training and cognitive support. In aerospace, when building its A350 aircraft, Airbus deployed AI to analyze process disruptions. If a worker might encounter an unfamiliar problem, the AI can suggest solutions by analyzing a mass of contextual data on similar problems from other shifts or processes. The AI cut time lost to disruptions by a third[42]. AI is also enhancing workforce training (using virtual reality) and cognitive assistance (using augmented reality). For example, a technician might see suggested solutions to production problems projected on a safety visor.[43]

We are just scratching the surface of AI and its possibilities, as the diffusion of AI and other digital technologies in business and manufacturing can only exponentially increase. Companies that do not want to miss out on the revolutionary future of business, must, inevitably, embrace the use of AI as a guiding light.[44]

[42] Ransbotham S. et al., *Reshaping business with artificial intelligence: Closing the gap between ambition and action*, MIT Sloan Management Review, Massachussets Institute of Technology, Cambridge (2017)
[43] Airbus, Artificial intelligence -Capitalising on the value of data (2021)
[44] Lee J., Singh J., Azamfar M., *Industrial AI: Is It Manufacturing's Guiding Light? Manufacturing Leadership Council*. (2019)

‘Drivers’ of the adoption and application of AI

2.1 Innovation ecosystem 39
2.1 AI National Strategies and Support Mechanisms 40
2.2 Technology advances 43
2.3 Competitiveness and market dynamics..... 45
2.4 Regulations and Standards..... 49
2.5 Health and safety and cybersecurity.....51

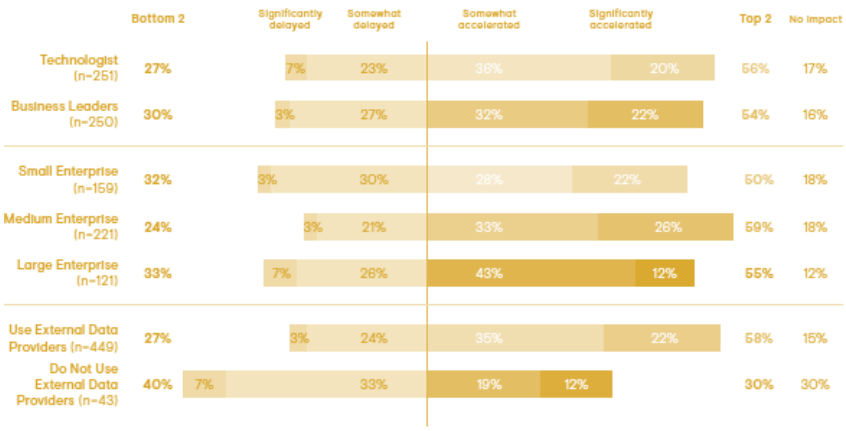
Chapter 2: 'Drivers' of the adoption and application of AI

2.1 INNOVATION ECOSYSTEM

The ongoing COVID-19 pandemic has had a notorious impact on AI adoption trends. Two studies conducted on US-based companies reveal valuable insights. A study conducted on 501 SMEs and large enterprises revealed that COVID-19 significantly impacted the acceleration of AI-related efforts.

Medium sized enterprises showed a growing upward trend.[45] Similarly, the survey results exhibited that 52% of companies increased their AI implementation plans in the aftermath of the pandemic. In contrast, 86% declared that AI would become a mainstream digital technology within their organizations by the end of 2021 (See Figure 2)[46].

Figure 2: Covid Impact on enterprises' AI strategies.



Source: Appen, *The State of AI and Machine Learning* (2021)

Globally, the adoption trends point towards a similar direction. IBM's Global AI Adoption Index 2021 explains that due to the Covid-19 epidemic, 43% of firms said that they had expedited their AI rollout.[47] In other words, AI represented businesses worldwide as an alternative to adapt, remain competitive and operational amidst disruptions, limitations and changes brought by the pandemic. Together with COVID-19, other factors are driving the adoption of AI forward. This chapter discusses a selection of them.

[45] Appen, *The State of AI and Machine Learning. AI Industry Accelerates Rapidly Despite Pandemic, Driven by Data Partnerships and Increasing Budgets* (2021)

[46] PwC, *PwC's annual AI Predictions survey* (2021)

[47] IBM Watson, *Global AI Adoption Index 2021* (2021)

2.1 AI NATIONAL STRATEGIES AND SUPPORT MECHANISMS

Either as part of a national strategy for improving the adoption rate of digital technologies or the improvement of the innovation ecosystem, national support mechanisms play a pivotal role in adopting AI among businesses. Global leaders on AI have designed strategies and instruments to systematically support the development of their national competitive advantages, or at the minimum, to keep pace with their peers.[48] Implementing such measures is among the factors contributing to the development and maintenance of their leading-edge on AI adoption maturity and AI adoption.

As with support mechanisms for science, technology, and innovation (STI), AI support mechanisms address and strengthen a wide range of aspects. Based on an analysis of existing AI policy initiatives, Table 2 below depicts the major areas of support.[49] From the table, initiatives supporting AI (383 initiatives) can be distinguished from those related to AI and those supporting AI specifically among SMEs (63 initiatives). Improving governance and the provision of loans, guarantees, subsidies, grants and loans, and other direct financial support are in both cases the two most prominent areas of assistance.

Table 1: Main areas of support of AI policies

Area	AI Initiatives	AI Initiatives Relevant for SMEs
Governance	198 (51.3%)	31 (39.7%)
Direct financial support	81 (21.0%)	21 (26.9%)
Collaborative infrastructures (soft and physical)	62 (16.1%)	15 (19.2%)
Guidance, regulation and incentives	41 (10.6%)	9 (11.5%)
Indirect financial support	4 (1.0%)	2 (2.6%)

Source: Author's elaboration based on OECD, *Studies on SMEs and Entrepreneurship. The Digital Transformation of SMEs* (2021)

[48] Deloitte, *Future in the balance? How countries are pursuing an AI advantage* (2019)

[49] OECD, *Studies on SMEs and Entrepreneurship. The Digital Transformation of SMEs* (2021)

The overall number of initiatives, at least partially addressing AI, is growing as a share of STI total initiatives. Currently, around 35% of the policy initiatives listed in the EC-OECD STIP Compass have references to AI.[50][51] Although the percentage decreases to about 6% when only initiatives addressing AI specifically for companies are considered, the sway of those initiatives in global leaders is having a direct positive impact on AI adoption in general.

The support of national AI agendas, plans, and strategies has undoubtedly influenced the rise of startups and so-called unicorn startups. The latter is characterized by rapid growth and a market value of over 1 billion USD and can play a critical role in advancing research and development, establishing new industry practices, and integrating new market players into the ecosystem. Moreover, by increasing demand for AI, promoting disruptive effects in market trends and consumer patterns, these fast-growing companies can support an innovation ecosystem that enables other startups to thrive. In addition, the latter can usually benefit from mentorship support, acceleration programmes and venture capital sponsored and attracted by unicorn companies[52].In 2019, AI companies raised a record USD 26.6 billion, spanning more than 2,200 deals globally, as part of an annual look at global AI investment trends. In 2018, around 1,900 deals totalled USD 22.1 billion, compared to nearly 1,700 acquisitions totalling USD 16.8 billion in 2017.[53] From 2014 to 2021, annual investments in AI startups have steadily grown. As a result, AI businesses received roughly 36 billion dollars in funding in 2020. This sum was surpassed in the first six months of 2021, reaching 38 billion dollars.[54] Coincidentally, since 2018 the number of AI unicorns has doubled every year, reaching almost 80 startups under that categorization[55].

Initiatives and support mechanisms (Figure 3) seem to correlate with the development of AI startups (Figure 4). In both cases, lighter colours indicate lower numbers and darker colours greater concentration. As argued above, support mechanisms are driving AI adoption, either directly through the promotion of new startups or indirectly through the effects of thriving AI startup ecosystem produced as a result thereof, or indirectly through the market leaders in creating global market disruptions establishing trends. However, more research is needed to assess their impact in countries with more incipient engagement with AI.

[50] Ibid.

[51] The STIP Compass can be consulted in the following link: stip.oecd.org/stip/

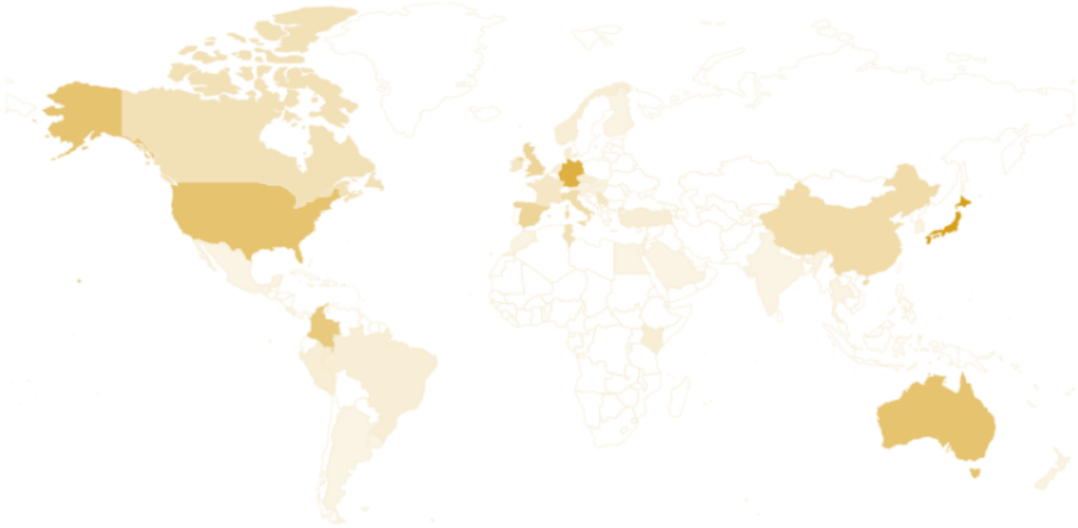
[52] Prohorovs A., *Unicorn Exits as a Trigger for the Development of Small Countries' Startup Ecosystems Forbes*, Latvian edition (2020)

[53] Johnson K., *CB Insights: AI startup funding hit new high of USD 26.6 billion in 2019*, Venture Beat (2019)

[54] Shanghong L., *Funding of artificial intelligence (AI) startup companies worldwide from 2014 to 2021*, Statista (2021)

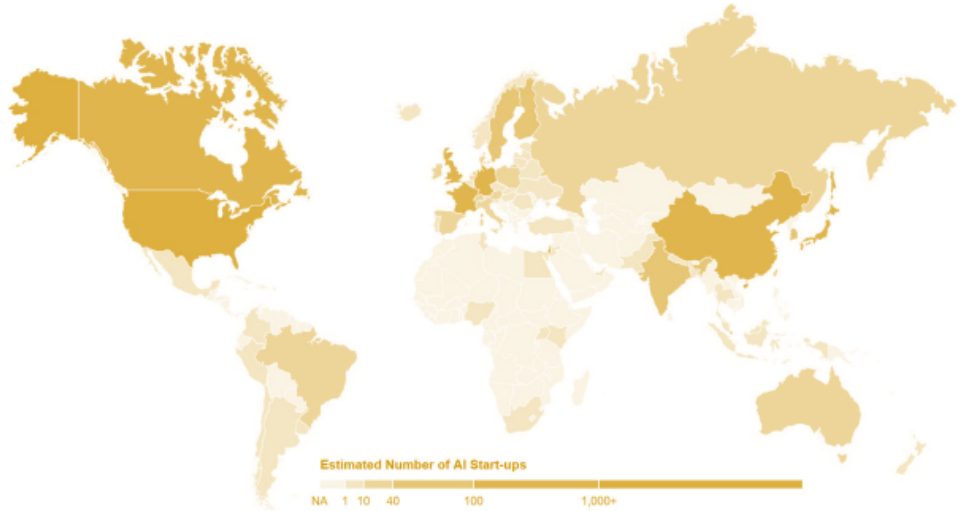
[55] Gopani A., *78 AI Companies Around the World That Are Unicorns Today*, AIM, (2021)

Figure 3: Number of AI policy initiatives



Source: OECD, Policy Observatory and Accuracy Analysis,
White House National AI R&D Strategic Plan.

Figure 4: Estimated number of AI Start-Ups



Source: OECD, Policy Observatory and Accuracy Analysis,
White House National AI R&D Strategic Plan

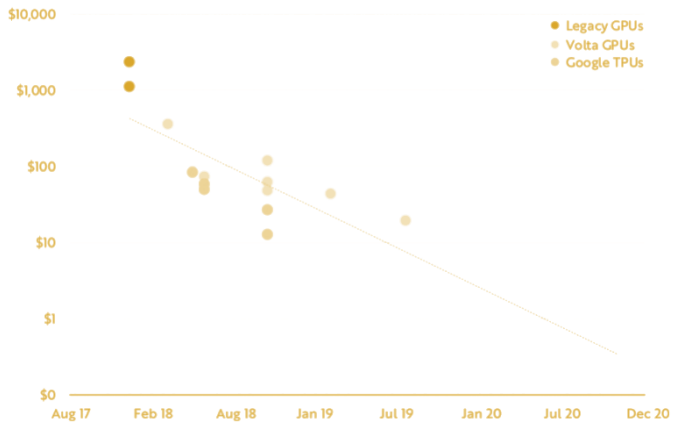
2.2 TECHNOLOGY ADVANCES

The rapid expansion of the global market for AI has contributed to a significant decrease in the overall costs of software and hardware. For example, between 2017 and 2019, expenses required to train a neural network decreased approximately 100-fold, and the training performance of V100 graphics cards, commonly used to train large AI systems, has improved by around 800%, mainly due to software innovations from major companies such as Google, and Microsoft[56]. Similarly, the training costs of an AI-based image classification system went from around USD 1,000 in 2017 to USD 10 in 2019.[57] Concurrently, the amount of computing power needed to train the network dropped about 44 times.[58]

The cost of training a Neural Network is expected to drop to USD 1 at the current rate of improvement, and in parallel, the price of inference —running a trained model in production— is expected to reach around USD 0.03. Figure 5 shows how the downward costs trends of ResNet-50, a deep residual network.

This drop in the cost of AI training and AI inference and the decreasing costs of overall costs of software and hardware are increasingly making AI available for a broader public. In other words, technological advancements and an accelerated decrease in costs are promoting the adoption of AI.

Figure 5: Cost to train a Neural Network



Source: W. Kyle (2020)

[56] Wiggers K., *AI training costs dropped 100-fold between 2017 and 2019, ARK Invest* (2020)

[57] Wang J., *The Cost of AI Training is Improving at 50x the Speed of Moore's Law: Why It's Still Early Days for AI*, ARK Invest (2020)

[58] Hernandez D., Brown T. B., *Measuring the Algorithmic Efficiency of Neural Networks* (2020)

Raising computational power

Emerging technologies and computer advancement are mutually advantageous. An increase in computer power— the ability of a computer to perform a given task quickly and accurately— leads to a rise in AI, leading to a rise in computing power. For example, computing power is doubling seven times faster every year since 2012. In other words, computational use for AI models grew 300,000-fold by 2019.[59]

This rapid growth and development require expensive AI-specific hardware, which is different from standard computing hardware. Thus, to apply ML, neural networks, computer vision, and other AI tools, AI-specific hardware requires a graphics processing unit (GPU), microprocessors or microchips that guarantee fast computing power.

Given the increasing demand for AI hardware, it is expected that a new generation of AI hardware will be developed that offers more computing power at a lower cost. In addition, new materials for manufacturing the hardware, new architecture and faster insights are among the desirable capabilities of AI hardware.[60] Advances in AI hardware promise corresponding advances in AI software, i.e., AI technology for various purposes and tasks.

The computing power of modern chips has improved exponentially, to the point where they can run trillions of calculations per second in modern computers.[61] In addition, technological advances have allowed tiny chips to operate at unimaginable speeds while consuming only a fraction of the energy that conventional ones do. This represents a major driver for the adoption and application of AI, countering criticisms such as the environmental footprint attributed to AI algorithms.

Cloud Computing and other technical possibilities facilitating broader AI adoption

With the increasing aspiration of AI to Cloud Computing, Cloud Computing is expected to act as a significant driver to increase the scope and impact of AI on the overall market as it becomes more widely accessible. Furthermore, through Cloud Computing, even businesses with inadequate technical infrastructure can benefit from AI technology without making upfront investments, as sophisticated computing services are accessible via the Internet or on a fee-for-service basis. This is particularly important for SMEs as it enables them to keep pace technologically with the progress of their larger competitors.[62]

[59] Mindsync, *Is High Computing Power A Roadblock in the Path to AI Systems Deployment? Probably Not* (2021)
[60] Ibid.
[61] Cybiant, *The challenges of AI implementation* (2021)
[62] Senarathna I., Wilkin C., Warren M., Yeoh W., Salzman S., *Factors that influence adoption of Cloud Computing: An empirical study of Australian SMEs* (2017)

Cloud Computing models are playing a significant role in shaping AI use cases. Furthermore, since enterprises will have considerable volumes of data with processing capability on-premise, edge computing, which extends cloud capabilities to on-premise with low latency and even offline capabilities, is expected to enable new use cases.[63]

However, despite the growing possibilities Cloud Computing offers for leveraging from AI, it is essential to mention that the cost of developing this technology remains a challenge for many companies. On the other hand, it is also necessary to consider that developing more sophisticated ML models in the cloud remains expensive. For example, OpenAI reportedly spent USD 12 million to train its GPT-3 language model, and Google spent about USD 6,912 to train BERT, a bidirectional transformer model to modernize 11 natural language processing tasks.[64]

2.3 COMPETITIVENESS AND MARKET DYNAMICS

One of the most important drivers for AI adoption is the continuous need of companies to remain competitive. The reasons are mainly economics, such as competition with low-cost producers or countries, having better production and deliverables times in the competitive e-commerce segment, ensuring the best customer experience and customer retention, having decision-making accuracy, avoiding downtimes of the production machinery, to offer hyper-personalized products or find a new niche to explore new business opportunities.

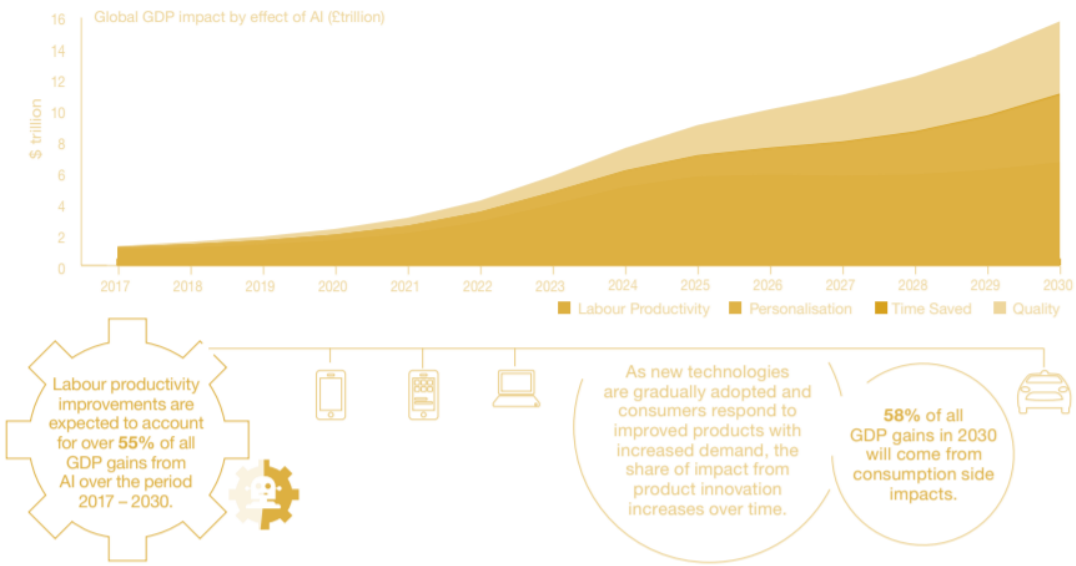
Productivity and efficiency

The increased potential value of AI can influence top-line-oriented functions, such as marketing and sales, and bottom-line oriented operational functions, such as supply chain management and manufacturing. Thus, not only is the technology proving beneficial to large companies seeking highly competitive gains, but SMEs are also benefiting from better strategic development using AI.

According to PWC, global GDP will be up to 14% higher in 2030 due to the accelerating development of AI, an equivalent of USD 15.7 trillion[65]

[63] Uslu K., *The Role of Cloud Computing in Artificial Intelligence. Towards Data Science* (2020)
[64] Synced, *The Staggering Cost of Training SOTA AI Models* (2019)
[65] PwC, *Sizing the prize What's the real value of AI for your business and how can you capitalize?* (2017)

Figure 6: Where will the value gains come from with AI?



Source: PwC, *Sizing the prize – What's the real value of AI for your business and how can you capitalize?* (2017)

In general terms, the global economy will see productivity gains from AI thanks to businesses automating processes, companies expanding their existing operational force through AI technologies and the Increased consumer demand resulting from the availability of personalized and higher-quality AI-enhanced products and services.

Machine learning and data visualization can be used to automate decision making and analyze data in ways that were not possible before. This creates a better database and should improve the quality and efficiency of decision making. Industrial manufacturers and SMEs have recently begun using AI to analyze historical data and market trends to do more predictive modelling and increase the accuracy of their forecasts, so that their managers can improve their decision-making accuracy. As a result, AI can improve margins, maximize the top line, and predict what will be needed in the supply chain and on its production line without wasting time, money, or resources.

On the manufacturing side, SMEs worldwide are using AI to improve the efficiency of manufacturing processes. AI systems can monitor quantities used, cycle times, temperatures, lead times, errors, and downtime to optimize production. Currently, most of those applications are in "operator assistance" mode, in which AI will operate in the background and suggest solutions to the operator. But soon, AI systems will learn how the

human mind acts on these situations to work in an "operator replacement" mode where machines will make most of the decisions autonomously, only with human interaction in specific cases.

AI can also play a key role in improving cost efficiency by performing maintenance when needed (predictive maintenance), rather than following a set schedule. It also helps to avoid unexpected equipment failures by ensuring that management always has the right information about equipment.

E-commerce and market demand

One of the drivers pushing SMEs to use AI in the e-commerce sector is finding ways to compete with top digital retailers like Amazon. Differentiation and personalized experiences are key factors for customers. However, only a truly personalized, consumer-centric business model will succeed in making a dent in the competition against online retail giants.

Eventually, the GDP uplift from product enhancements and subsequent shifts in consumer demand, behaviour and consumption emanating from AI will overtake the productivity gains, potentially delivering more than USD 9 trillion of additional GDP in 2030[66]

E-commerce in the United States has seen a 30% increase in the two years up to 2020. Now major retailers are considering previously nascent or hard to implement technologies; and AI is one of those technologies with the fastest growth, with USD 7.3 billion forecasted to be spent by retailers in 2022.[67]

One of the areas that have been moving the attention of companies to improve is the digital interactions with the customers with the help of AI technologies and to understand better customer demands and offer them their preferred products. Based on the results extracted from collected data, companies can provide personalized solutions to their customers, attracting more customers in the process. In addition, sales intelligence helps intercept customer behaviour before and after a purchase, enabling companies to create better customer engagement channels.

Companies also use an AI algorithm to analyze data on individual consumer trends and product and service usage and then match the resulting data to the existing product or service portfolio to expand business with existing customers.

[66] PwC, *Sizing the prize What's the real value of AI for your business and how can you capitalize?* (2017)

[67] eMarketer. US Ecommerce Growth Jumps to More than 30%, Accelerating Online Shopping Shift by Nearly 2 Years (2020)

Product specialization

Another driver for companies to keep up with the competition and the market dynamics is to deliver unique and personalized products to their customers. In the past, firms had to rely on demographics and behavioural skills to segment their customers. This allowed for some personalization, but accuracy remained low.

Harvard Business Review states that personalization can reduce acquisition costs by as much as 50%, lift revenues by 5 to 15%, and increase the efficiency of marketing spend by 10 to 30%[68]. Similarly, Starbucks launched a mobile app that combines its loyalty program with personalization, giving customers the ability to fully customize, preorder and pick up drinks from any location. Currently, the app drives approximately 22% of all U.S. sales[69].

All the examples above show that the goal of marketing teams at enterprises is to deliver the right product to the right person at the right moment; when this is done, it's called 'hyper-personalization', which is possible by AI and big data analytics.

Through hyper-personalization, organizations can build a unique profile of customers and have that profile learn and adapt over time based on behavior. Then, it uses customer information to give personalized products and services to match customers' preferences. Companies worldwide are now using hyper-personalization to provide a wide range of services, including virtual stylists, AI-based personal trainers, or robot concierge services in hotels, among other products or services.

New growing niches powered by AI

Every day, there are exciting new applications of AI. The DL algorithms have opened the doors of many possibilities and unique niches that enterprises can use as drivers to grow and be up to the market dynamics. Some of the most interesting new growing niches for AI are in manufacturing, banking, or health, to name but a few.

In the banking and manufacturing industries, it is expected that only in Europe will be spending USD 22 Billion by 2022 over the five-year forecast period accordingly with IDC[70]

In healthcare AI technology could be used for various health applications. For instance, in 2015, misdiagnosing illnesses and medical errors accounted for 10% of all US deaths[71]. Considering that, the promise of improving the diagnostic process is one of AI's most exciting healthcare applications. The drug development industry is increasing development costs and research that takes thousands of human hours. Putting each drug through clinical

[68] Ariker M., Heller J., Diaz A., Perrey J., *How marketers can personalize at scale*, Harvard Business Review (2015)
[69] Richman D., *How Starbucks is using artificial intelligence to connect with customers and boost sales*, Geekwire (2016)
[70] Minonne A., European Spending on Artificial Intelligence Will Reach USD 22 Billion in 2022, Supported by Strong Investments Across Banking and Manufacturing, Says IDC, IDC (2021)
[71] USCF, *Big Data, Analytics & Artificial Intelligence The Future of Health Care is Here* (2016)

trials costs about USD 2.6 billion, and only 10% of those drugs are successfully brought to market. Due to breakthroughs in technology, biopharmaceutical companies have quickly noticed the efficiency, accuracy, and knowledge that AI can provide. In addition, researchers in Mount Sinai, New York, built an AI system that could help diagnose patients with COVID-19[72] using an algorithm trained on more than 900 computerized tomographies (CT) scans of lungs from patients.

In sum, rising competition in international markets, coupled with the possibilities offered by AI to automate decision making, enable predictive modelling and cost and time automatization, which in turn contribute to improving productivity and efficiency, are driving the adoption of AI among a more significant number of SMEs. The already fast-growing e-commerce sales, further exacerbated by the pandemic, are pushing the overall retail industry to move online. Given the applications offered by AI to support this transition, many SMEs are now considering AI to support their adaptation to the new market trends. Other factors such as the adoption of new business models and new market niches evolving and greater demand for personalization are also improving the demand and increasing the relevance of AI, thus promoting its broad adoption.

2.4 REGULATIONS AND STANDARDS

REGULATIONS

The regulatory landscape of AI is a nascent but key driver in enabling AI adoption. As a result, governments and other stakeholders have been working to develop regulatory frameworks appropriate for AI technology, whether by examining if existing legal frameworks are adequate to address the new challenges posed by AI or by developing new regulatory mechanisms as needed. While some national legislation is being discussed and approved, this section will explore a prominent European Commission (EC) legislative proposal to promote the adoption of AI.

The EC published in April 2021 the first legislative proposal of its kind worldwide regulating the use of AI. With this initiative, the EC is trying to directly address AI implementation by publishing a Coordinated Plan on AI released alongside the proposed regulation. The plan contains initiatives intended to help the EU become a leader in AI technology and a driver for its adoption.

The main purpose of the EU regulation is to force new requirements on "high-risk" AI systems. The legislation requires developers to deploy an AI quality management system that meets requirements relating to high-

[72] Mei X., Lee H. C.,Yang Y., *Artificial intelligence-enabled rapid diagnosis of patients with COVID-19,* Nature Medicine (2020)

quality data sets, transparency, record-keeping, human oversight, correctness, robustness, and security.

Additionally to the regulation requirements, the Coordinated Plan has several initiatives to promote AI development and implementation and to support its R&D, with data sharing spaces, testing and experimentation facilities, investment in AI research and excellence centers, funding for education, digital innovation centers, and specific programmatic investments in AI for climate change, robotics, health, the public sector, law enforcement, and agriculture.

One of the first attempts to regulate AI to ensure safety and fundamental rights protection was made by the European Union in the first semester of 2021; the EU proposed an AI regulation to harmonize rules regarding this technology.

The EU proposed AI regulation objectives addressing the following elements:

- Ensure that AI systems used in the EU are safe and respect existing legislation on fundamental rights and EU values.
- Facilitating investment and innovation in AI and ensuring legal certainty.
- Improving governance and compliance with fundamental rights legislation and applicable security requirements.
- Facilitating the development of a single market for legal, secure and trustworthy AI applications and avoiding market fragmentation.

The proposal categorizes AI by risk level, including:

- The unacceptable risk category, which includes the AI systems that are considered a threat to people.
- The high-risk category includes the AI technology that could put the health and life of citizens at risk, may interfere with people's fundamental rights, justice administration, and democratic processes, and will be subject to rigorous assessments before they can be released.
- The limited risk category covers the AI systems with specific transparency obligations, such as AI-powered customer service bots. In this case, users should be aware that they are interacting with machines to make informed decisions.
- The minimal risk category includes AI systems that represent minimal or no risk for citizens' rights or safety.

The examples provided above help to emphasize the importance of regulatory frameworks for AI. Although the participation of developing countries remains comparatively lower, SMEs in developing countries should follow closely the development and implication of new legislations and guidelines for informing their decisions concerning AI. The EU regulatory efforts are important milestones that are enabling and promoting a

widespread adoption of AI. Even if their scope is still limited to a particular geography, they are likely to guide the efforts of other countries.

Regulations and standards can foster consumer interests and limit potential negative consequences of these developments by providing general rules that reflect societal values and preferences. However, if not adequately informed, regulations and standards can restrict SMEs freedom of action and even limit innovation, thus even becoming barriers to innovation.

Standards

Developing standards is a significant task in the AI field, and it has been increasing in the last few years. Currently, technical standardization work is being actively pursued by international SDOs like ISO, IEC, ETSI, ITU-T and Institute of Electrical and Electronics Engineers (IEEE). In addition, national standards organizations (NSO) have also entered enthusiastically into the field, particularly in China, the USA, and the UK.

Since 2017, the International Organization for Standardization (ISO) has had a specialized AI committee (ISO/IEC JTC 1/SC 42) [73]. It is under the Information Technology Committee and is administered by the ANSI (American National Standards Institute). The committee has so far published nine ISO standards. It is developing another twenty-two on AI. Their scope is the standardization of AI, and it serves as the focus and proponent for JTC 1's standardization programme on AI and provides guidance to the JTC 1, IEC, and ISO committees developing Artificial Intelligence applications. The main subject of the published standards has been Big Data, the bias in AI systems and AI-aided decision making, the trustworthiness of artificial intelligence, and the assessment of neural networks' robustness.

Standards activity is extensive in AI. Because it is a transversal technology that influences many other IT fields and plays an important role in technological development and growth, standards provide safety and reliability, raise the users' and organizations' confidence, increase sales, grow new technology acceptance, and support regulators and legislators. Standards act as a interim measure while building regulations, thus allowing compatibility, interoperability, market access, economies of scale and innovation.

2.5 HEALTH AND SAFETY AND CYBERSECURITY

Health and safety

Workplace safety injuries in the United States cost USD 171 billion per year, according to the National Safety Council[74].

[73] ISO/IEC JTC 1/SC 42, Artificial Intelligence Committee

[74] National Safety Council, *Work Injury Costs and Time Lost* (2021)

And notwithstanding companies' investments in traditional safety actions, the improvements have not been significant. Of course, people must be safe when working, especially in manufacturing plants. Most of the time, products are manufactured by workers operating heavy machinery that often can be dangerous, so workers must be equipped with safety gear all the time. However, there are moments when employees do not follow the defined safety protocol, which puts them and other employees at risk of injury. Here is where AI can help SMEs worldwide reduce the incidence of workplace injuries and fatalities.

Rajesh Ramachandran, Chief Digital Officer – Process Automation, from ABB, suggest that 40% of safety incidents due to falling can be easily prevented. "By combining IoT technologies, real-time data collection and with advanced analytics, AI helps to improve the safety of personnel and physical assets within a manufacturing environment".[75]

In this field, the challenge for SMEs is to more accurately predict where incidents may occur or better prevent them from happening. For this reason, Artificial intelligence technology is becoming important in industrial organizations to Security and Cybersecurity.

solve safety problems and improve health and safety.

Many industries have or need to have strict workplace safety guidelines because of the type of processes executed in production or to comply with government safety regulations. Unfortunately, it isn't easy to ensure that all workers are always wearing protective equipment. The AI-powered image recognition technology, can be trained to recognize when safety practices are not being followed and notify the safety officer responsible.

In addition to the standard or mandatory safety compliance guidelines, with COVID-19, there are now new health guidelines about social distancing, maximum occupancy, and personal safety. For example, Image recognition can automatically count heads or determine whether employees wear masks or other required protective equipment.

Another way of improving safety is through wearable sensors, which can be worn over a jacket, on the wrist or the helmet. These sensors can stream data and monitor activities that are going on, potentially identifying situations that might be hazardous

Cybercrime costs are expected to reach USD 6 trillion annually by 2021, up from USD 3 trillion in 2025[76] and when the loss in the

[75] Eklahare J., *Safety in Manufacturing: the Role of AI*, Efficient Manufacturing Web Magazine (2021)

[76] Machado H., *Cybercrime will cost the world more than USD 6 trillion annually by 2021, up from USD 3 trillion in 2015* (2019)

United States is USD 4.24 million in data breaches, according to IBM[77], most companies can't afford this risk. This is where AI can help organizations improve security and cybersecurity threats.

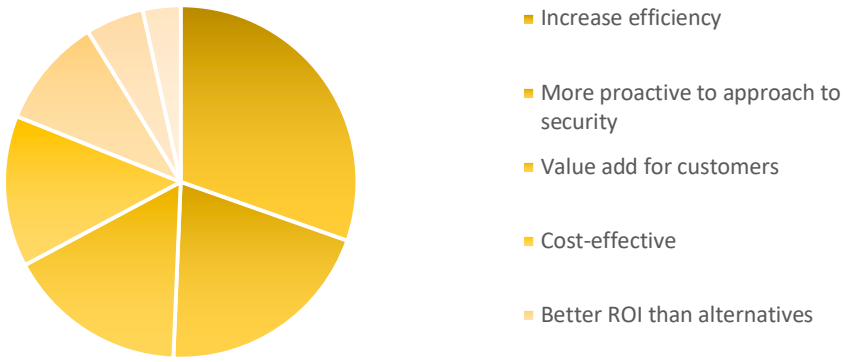
SMEs are just as at risk from security or cybersecurity threats as large enterprises. A common misconception for small businesses is that SMEs are too small to target, but sadly, this is not the situation.

As attackers increase automated attacks, it's easy to target multiple small businesses at once on the cybersecurity side. In addition, small businesses often have less stringent technological defenses, exhibit less awareness of threats and put less time and resources into cybersecurity; this makes SMEs an easier target for hackers than larger organizations.

In the industrial security arena, AI is driving growth and is helping to expand it beyond the traditional practice of monitoring only critical infrastructure. The growing focus on integrating 4IR technologies, like deep learning, analytics, AI, and Cloud Computing, is increasing the scope of video surveillance applications with traffic monitoring, people-counting, facial recognition, posture detection, heat mapping, post-forensic analytics etc. considerably.

According to the Calipsa reports, in a survey conducted in 2020 78, 87% of security businesses use video analytics and 98% on video monitoring stations. Moreover, 68% of the companies had AI-based surveillance, and almost half (57%) said that increasing efficiency was their main reason for adopting Artificial Intelligence- based video surveillance.

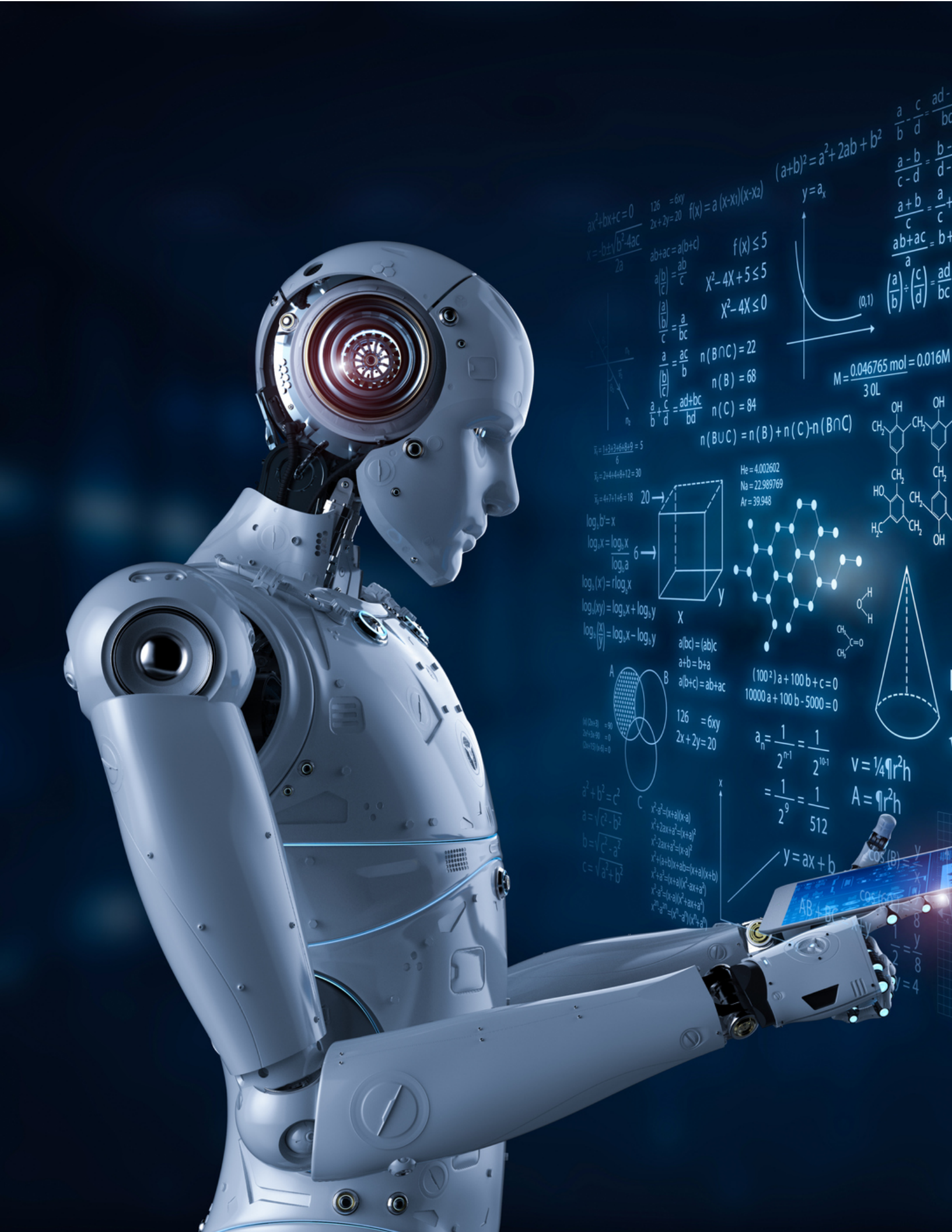
Figure 7: Why did you choose an AI solution?



Source: Calipsa, *The Calipsa Video Monitoring Report 2020* (2020)

[77] IBM, *How much does a data breach cost?* (2021)

[78] Calipsa, *The Calipsa Video Monitoring Report 2020* (2020)


$(a+b)^2 = a^2 + 2ab + b^2$
$y = a_x$
$f(x) \le 5$
$X^2 - 4X + 5 \le 5$
$X^2 - 4X \le 0$
$n(B \cap C) = 22$
$n(B) = 68$
$n(C) = 84$
$n(B \cup C) = n(B) + n(C) - n(B \cap C)$
$M = \frac{0.046765\ mol}{3\ 0L} = 0.016M$
He = 4.002602
Na = 22.989769
Ar = 39.948
$\log_a b = x$
$\log_a x = \frac{\log_b x}{\log_b a}$
$\log_a(x^r) = r\log_a x$
$\log_a(xy) = \log_a x + \log_a y$
$\log_a\left(\frac{x}{y}\right) = \log_a x - \log_a y$
a(bc) = (ab)c
a+b = b+a
a(b+c) = ab+ac
126 = 6xy
2x + 2y = 20
$(100^2)a + 100b + c = 0$
$10000a + 100b - 5000 = 0$
$a_n = \frac{1}{2^{n-1}} = \frac{1}{2^{10-1}}$
$= \frac{1}{2^9} = \frac{1}{512}$
$V = \frac{1}{4}\pi r^2 h$
$A = \pi r^2 h$
$y = ax + b$
$a^2 + b^2 = c^2$

Barriers that SMEs in Developing Countries face in adopting and applying AI

3.1 Finance and financial sustainability 56
3.2 Skills development, gender imbalance, capital-skill complementarity 59
3.3 Infrastructure and process standardization 61
3.4 Partnerships 63
3.5 Ethical concerns within the adoption of AI 64
3.6 Regulations and Standards 67
3.7 Social and Cultural barriers 68
3.8 How to mitigate the effect of barriers in the AI applications in SMEs 68

Chapter 3: Barriers that SMEs in Developing Countries face in adopting and applying AI

The adoption of AI-based solutions for SMEs in developing countries can be a complex process, which relies on different factors that create various barriers that will be discussed in this chapter. Those barriers can be internal and external to the companies.

On the internal ones, the shortage of financial resources and/or economic sustainability is one of the main concerns about implementing AI on SMEs; but even if the company have the economic possibilities, the lack of knowledge and understanding about its benefits by the SMEs' managers may be a drawback for its application. Another internal barrier is the company's infrastructure and most importantly, its process standardization: if a company has low degree of standardization and poor understanding of integration and systems architecture, it is hard and expensive, if not impossible, to design and implement an AI solution or get any real benefits of it. Finally the lack of a skilled workforce or conflicts between workers due to changing working environments may be additional internal barriers to consider.

As with external barriers for adopting AI, a low number or even absence of local technological partners with enough expertise to successfully implement an AI project; the lack of government regulation and coordinated national policies to facilitate the adoption of AI and 4IR technologies

in SMEs, and some ethical, social and cultural concerns within the adoption of AI can prevent the easy adoption of AI applications by SMEs, especially in developing countries.

3.1 FINANCE AND FINANCIAL SUSTAINABILITY

One of the greatest barriers to SMEs implementing technology in a developing country is implementation costs, and for AI adoption, this is not the exception. In earlier days, only giant tech companies like Facebook, Microsoft, Mercedes Benz, Boeing, Bosch, Amazon or Google could afford to develop AI-powered software to improve their internal processes.[79]

79 Tech Advisor, *How tech giants are investing in artificial intelligence* (2019)

Now almost every mid-size and big business organization in the world is embracing artificial intelligence on some level and AI solutions are improving traditional industrial processes and propelling companies toward digital transformation. Thanks to the emergence of several affordable tools, libraries and frameworks, new service providers are offering pre-built and out-of-the-box AI solutions, giving the rise for Artificial Intelligence as a Service (AIaaS), for different industries, and industrial processes, and this has made AI more affordable for small-scale organizations worldwide.[80]

When it comes to implementing a working AI solution for SMEs, different factors must be considered because the budget is usually the main restriction.

First, there are two types of AI SMEs can obtain:

- ☑ The first one is known as a custom AI solution specifically designed for the company and its needs. For example, a company has a unique industrial process that cannot improve with generic pre-built AI solutions. Generally speaking, custom AI solutions are much more expensive as programmers and software experts have to create the entire system from scratch; it requires an in-house development team with data scientists. Each data scientist earns an average salary of USD 94,000 per annum in developed economies and about half that figure in developing countries.[81i]
- ☑ The second type of AI provides out-of-the-box AI solutions that are cloud-based, usually called AIaaS or Artificial intelligence as a Service, that are AI platforms that facilitate SMEs and big companies to implement and scale AI solutions at a fraction of the cost of a full, in-house AI development. Industry-leading digital companies offer these services as Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform (GCP) or IBM Watson. But often, it doesn't have all the features that manufacturing SMEs might need. This type of software is much more affordable but still unreachable for some SMEs in developing countries and can start from a few thousand US dollars for a simple AI running application.

80 Srinivasan P., *AIaaS – Out of the box pre-built Solutions* (2021)

[81] Wisconsin University, *How Much Is a Data Scientist's Salary?* (2021)

The AI implementation costs for SMEs also vary based on their complexity, performance, and the purpose of the solution that the company is looking to solve. Therefore, during the planning stage, the company must define the level of the below four factors:

- ☑ **The level of intelligence of the AI that is planned to have:**
  It depends on the level of intelligence the companies expect from the applications; it is not the same to use a narrow artificial intelligence output that can be programmed to perform a specific task or a highly intelligent AI application that can perform tasks with little to no human instructions.

- ☑ **The performance of the AI algorithm:**
  The algorithm performance is one of the cost factors to consider because accurate predictions made by the AI require several rounds of learning sessions, which raises the cost of implementing AI solutions.

- ☑ **The complexity of the AI solution:**
  It depends if it is a cloud-driven or local server-based, the type of back-end used and other factors that might increase the AI solution development and, therefore, its cost.

- ☑ **The amount of data the AI will use:**
  AI devices perform according to the data available and loaded in the system. It can be used from both structured and unstructured data. Anyhow, when it comes to cost, structured data is cheaper to work with but requires some infrastructure to capture and structure the data.

Additional factors which must be considered by the SME when investing in an AI solution include inter alia:

- ☑ Data format;
- ☑ Data storage;
- ☑ Data Integration;
- ☑ Data structure (unstructured or structured);
- ☑ Data processing speed;
- ☑ The minimum accuracy rate for predictions;
- ☑ Data visualization;
- ☑ Dashboard requirements.

Even when AI models work properly, there are sometimes difficulties in maintaining the quality of AI results, as data is constantly changing. Therefore, maintenance is another aspect to consider when SMEs adopt AI solutions to improve their processes.

Part of maintenance is also about ensuring easy reusability and scalability of the data across organizations, meaning that people can easily access information and consume what has been done by others.

In 2021 the prices of AI solutions go from a prototype development that starts from USD 2,500 to a Minimum Viable Product (MVP) that might cost USD 8,000 up to USD 15,000 or even USD 1,000,000.[82]

3.2 SKILLS DEVELOPMENT, GENDER IMBALANCE, CAPITAL-SKILL COMPLEMENTARITY

During the decades of the Second and Third Industrial Revolutions (IR), the manufacturing sector relied heavily on low-skilled physical labour, making it one of the largest employment producers. Developing countries with large and young populations took advantage of this by offering an abundant number of low-wage workers to global enterprises and local SMEs.

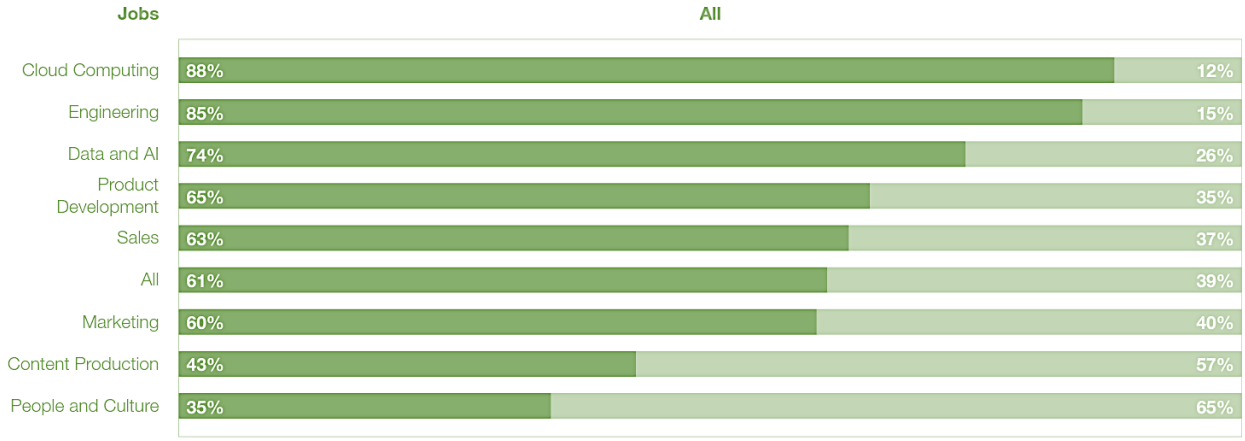
But with the latest Fourth Industrial Revolution technological advancements, as AI and automation, are redefining manufacturing and its dependency on low-skilled workers in developing countries, moving back some manufacturing industries like automotive to developed countries as they are now highly automated and smart, and only require few numbers of professionals with high technical skills.

In addition to that, limited academic curricula, improper educational facilities, existing poverty, and governmental disinterest in promoting higher education are significant barriers for SMEs, since they often encounter difficulties in finding qualified professionals. This problem especially affects women, who are often required to deal with family commitments or are limited by traditional gender roles. The World Economic Forum in its Global Gender Gap Report in 2020[83] highlighted the fact that women continue to be under-represented among workers with Disruptive Technology skills and just 26 % of professionals in Data and AI are women.

[82] Sanyal S., *How much does AI cost in 2021?*, Analytics Insight (2021)

[83] WEF, *Global Gender Gap Report 2020* (2020)

Figure 8: Share of men and women by professional cluster globally



Source: World Economic Forum https://www3.weforum.org/docs/WEF_GGGR_2020.pdf

The most significant way in which the labour market is expected to be affected by AI refers to roles in manufacturing, which at some point in the future are going to be taken over by machines using AI, making simple decisions that involve repetitive, simple or dangerous tasks that are more suitable for robots than humans, thus reducing errors and risks and improving productivity. To counter that situation and realize large-scale reskilling aspirations, developing countries' governments must significantly create or increase the reeducation of low-skilled workers, as far as possible, in new technologies associated with the their sectors. Of course, these comprehensive reskilling programmes will take several years. Still, they are visible and important investments for the future of developing countries and must be planned and executed before the effects of these trends become unsustainable.

A great opportunity exists for governments of developing countries to properly address educational efforts and technology access, by creating massive training plans for new generations in 4IR and AI. This would allow them to overtake the ageing labour force in developed countries, taking into account the following factors and using them as a competitive advantage: the number of young people is reaching unprecedented levels in most developing countries; the cost of technology decreases every year; the fact that more young people have access to digital devices, are more exposed to technology; and finally that young population are often considered to be digital natives, given their easy access to mobile phones and the Internet compared to previous generations.

3.3 INFRASTRUCTURE AND PROCESS STANDARDIZATION

When it comes to AI, it is all about data, and getting the data requires data acquisition infrastructure, and process standardization in SMEs. Thus, among the first barriers SMEs in developing countries have to face is the infrastructure of the company and standardization of the processes. If a company doesn't use standardized process methodologies, for example, lean methodologies or lacks basic data acquisition systems, then the final cost of AI implementation would rise exponentially. Before applying AI solutions, a company necessarily needs to train the employees, implement procedures and acquire infrastructure.

Reliable and accurate data acquisition, management and governance are critical to effectively apply AI algorithms to business processes and of course get satisfactory results. AI is not some kind of magic that works by throwing data at algorithms. The SME must get the data right; the quantity and quality of data is key, so companies need to be on top of every detail when collecting and aggregating it.

Sensor data from factory- connected equipment sensors, and the Industrial Internet of Things (IIoT) are a key source of data in manufacturing, so the preparation of the production line and factories play a critical role in the data acquisition process acquiring devices to collect and save data.

Before and in order to implement AI, SMEs must build "data lakes" to collect raw data from sensors, and the corresponding data exchange channels, manufacturing execution systems (MES), maintenance processes and quality controls in a central location to feed AI algorithms.

These big data management systems require proper cataloging and data lineage to keep track of all available information and flows, and to make the data easily accessible to a large number of users.

The development of any AI solution starts with a reliable machine learning system. The most relevant issues to face relates to data. Creating the best machine learning system requires much more effort than merely coding . Therefore, access to high-quality training data is critical to success. The following are some data-related considerations SMEs must have in mind to create a reliable AI solution:

Lack Of Quality Data

Any AI solution needs access to data sets that allow the system to determine the relationship between inputs and outputs.

In any case, within industrial environments, it is not always easy to generate all the data needed to achieve this, which means firms must rely on third-party data sources.

The SMEs will need a large sample of data to ensure that the solution is based on high-quality information. One way to do that is to use data augmentation methods to increase the original sample, but it has its problems because it might negatively affect data quality.

☑ Complex Extract, Transform, and Load Procedures

The data used to train the Machine Learning system always needs to be well organized, stored and formatted correctly so that the system can make the proper connections. This requires a database, and the key is to have all information stored in the same place, either locally-based or cloud-based or using multi-cloud Indexation process (like Elastic) which allows firms to work with different data-lakes.

☑ Unstructured Data

The structure of data usage plays an important role in determining the total costs of the implementation. If the data used is structured correctly, the implementation prices get lower. But if the SME have to invest first in cleaning and structuring the data, the costs will increase.

It is good to note that an industrial AI solution can be built from unstructured or semi-structured data, but that requires special Machine Learning algorithms developed for that specific type of data that may increase the entire implementation cost.

• Performance-related Issues

Ensuring the optimization of the algorithm performance also impacts the AI costs. The AI algorithms always must go through rounds of testing and tuning. The following are performance-related issues that may be considered:

☑ The Accuracy Rate

Accuracy Rate is the percentage of correct predictions for a dataset. This means that when a Machine Learning model is said to have an accuracy rate of 85%, statistically, it is expected to have 85 correct ones out of every 100 predictions. While a system with 70% accuracy predictions may seem good enough, in some cases is not. Increasing the accuracy rate increases the cost, so the SME must define what the acceptable level of accuracy is for the process involved.

☑ Algorithm Processing Performance

Training Machine Learning usually requires several tries before it can provide high-quality results; this depends on the quality of the data and the features extracted by the algorithms. Algorithms can become a bottleneck during the feature extraction process because complex data usually requires more than just training the model. This problem can be eliminated on cloud-based servers that can increase the processing power of the algorithms.

3.4 PARTNERSHIPS

Partnerships can be seen as the engine of business development, competitiveness, and sustainability. By leveraging complementary competencies and financial resources, partnerships enable companies to grow. However, due to their size and location, developing countries SMEs have fewer opportunities to build strong partnerships compared to larger companies, such as multinationals.

SMEs in particular are affected by the speed and risks associated with this technological transformation, but despite not being high-tech, they often present characteristics adapted to respond to changing contexts such as flexibility, informal culture and organic structure. However, SMEs usually don't have the resources to undertake strong technological collaboration on their own: that often takes time and hard compromises to produce concrete results. As a result, they face numerous challenges.

The local support by the following stakeholders in developing countries might be key to helping SMEs to gain access to new technologies such as AI and to develop and implement projects in this field:

- ☑ Local industrial associations;
- ☑ The university-industry-government collaboration forums;
- ☑ The collaborations between firms and local or government-funded AI research institutions;
- ☑ Technical International cooperation projects.

In addition to the above stakeholders, UNIDO with its forthcoming Investment Portal will provide a unique liaison feature for investor and investee through the structured data collection of more than 500 variables (investment projects, performance, impacts and trends). It provides a platform for companies to attract investors and feature specific investment opportunities linked to their business, expansion or diversification plans requiring external debt or equity finance.

In its future releases, the UNIDO Investment Portal will incorporate AI and ML to provide a more streamlined and a more accurate prediction/recommendation to the investors and investees. The information sources that will be used to feed the model can include regulatory filings, analyst reports, e-commerce activity, speeches, video, geolocation data, and satellite imagery, basically any information that can be linked to an industry, company, or economic activity that has the potential to affect an investment decision.

By applying the machine learning algorithm to the data available on the Public Domain Data (PDD), the platform can identify top

performers in every sector, discover emerging industries, territories and targets to pursue, see a company's active and former investors and study the impact of external factors e.g. the weather, area of land, environment on business and sectors.

The UNIDO Investment Portal, once fully incorporating AI and predictive models, will be able to identify and derive market predictability, patterns, past performance, and optimal investment partners.

3.5 ETHICAL CONCERNS WITHIN THE ADOPTION OF AI

☑ Power Balance in global markets

Big companies, mostly from developed economies are using artificial intelligence to crush their competitors. So how will the governments make sure that the monopolies created by that situation will allow SMEs to compete in a healthy market environment, allowing wealth to flow equally worldwide? Balancing this power differential created by AI is a challenge that governments must address to guarantee fair competition in global markets, especially for developing countries.

☑ AI decision making

Governments and businesses are deploying Artificial Intelligence across a wide spectrum of sectors and applications. Some of those applications imply high-level decision making, actions that until now has always been done by humans.

One good example is the autonomous driving systems or medical devices powered by AI, that rely on that technology to make fraction of second life or death decisions on their own, without any human influence, raising the question of how liability risks will play out for AI.

Unintentional errors in daily AI decisions may cause serious physical or monetary harm, but at this point, it is unclear how the law will treat AI systems.

Persons and legal entities can be held legally responsible for their acts because they are treated as legal subjects. On the opposite side, artificial intelligence systems generally fall under the category of products. Thus far it has not been possible to hold non-human entities legally- responsible for their own decisions; thus, the question of who will be held liable for possible damages arises.

At this point, companies, who are the main beneficiaries of artificial intelligence technologies in the industrial field, must also be the main guarantors of its liability and must ensure that the software and systems based on artificial intelligence do not make decisions that may cause damage; as they will be possibly the main entities responsible for the harms caused by their systems and products, even if they are not at fault.

☑ Environmental Impact

Using data in the cloud seems to be transparent or even environmentally-responsible, given that are no longer papers or even local servers involved that at some point will be replaced, increasing the electronic waste. However, the computer centers that run cloud- based AI infrastructure are power-hungry; training or running AI algorithms can create more carbon emissions than other processes that don't use AI. This is something that might also be considered at some point when the usage of AI becomes more mainstream.

☑ Singularity

A serious question may arise about artificial intelligence in the near future: one day, will a sufficiently advanced machine surpass human intelligence? This is called the "singularity" theory, the moment when human beings are no longer the most intelligent beings.

The technological singularity is a hypothetical point where technological growth becomes uncontrollable and irreversible, leading to unpredictable changes, challenging human predominance and interests.

This is far away from the current AI application in factories, but still, there are some ethical concerns about the growth of the technology. It is evolving rapidly, and there are possible problems that it might bring to humans.

☑ Data governance

It is well known that more and more data is being collected by companies and processed with AI, in order to sell it to other companies. But then, there are some ethical issues about how AI can reveal private information that might compromise companies, processes, or people's privacy, that at a glance is not possible to see with the raw data information. When AI becomes more accurate in detecting patterns or predicting situations, these problems must be discussed and addressed.

Depending on the specific country context, it would be important to adhere to existing data protection frameworks and governance mechanisms, where they exist. If they don't exist, reference should be made to international data protection principles and standards concerning the collection, use and disclosure of personal data and exercise of their rights by data subjects, while ensuring a legitimate aim and a valid legal basis for the processing of personal data, including informed consent.

☑ AI rights

Artificial intelligence systems are usually built based on reinforcement learning, in some ways, similar to reward and aversion mechanisms. It is like training a puppy; the performance is improved by reinforcing it with a virtual reward.

These systems and methodologies are just at the beginning, but with time, they will become more complex and will get similar to

a complex living entity. In that case, when could it be considered that a system is suffering when its reward functions give a negative input? Or, in the case of genetic algorithms, that works based on the premise of Darwin natural selection theory, where only the most successful instances of a system "survive" and combine to form the next and superior generation of instances, improving the system, but with the "collateral damage" of eliminating the unsuccessful or less capable instances. At what point, or on which intelligence level, could this be considered a murder?

At some point, machines with AI will perceive, feel, and act. So, it is not hard to think that protectionist organizations and others will start to call for clarifying their legal status. So, at that point, should AI be treated similar to animals of comparable intelligence, or even like humans?

UNESCO's Ethics of AI Recommendation

UNESCO recognizes the positive and negative impacts of AI, and drafted a Recommendation addressing ethical issues related to AI, to guide societies in dealing responsibly with the known and unknown impacts of AI technologies on human beings, societies and the environment and ecosystems.[84] The UNESCO Recommendations on the Ethics of Artificial Intelligence seeks to:

- ✓ Provide a universal framework of values, principles and actions to guide States in the formulation of their legislation, policies or other instruments regarding AI, consistent with international law;
- ✓ Guide the actions of individuals, groups, communities, institutions and private sector companies to ensure the embedding of ethics in all stages of the AI system lifecycle;
- ✓ Protect, promote and respect human rights and fundamental freedoms, human dignity and equality, including gender equality; to safeguard the interests of present and future generations; to preserve the environment, biodiversity and ecosystems; and to respect cultural diversity in all stages of the AI system life cycle;
- ✓ Foster multi-stakeholder, multidisciplinary and pluralistic dialogue and consensus building about ethical issues relating to AI systems;

[84] UNESCO, *Recommendations on the Ethics of Artificial Intelligence* (2021)

3.6 REGULATIONS AND STANDARDS

Regulations are often considered a major barrier for SMEs development given that compliance usually requires additional investments to the ones needed for the product development, and the technical knowledge required usually is available only to the strongest organization.

On the other hand, governments and legislators need to protect their citizens from the failures of the market system.

While a market system based on "supply and demand" generally works well to optimize prices, quality, and services, often market pressures drive down prices or obligate firms to incur in questionable practices, resulting in products of a quality or characteristics that can be dangerously low and unsafe.

Usually, consumers are poorly prepared to distinguish between acceptable and dangerous products or services that may affect their health and safety, due to that governments must get involved to regulate the market and establish minimum standards, accompanied by legal sanctions for non-compliance. This is all achieved through the issuance of regulations.

The European Commission AI regulation proposal[85] is a great step forward for there to be clear rules in using artificial intelligence, even though the proposal regulates only issues related to AI but does not contain any regulation on AI liability, a pending subject. It is expected that other countries and regions worldwide follow this path, which is one of the most advanced to date and a great example of how to approach the AI challenges for humanity[86].

Governments and regulators play a big role in encouraging digital innovation and incentivizing the development and implementation of new technologies like Artificial Intelligence for the benefit of society. In addition, regulations can foster consumer interests and limit potential negative consequences of these developments by providing general rules that reflect societal values and preferences.

However, complying with regulations usually increase costs or restrict firms' freedom of action and sometimes innovation. Moreover, in developing countries, governments might be unaware of the nature of the policy problems they are trying to solve and could be unsure of what a regulatory solution might look like. In those cases, regulatory frameworks could go against new technological developments and their implementation.

At that point, the current lack of regulatory framework or regulation plans for AI in most developing countries might be an opportunity for SMEs to responsibly experiment with new AI applications and

[85] EC, Regulation of the European Parliament and of the Council (2021b)

[86] Food and Drug Administration (FDA), *Artificial Intelligence/Machine Learning (AI/ML)-Based Software as a Medical Device (SaMD) Action Plan* (2021).

take up new opportunities that could not occur in more regulated markets. However, although there may not be a regulatory framework in place, it would be important for SMEs to develop impact assessments, to identify and assess benefits, concerns and risks of AI systems, as well as appropriate risk prevention, mitigation and monitoring measures, among other due diligence and oversight mechanisms.

On the other hand, as standards are the result of collective work by experts in a field that provides a consensus to harmonize a product or process, those might not be a significant barrier for AI development and growth. Conversely, those can be growth drivers, as it was described in the last chapter of this document.

3.7 SOCIAL AND CULTURAL BARRIERS

New technologies like AI require people with specific analytical skills in the manufacturing field. As a result, big manufacturing companies and consulting companies have started to hire data scientists over the past few years. However, those professionals' availability in developing countries isn't typically as flexible as is in developed countries.

One of the barriers for SMEs in developing countries is to find not only data scientists but also data engineers, data stewards, solution architects and analytics translators. Those profiles are essential to collaborate with teams of the various manufacturing functions of the companies to jointly develop and put into practice AI solutions for specific use cases.

3.8 HOW TO MITIGATE THE EFFECT OF BARRIERS IN THE AI APPLICATIONS IN SMES

To guarantee a long term and wide implementation of AI applications in SMEs, the above barriers and some others such as the resistance to change, the lack of internal digital culture, or the lack of clarity regarding the economic benefit of AI applications in SMEs must be taken into account not only by companies but also by the governments, which must formulate national strategies and policies for incentivizing AI and 4IR implementations, to don't rely only on individual corporate initiatives and have national and coordinated policies to widely support AI adoption.[87]

[87] AI adoption is a matter of culture and it affects to different levels of maturity inside organizations.
The AI Maturity Model in organizations developed by the AI Xavier Health University is summarized in the link below: https://static1.squarespace.com/static/58d0113a3e00bef537b02b70/t/5f465513500be76b443b84d3/1598444819754/AI_Poster_MaturityModel_2020.pdf and https://www.xavierhealth.org/aio-whitepaper-maturity-level-characterization

Table 2: Summary of AI barriers

High Cost and Uncertainty about AI Benefits	• Building and maintaining an AI system remains a costly investment • An effective implementation of an AI System requires complementary technologies and adoption of a solid Digital Transformation • AI transformation may not deliver immediate gains, which may raise sunk costs for SMEs before a growth potential could be achieved
Reputational and Legal Risks	• The lack of clear definitions for AI systems in particular for those using machine learning has been one of the obstacles to further adoption and could raise a series of challenges for users and producers of AI solutions. • SMEs using AI-enhanced tools to interact with customers could face reputation issues and legal liability especially if the AI model used is perceived as unethical or discriminatory.
The Human Factor	• Unclear understanding of potential and risks of using AI, from managers to workers. • Raising the skillset for an effective implementation of AI Solutions
Lack of Data Culture and weak data management practices	• SMEs are less prepared to valorise their data • SMEs need to raise data readiness with appropriate data management practices • The enhanced volume and granularity of data collected and managed may expose SMEs to more data breaches.

Source: OECD (2019), OECD SME and Entrepreneurship Outlook 2019, OECD Publishing, Paris

Benefits of the adoption and application of AI

4.1 Economic benefits 72
4.2 Social considerations 74
4.3 Environmental considerations 76

Chapter 4: Benefits of the adoption and application of AI

Adoption and application of AI have already shown significant impact to the industry and society at large. Furthermore, it is expected that the emergence of new AI applications will deepen the benefits. The sub-chapters below summarize the potential benefits of AI, focusing on SMEs in productive sectors.

4.1 ECONOMIC BENEFITS

AI can improve SMEs' productivity, efficiency and quality resulting in the increased competitiveness and long-term sustainability. Furthermore, the required digitalization, the data standardization process, the data governance and skill improvements required to deploy AI brings collateral benefits, such as modernization and adaptation. AI has potential to contribute to all business processes of SMEs, starting from product development and finishing with sales and services.

4.1.1 LOWER OPERATIONAL COSTS

Many companies think that AI in the manufacturing industry requires a huge capital investment, and at some point, it is true. On the other hand, the return of investment is significant and will increase over time. Once smart processes start giving the expected results, companies will benefit through significantly reduced operating costs, and predictive maintenance will also help minimize machine downtime.

Another AI economic benefit for SMEs is improved internal security through application of AI-enabled automatic detection of cyber-attacks. As IT-security is becoming a crucial issue, simple cloud-based AI solutions can be a perfect tool for SMEs.

SMEs can also benefit from the AI-driven solutions for human resource management and trainings. More personalized, adapted training modules will improve the companies' skills and knowledge base. Augmented and virtual reality tools will contribute to staff trainings and routine operations. AI will also ease skills management and job matching by providing big data analytics.

AI can assist SMEs in improving the supply chain management by better tracking goods and automating stock management. For instance, predictive analysis can minimize the likelihood of inputs shortage and delays, visual recognition can ensure fast and efficient quality control of raw materials, and autonomous driving and drones can significantly reduce costs of logistics and provide precise, just-in-time delivery.

4.1.2 QUALITY MANAGEMENT

AI is very useful for quality management, in many cases avoiding the need for time-consuming and frequently inaccurate quality control done by humans. Predictive maintenance of machinery and equipment or detecting production problems at early stages are just a couple of examples of how AI can benefit SMEs in manufacturing. By using sensors to monitor performance and operating conditions, machines can learn to forecast breakdowns and possible failures and also take action before they occur, eradicating unplanned downtime. Machine vision and other sensors with AI can detect microscopic defects far beyond the capability of human eyes, improving productivity and reducing or eliminating the percentage of defective items that will get to the clients. AI also helps speed up many routine processes and improves its accuracy, improving quality and reducing costs.

AI is already widely used to improve the efficiency and quality of production (including by automating repetitive tasks, and preventing or reducing human errors), and to predict potential downtime, allowing manufacturers to schedule functional equipment maintenance and repair before a failure occurs. AI can assist in defect detection improving quality of final products using image or sound recognition. Production is one of the main areas where AI has biggest potential for SMEs by reducing labour costs and improving the efficiency at the firm level.

4.1.3 IMPROVING DECISION MAKING

When 4IR applications like IoT and Cloud Computing are combined with AI, companies and managers can exchange critical information in real-time, regardless of geographic location. AI enables companies to forecast future production needs to take quick production decisions and improve the communication between manufacturers and suppliers.

AI can also improve the management of SMEs by providing better analytics and data visualization, receiving data in form of dashboards, trends and predictions. Managers and owners of SMEs will be assisted to make quicker and data-supported decisions.

AI helps SMEs' market reach by foreseeing future market or consumer trends. By accurately predicting sales trends, AI has demonstrated its use as a tool to define an effective marketing strategy. Similarly, AI-enabled data management can also support in predicting materials prices and potential profits, thus helping set appropriate prices in the context of dynamic markets. AI also helps to engage with customers, by facilitating communication through digitalized AI-based software.

4.1.4 IMPROVING PRODUCT DEVELOPMENT CYCLES

AI makes it possible to shorten product development cycles and reduce the time required from design to commercialization. Before launching a new product, companies need to create a prototype. With AI, this process can become faster than traditional methods; SMEs can cut weeks off the production schedule and deliver a prototype in a few days; allowing flexibility and improving demand accuracy.

SMEs can get benefits by improved internal knowledge generation, reduced the costs of experimentation, improved data sharing and reproducibility, making product development more efficient. For instance, use of Digital Twins and digital factories can significantly improve SMEs' opportunities for testing and prototyping. Product development processes are becoming cheaper, and product design improves as well through optimized material and energy consumption. In combination with 3D-Printing, SMEs resource efficiency can be additionally boosted. AI also helps to develop more personalized products through IoT and Big Data analysis. Moreover, data is a market itself and SMEs potentially could benefit from accessing it.

4.1.5 BETTER TALENT MANAGEMENT

Companies use AI to improve talent management. For example, AI-based hiring processes can save companies recruitment costs and impact workforce productivity by identifying the most qualified candidates for the right positions. Also, AI tools are being used to measure employee satisfaction at work, identify and retain high performers, as well as helping low performers to recognize their competencies.

AI will simplify many business processes which involves routine tasks, such as bookkeeping, billing, contract management and documentation flows. AI will assist SMEs to produce automated reports, invoices and contracts, avoiding potential human errors and saving time.

4.2 SOCIAL CONSIDERATIONS

With better monitoring, analyzing and diagnostic capabilities, AI can dramatically and positively influence many services in our society. For example, with the introduction of autonomous transportation and with introducing AI to traffic monitoring this can save countless hours of productivity that would otherwise be wasted in traffic jams.

The below are a few more example of how AI can positively impact on our society and can transform the way we live in.[88]

[88] Marr B., *What Is The Impact Of Artificial Intelligence (AI) On Society?* (2021)

4.2.1 SAFETY IN INDUSTRY

Mistakes and accidents happen in factories; this is a situation that AI can mitigate. AI can make work safer by allowing devices or robots to handle dangerous tasks, for example, in stamping or cutting processes or toxic environments. AI can also decrease the health risks of occupations that can harm workers through repetitive motions or driving in unsafe conditions. Even in stable, low-risk work environments, AI can reduce the incidence of workplace accidents by supporting IIoT and machine vision devices to control safety guards, barriers, or personnel's access to dangerous plants.

4.2.2 IMPROVING WORKERS TRAINING AND SKILLS DEVELOPMENTS

AI can increase the efficiency of the companies' training to their employees. This application has the potential to provide personalized tutoring to all workers based on their knowledge and capabilities; this way, everyone can get continuous, consistent, and personalized tutoring based on the specific needs of the worker and the position.

While this AI personalized learning application is still in its early stages, it can create highly personalized lesson plans and reduce training times. AI has the potential to democratize technical education by providing world-class training to SMEs regardless of the company's location.

AI can contribute to promoting inclusivity and social sustainability. When AI technologies are promoted within an SME, more women and young people can be elevated to controlling and operating positions. Additionally, considering that new technologies are more easily handled by the new generation of professionals, the integration of AI within SMEs should promote the involvement of young people. Young people could represent a great plus to transforming a business from one with a survivalist nature to that of an expansionist nature, being highly receptive and needing less time to be trained to apply AI. By automating some tasks, AI facilitate some physically challenging work, thus facilitating the integration of women and youth in production processes.

AI can contribute to guaranteeing the safety and health of workers, by helping avoid accidents: AI helps to eliminate hazards by removing humans from hazardous situations that involve a risk of stress, overwork, or musculoskeletal injuries. AI is also often used to monitor proper execution of tasks and areas, analyze risk, and predict machine failures before they cause any damage to workers' health and safety.

4.3 ENVIRONMENTAL CONSIDERATIONS

The application of AI can also have positive impact on SMEs' environmental sustainability. For instance, AI facilitates the application of circular economy principles within several phases of the production cycle, e.g. use of AI in product design can improve resource and energy efficiency.
Additionally, the above-mentioned capacity to predict market trends, would allow manufacturers to avoid waste, by tailoring the production to actual market demand. AI can support SMEs in energy management through optimization of production. AI also can help to detect dangerous emissions, monitor and optimize energy consumption.
SMEs can use AI to improve waste management processes. AI-based Waste management technology helps plants to sort different production plants wastes intelligently. The technology uses IoT, machine vision, sensors, and AI's machine learning, enabling better sorting of recyclable materials, reducing costs in industry, and improving the environment.


0101
0101
0101
0101

Pathway to the Adoption of AI

5.1 Introduction 79

5.2 First Phase: AI Transformation Framework 80

5.3 Second Phase: Build your AI Strategy, standards, and processes 86

5.4 Third Phase: Data governance standards 90

5.5 Fourth Phase: The risk of doing nothing (embrace AI Data-Driven Decision Making) 91

5.6 Fifth Phase: Piloting your first project 93

Chapter 5: Pathway to the Adoption of AI

5.1 INTRODUCTION

AI is a truly disruptive technology. We have already seen cases where AI has revolutionized the way we do things. AI systems are now better at spotting skin cancer than skilled oncologists[89]. AI systems are the core enabler for many new emerging applications such as self-driving vehicles. And in the world of business so-called intelligent agents are having a real impact. An intelligent agent (IA) is a specific form of AI which is dedicated to solving one problem and solving it well. IAs are focused, tireless, and driven, but still intelligent. They are particularly well-suited to the sorts of tasks that humans find dull, repetitive, and hard.[90]

When you get it right, using AI in your business will generate a significant return on your investment. This comes about because of two things. Firstly, AIs never stop, they are productive 24/7, 365 days a year without a break. Secondly, AIs can often replace or augment existing staff. This is particularly true for unskilled jobs. People are empowered to better engage with machines and improve the overall result in terms of performance (e.g. better quality) and costs (e.g. faster and more efficient).

One of the biggest impact AI can bring is efficiency. A well-designed intelligent agent will complete its task far more efficiently than any human ever can. AI systems are never ill, never sleep, and never take a vacation. In fact, they are like the perfect worker. Get it right and you could see productivity catapult significantly.

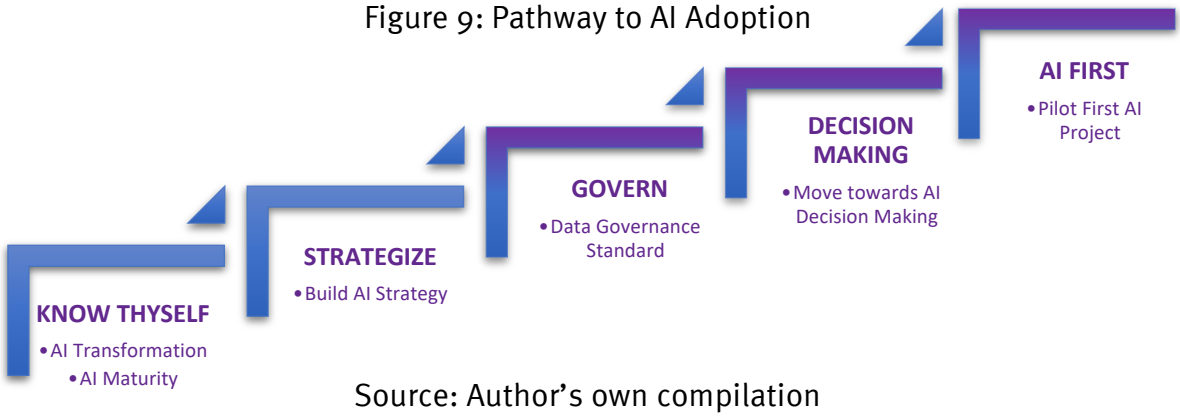
Every single company has the potential to enhance operations with the correct implementation of artificial intelligence technologies. However, there is a significant difference between utilizing AI for its own sake versus properly embedding the technology to fulfill a specific set of firm objectives.

In fact, an uncalculated broad business implementation of AI has the potential to do more harm than good. Without a proper plan for adoption, SMEs can experience the detrimental consequences of resource and funding misallocation. Which is totally the opposite of optimization and would result in wasted time and ultimately negative return on investment (ROI)–factors that a fast-paced digital company cannot risk and (specifically in the case of SMEs) can be deadly to the business.

Therefore, it is imperative to establish a strategic roadmap for AI adoption that SMEs can follow, implement, and subsequently

benefit from. This chapter will introduce an overview of the pathway to adoption of AI, which includes five stages, starting with the first stage of SME getting to know themselves in greater detail and examining their AI transformation processes, as well as evaluate their AI Maturity level (Section 5.2). Once the SMEs determine their readiness and ability, the second stage would be to build their AI strategy, this includes establishing legal framework, committing to resources, and setting up the standards (Section 5.3). As all AI systems are based on the availability of quality data in reasonable quantities, the third stage in the pathway is to establish a proper data governance standard to deal with digital data (Section 5.4). The fourth stage is to embrace AI data-driven decision making and to minimize human bias and personal judgement in that process (Section 5.5). The final stage in the pathway to AI adoption is by starting to pilot the first AI project for your SME that can be used as a Proof of Concept (PoC), examining the knowledge gained in the previous stages and analyzing the new status of the SME in the AI adoption scheme (Section 5.6). Each stage of the pathway is discussed in more details in the following sections:

Figure 9: Pathway to AI Adoption

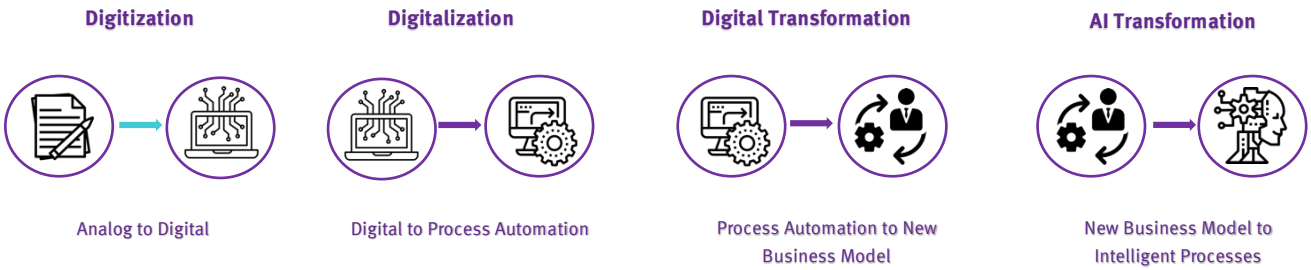


Source: Author's own compilation

5.2 FIRST PHASE: AI TRANSFORMATION FRAMEWORK

AI transformation is the next step after digital transformation. After a company adopts digital processes, next step is to improve the
intelligence of those processes. This would increase the level of automation as well as the effectiveness of those processes.

Figure 10: Process towards AI Transformation



Source: Author's own compilation

As can be seen from the Figure 11, the process towards AI transformation goes through 4 main phases:

Digitization (Collect the data): the process of converting analog assets such as documents, images, worksheets and any other hard copy to digitized equivalents. Whereas scanning documents is the first critical step in digitization, however, data must be extracted, analyzed, stored and accessible, otherwise this would lead to "dark data" which are data that are simply images and cannot be further used in any process automation. For SMEs with limited resources, there currently exist free AI enabled software systems to intelligently scan documents such as Adobe Scan[91].

Digitalization (Identify automation tasks): the aim of this phase is to look for human driven processes that require perceiving, reasoning and sensing to automate using digital systems. By automating these systems, SMEs will reach a milestone where they realize gains in process optimization and benefit in terms of time, effort and human engagement. Infusing AI into the process automation could lead to unprecedented automation and efficiency capabilities. For example, in a food processing factory, instead of relying on the human eye to detect faulty products on a conveyor belt, the factory can use a Robotic Process Automation (RPA) which is a software technology that uses AI to emulate human actions except they can do it faster and more consistent.[92]

[91] Adobe, *Now your scanner is in your back pocket* (2021)
[92] UiPath, Robotic Process Automation (RPA)–Automation software to end repetitive tasks and make digital transformation a reality (2021)

Digital Transformation (define automation non-learning / non data driven tasks / rule based): SMEs that achieve digital transformation have intelligently digitized assets, extracted data and used that data to automate processes. It is important in this phase to understand that digital transformation is a recurring milestone, SMEs must continue to digitize, digitalize and achieve digital transformation over time. Digital transformation should automatically lead the SMEs to change their business model to reflect their new responsive, boosted productivity and much higher accuracy. At this stage, the SMEs should assess their own level of maturity to match the right AI to their particular strategy and new business model.

AI Transformation (define data driven automation self-learning tasks): Upon reaching the digital transformation goal, the next step is to improve the intelligence of those processes. This would increase the level of automation as well as the effectiveness of those processes. A successful example of a company that has undergone a dramatic transformation is the case of Nike, where the company focused on powerful data analytics, updated its e-commerce strategy, created more digitally intelligent marketing campaigns and in only two years they managed to achieve gains of over 59%[93].

AI transformation touches all aspects of a company including both commercial and operational activities. Tech giants are integrating AI into their processes and products. For example, Amazon, Google, Facebook and Microsoft are all now called "AI-first" organizations. Besides tech giants, the International Data Corporation, a global market research company, estimates that at least 90% of new organizations will insert AI technology into their processes and products by 2025.[94]

There is a temptation for senior managers to say AI is the solution to any and every problem that faces them. Unfortunately, as we have seen in earlier chapters, AI has real limitations. If your business processes are flawed, chances are no amount of clever AI is going to fix it. Equally, it is essential you understand when AI simply cannot work. For instance, Machine Learning requires a large volume of data with enough quality to use to train the models. Natural Language Processing (NLP) will struggle if it is asked to process documents full of industry terminology. Therefore, one must work out how to achieve AI business transformation.

If you want AI to transform your business, you must plan things carefully. This may sound obvious, but people forget that AI must be treated like any other disruptive technology similar to Blockchain, 3D

[93] Capgemini Consulting, *Nike: From Separate Digital Initiatives to Firm-Level Transformation* (2012)
[94] Shroff R., *Preparing Corporations for Artificial Intelligence Adoptions* (2020)

Printing and IoT. This means proper planning, getting buy-in from your team, planning on how to roll out the new technology, and, probably most importantly, creating back up and contingency plans in case there is an issue.

In the 4IR era, the importance of information intelligence and its ability to add a competitive advantage to the business over its rivals makes the adoption of AI in the company's business model extremely attractive. However, despite the many benefits of AI, many SMEs are still far from applying AI to their businesses or their value chain. To help businesses find a path to enhance their performance and meet their objectives by evaluating their capability, the notion of the "maturity model" was invented.

Maturity models[95] are action-oriented standards that consist of discrete maturity levels for a class of processes or organizations. It represents the stages of increased quantitative or qualitative capability changes of these processes or organizations to evaluate their progressions concerning defined focus areas.[96]

Maturity models can aid SMEs in focusing on their AI initiatives. These models provide a useful framework for identifying AI's potential strategic business impact, assessing an organization's current AI capabilities and prioritizing investments toward AI technologies, skills and processes that are needed to boost readiness and achieve the desired outcomes.

Currently, there are several ways to calculate the maturity level of AI adoption for enterprises, which can help point companies in the right direction for implementation. A detailed study on different Maturity Models has been published by the University of Oviedo, which lists and describes the major available maturity models to show their commonalities and differences[97]. One such tool , which can be utilized free online by all companies, is developed by the IMPULS Foundation of the German Engineering Federation (VDMA) and gives an Industry 4.0 scorecard indicating areas where a company is well prepared and other areas where the company still has room for improvement[98]. It is based on 6 assessment levels as can be seen in Figure 12.

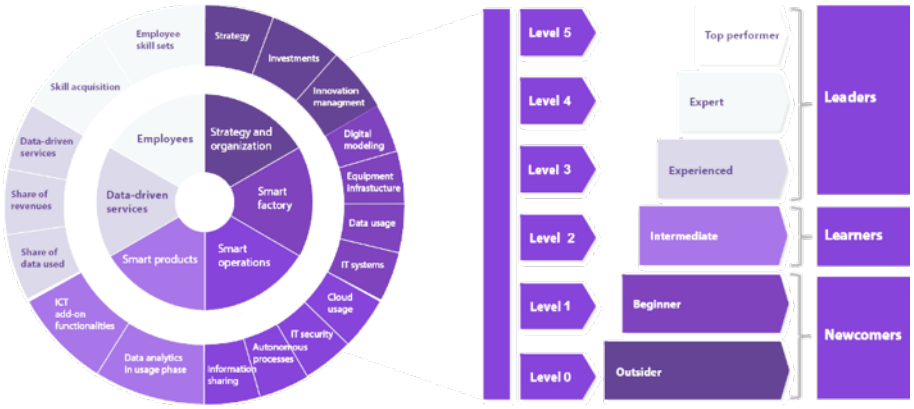
[95] Other examples:
AI Sweden's AI Maturity Assessment Tool, www.ai.se/en/ai-maturity-assessment-tool; XAVIER AI in Operation Team static1.squarespace.com/static/58d0113a3e00bef537b02b70/t/5f465513500be76b443b84d3/1598444819754/AI_Poster_MaturityModel_2020.pdf;

[96] See: Becker, Knackstedt, Pöppelbuß, 2009; Dzazali, Zolait, 2012; Fraser, Moultrie, Gregory, 2002; Kohlegger, Maier, Thalmann, 2009

[97] Kupilas K., Montequín V., Alvarez C., Balsera J., *Industry 4.0 and Project Management and Engineering*, Researchgate (2020)

[98] See: www.industrie40-readiness.de/?lang=en

Figure 11: IMPULS Readiness Model



Source: IMPULS Foundation, www.industrie40-readiness.de

Another Maturity Model is provided by Microsoft, which uses a survey-based questionnaire to gauge the adoption capacity of enterprises. (Minevich, 2020)

Figure 12: Microsoft AI Maturity Model

Source: Microsoft, info.microsoft.com/ww-landing-ai-maturity-model-website.html

The Microsoft AI Maturity Model classified organizations into four readiness categories, beginning with Foundational (initial investigation), to Approaching (beginning digital transformation), followed by Aspirational (experimenting with the technology), and Mature (full readiness). Understanding where an organization stands in their AI journey will help set the stage for its AI Strategy.

For the Foundational category, an SME should spend time demystifying AI and the edges and boundaries of various associated technologies and should seek to understand how other SMEs are utilizing AI in their industry to learn how to apply it[99].

A transition to a data driven culture, along with focusing on the empowerment of the organization's members and a growth mindset will be instrumental to AI adoption. For the Approaching category, the SMEs should continue to focus on adopting a data culture and should continue to utilize prioritized strategic initiatives to disrupt their industry by using AI to create new business models and streamline operational processes.

For the Aspirational category, the SMEs already understand that AI will be instrumental in helping them compete and transform. At that stage, SMEs are already on their journey to digital transformation and they are in the process of improving their processes and using data as the main source for their decisions.

Finally for the Mature category, SMEs should continue to evaluate tools to configure and customize AI while maintaining operational vigilance for implementing AI-based systems. They should also maintain AI talents, prioritize new strategic initiatives, and continue agile experimentation using AI.

Worldlink also provides an 8-step machine learning and artificial intelligence maturity guide to enable companies' self-assessment. More importantly, the utilization of said maturity assessments in tandem with already data-centric SMEs is a surefire way to align companies towards accelerated AI adoption and continual progress in maturation.[100]

[99] An excellent resource for existing AI applications in different sectors can be found under: deepindex.org/

[100] Monterio B., *8 Steps to assess your ML/AI Maturity Model*, Wordlink (2020)

Figure 13: 8 Steps AI Maturity guide

Source: Monterio B., *8 Steps to assess your ML/AI Maturity Model*, Wordlink (2020)

Maturity models enable SMEs to determine whether or not a given enterprise's AI ambitions are realistic or over-ambitious. Once the maturity models confirm the company's ability to embrace AI as a technology and fully integrate it into its business model the next step would be to start building the SME's AI Strategy.

5.3 SECOND PHASE: BUILD YOUR AI STRATEGY, STANDARDS, AND PROCESSES

The first step in building your own AI strategy is to take a deep look at your business model and your overall business strategy and examine your pain points. Look at your products, is there a way to make them more intelligent? Second is to look at your services, can they become smarter. Finally, check your processes, can they be optimized.[101]

[101] Davenport T., Guha A., Grewal D. et al, *How artificial intelligence will change the future of marketing*. Journal of the Academy of Marketing Science, 48, 24–42 (2020)

Figure 14: Build your AI Strategy, standards, and processes

Source: Author's own compilation

AI is not only for big tech companies, in fact it can be applied to most sectors, including services and low-tech sectors, as well as to all business functions, from pre-production to post-production. Marketing and sales, supply chain management and production are functions where AI could have great impact. Retail trade, transport and logistics services, or automotive and assembly manufacturing are sectors where AI could contribute to creating significant value.[102] For example, an SME with an online shop can deploy an AI module to analyze its sales and intelligently profile its customer base thus enable target marketing and more effective reach for its products. This in turn will lower significantly the marketing and campaign costs and move it from untargeted broad marketing to a focused customer-oriented approach.

[102] OECD, Artificial intelligence: Changing landscape for SMEs (2020)

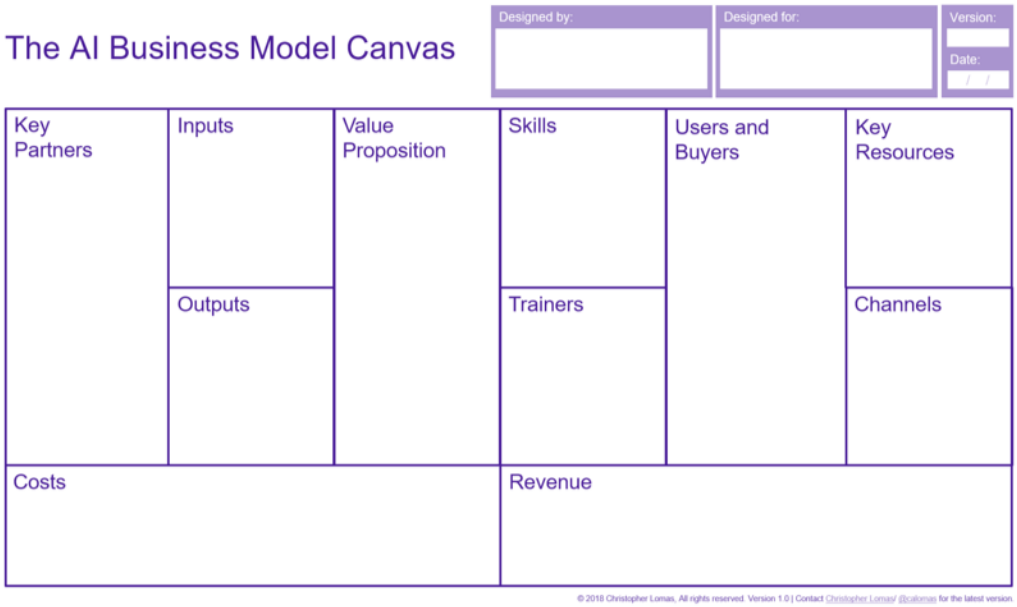
A good AI Strategy must be built on the following three pillars:

- ☑ **Feasibility:** whereas not all problems can be solved by AI, those that can be solved by AI may not be feasible to implement. For example, in some applications, the AI models must be implemented at the device level (a.k.a., edge AI) to comply with data privacy acts[103]. When the AI model is implemented at the closest points to the data collection the privacy concern is minimized. However, implementing AI models at this level does not give access to powerful computation power nor allow for development in a high-level programming language such as Python or R script since the required libraries do not exist at the device level.
- ☑ **Performance:** one must be careful of AI generalization errors when implementing a model. AnAI Generalization Error refers to the model's inability to adapt properly to new, previously unseen data, drawn from the same distribution as the one used to create the model[104]. This error usually comes from over training an algorithm and from over delineating thresholds on a given dataset thus removing the system's flexibility of adapting to changes. To minimize generalization errors and improve the performance of a model to make good predictions one must divide the data set into two subsets, a *training set* which is used to train the model and a *test set* which is used to test the model. A good performance on the test set is a crucial indicator of the overall performance of the model built.
- ☑ **Scalability:** It is easy to build AI models for a pilot project. However, it becomes harder when you decide to build an AI product and it becomes even harder when you decide to scale it. Having one model to address various contexts is not often possible, one needs to build different contextualized models to address different contexts. For example, AI chatbots must be designed specifically for the industry that they will be used for.

  A common method to help small business in creating their strategy is to use canvas, which help to clearly describe, design, pivot and challenge your business model. There exists in the market several canvasses that can be used to guide the process or you can even invent your own canvas, .The most important factor here is that you use whatever canvas you decide on to derive the discussions and thinking. As an example of AI business model canvas, one can use the canvas by Christopher Lomas[105] illustrated below.

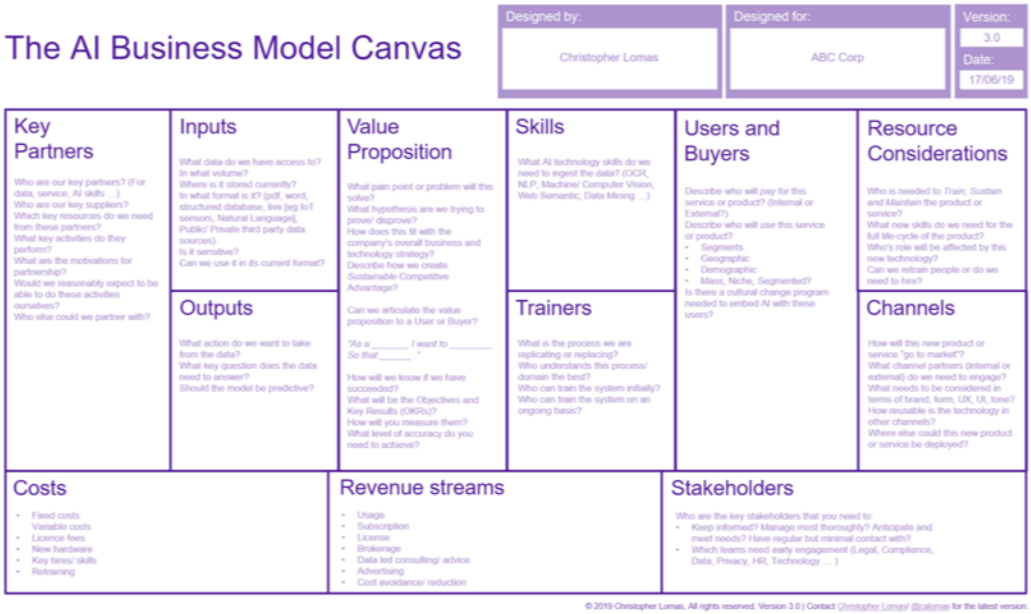
[103] Ataee P., *Artificial Intelligence, Unorthodox Lessons: How to Gain Insight and Build Innovative Solutions (Dance with Data)* (2021)
[104] Google, *Machine Learning Crash Course*, Google Developers (2020)
[105] Lomas C., *The AI Business Model Canvas*, LinkedIn (2018)

Figure 15: Example of an AI business model canvas by C. Lomas



Source: Christopher Lomas, www.linkedin.com/pulse/ai-business-model-canvas-christopher-lomas/

Figure 16: Example of a filled in AI business model canvas by C. Lomas



Source: Christopher Lomas, www.linkedin.com/pulse/ai-business-model-canvas-christopher-lomas/

Another example is the Data driven Innovation (DDI) Framework[106] which has been developed in the context of the Big Data Value Assessment (BDVA) project[107]. This framework is also used inside Siemens to train internal experts[108].

5.4 THIRD PHASE: DATA GOVERNANCE STANDARDS

Imagine the world before Google and other digital search engines, when one was looking for information, the only reliable place to look was to go to a library. Entrance to the library was controlled by a strict policy of a registered personal ID card that takes at least an hour to receive. Nonetheless you waited for your ID card and once inside the library, you had to navigate your way to find the genre you are interested in only to find out that the library is in disorder and there is no classification nor organization to help you quickly find out what you are looking for. After a long while you finally find the book you are looking for but once you open it you realize that the book has some missing pages and is very difficult to read and understand in that state and therefore of no value to you. Such an experience is frustrating and discouraging, we have all at one time or another in our lives shared such a feeling and just like that library no one would recommend to others to deal with such a process and if this was a commercial entity it will surely soon enough go out of business.

The first leg of the AI adoption journey requires businesses to already possess trustable and large interconnected data sources, strong data analytics and metric-gathering capabilities. Artificial intelligence technologies, such as Machine Learning algorithms, must be fed a substantial and consistent stream of data to be useful. If SMEs are not data-geared, the power of AI vanishes, as it lacks the fuel and capacity to provide any meaningful insights to guide the decisions of firms.

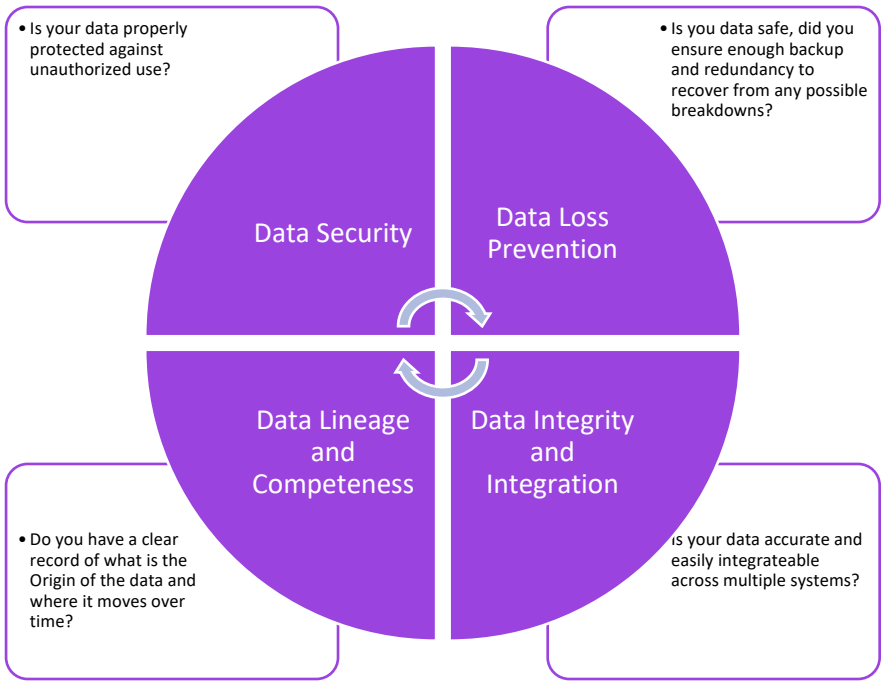
A data-centric mindset is imperative to successful roadmap completion. Proper acceleration of SME maturity for AI adoption means that companies should focus on optimizing their data units and preparing educational initiatives prior to commencing the implementation process.

Companies should also be dynamic in their approach and be willing to amend their business strategy to incorporate artificial intelligence at every step of the way. This is the essence of a digitally mature AI enterprise.

[106] Data-Driven Innovation (DDI), *Understanding the Obvious – That's the Purpose of our Activities Centered Around Data Driven Innovation* (n.d.)
[107] Data-Driven Innovation (DDI), Ecosystem (n.d.)
[108] Data-Driven Innovation (DDI), DDI is Part of Internal Training@Siemens. (n.d.)

Data Governance, in short, is the management of data's availability, usability, integrity[109] and security. It is critical for a successful AI transformation. A good method of ensuring proper data governance is tomake sure that you are covering the below standards[110]:

Figure 17: Data Governance for AI



Source: Author's own compilation based on B. K. Chan, *Why Data Governance is important to Artificial Intelligence*, Mind Data (2019)

5.5 FOURTH PHASE: THE RISK OF DOING NOTHING (EMBRACE AI DATA-DRIVEN DECISION MAKING)

Having identified strong data analytics capabilities, SMEs must then determine how AI can help by establishing a rigorously formulated business question. At this moment, the specific intent for AI is made

[109] Food and Drug Administration (FDA), *Data Integrity and Compliance with CGMP Guidance for Industry* (2016)
Wise J., et.al. Implementation and relevance of FAIR data principles in biopharmaceutical R&D. Drug discovery today (2019).

[110] Chan B. K., *Why Data Governance is important to Artificial Intelligence,* Mind Data (2019)

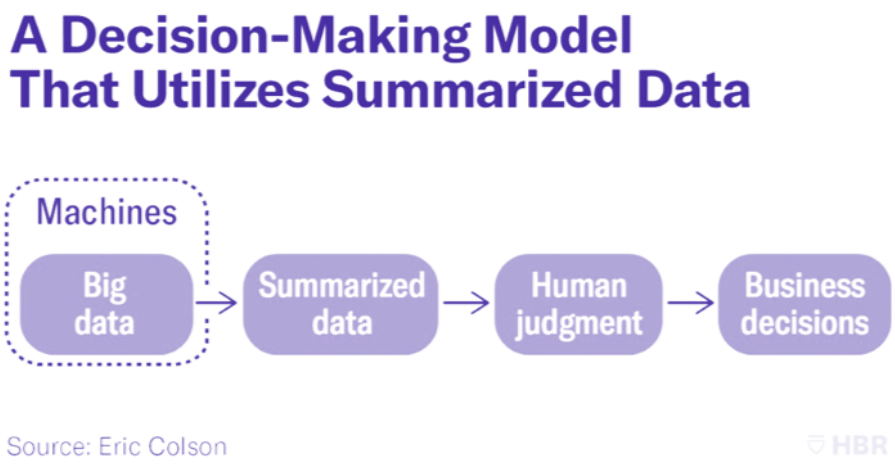
clear. The business disciplines based on science, usually work with theoretical approaches adapted to the physical conditions to be accurate. Linear approaches, monitoring and control of just a few variables and heuristic considerations in production are common in manufacturing industries. AI brings the opportunity to incorporate a multivariable and more realistic approach regarding the complexity of the production framework. Furthermore, AI models can exactly reproduce the productive context linking the equipment, product, human interaction and environment in just one expression, bringing science to the engineering by means of AI and technology. This scenario brings a more competitive advantage to SME when implementing AI. For instance, SMEs can optimize operations with AI through automation of human resources, or implement machine learning algorithms to analyze employee satisfaction and productivity. Whatever the objective may be, SMEs must come up with a proposal as to how artificial intelligence can be helpful in order to save time and accelerate the roadmap to proper AI integration.

To fully leverage the value contained in AI, companies need to bring AI into their workflows. SMEs need to evolve from human driven to AI driven workflows.[111]

Connected devices now capture extremely large volumes of data: every transaction, every customer gesture, how long they stare at a particular product, every micro- and macroeconomic indicator, all the information can inform better decisions. In response to this new data-rich environment AI algorithms analyze these mountains of data and reduce the unmanageable volumes of data down to digestible summaries for human consumption. The summaries are then further processed by humans using the tools like spreadsheets, dashboards, and analytics applications. Eventually, the highly processed, and now manageably small, data is presented for decision-making. This is the "AI data-driven" workflow. Human judgment is still the central processor, but now it uses summarized data as a new input.

[111] Colson E., *What AI Driven Decision Making Looks Like*, Harvard Business Review (2019)

Figure 18: Decision Making Model



Source: Eric Colson, Harvard Business Review (2019)

Moving from Human-driven to AI-driven decision making is the next phase of business evolution. Embracing AI in a company's workflows affords better processing of structured data and allows for humans to contribute in ways that are complementary, thus giving the company a much higher chance of survival in the future.

5.6 FIFTH PHASE: PILOTING YOUR FIRST PROJECT

A good AI pilot project candidate should have certain characteristics:

It should create value in one of 3 ways:

- ☑ By reducing costs;
- ☑ By increasing revenue;
- ☑ By enabling new business opportunities.
- ☑ It should give a quick win (6-12 months);
- ☑ It should be meaningful enough to convince others to follow;
- ☑ It should be specific to your industry and core business.

An initial AI project candidate should be chosen via a process consisting of several steps and should eventually lead to implementing a single AI project in production. Furthermore, the pilot project should provide the analysis and guidance for the scale-up and industrialization of all the key pieces deployed during the project. Many pilots failed because they couldn't scale-up at production level.

A 5 step approach was introduced by DZone AI Developers, which is summarized as below[112].

[112] Wilson F., *The 5 Step Approach to a Successful Product Launch*, Agile Zone Analysis (2018)

Figure 19: 5 Step approach to AI project development

Source: Author's own compilation

Step 1: Ideation

Start with a brainstorming session to investigate areas that might be enhanced with AI, e.g., parts of processes to improve, problems to solve, or tasks to automate. The understanding of what AI is and knowledge of AI Landscape, including basic technology, data, and what AI can and cannot do is crucial at this stage.

Having that as a baseline, then identify major business value drivers as well as current pain points and bottlenecks trying to answer questions such as:

- ☑ What in the current processes impedes business development?
- ☑ What tasks in current processes are repeatable, manual, and time-consuming?
- ☑ What are the pain points, bottlenecks, and inefficiencies in the current processes?

This step results in a list of several (usually 5 to 10) ideas ready for further investigation on where to potentially start applying AI in the company.

Step 2: Business Value Evaluation

The next step strives to detail the previously selected ideas. One defines detailed business cases describing how problems identified in step 1 could be solved and how these solutions can create business value.

Every idea is broken down into a more detailed description using the Opportunity Canvas approach — a simple model that helps define the idea better and consider its business value. Using filled canvas as the baseline, we analyze each concept and evaluate against the business impact it might deliver, focusing on business benefits and user value but also the expected effort and cost.

Eventually, we choose 4-8 ideas with the highest impact and the lowest effort and describe detailed use cases (from business and high-level functional perspective).

Step 3: Technical Evaluation

In this phase, we evaluate the technical feasibility of previously identified business cases in particular, whether AI can address the problem, what data is needed, whether the data is available, what is the expected cost and timeframe, etc.

This step usually requires technical research to identify AI tools, methods, and algorithms that could best address the given computational problem, data analysis to verify what data is needed vs. what data is available, and often small-scale experiments to better validate the feasibility of concepts.

We finalize this phase with a list of 1-3 Proof of Concept (PoC) candidates that are technically feasible to implement but more importantly are verified to have a business impact and to create business value.

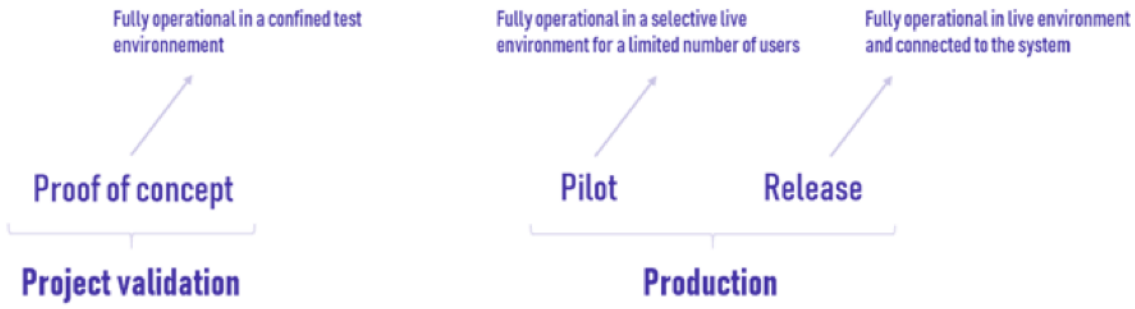
Step 4: Proof of Concept

Implementation of the PoC project is the goal of this phase and involves data preparation (to create data sets whose relationship to the model targets is understood), modeling (to design, train, and evaluate machine learning models), and eventual deployment of the PoC model that best addresses the defined problem. It results in a working PoC that creates business value and is the foundation for production-ready implementation.

Step 5: Product development

Once the results of the PoC are satisfactory, the solution will have to be brought to production to fully benefit from the AI-driven tool. Moving pilots to production is also a crucial part of scaling up AI adoption. If the successful projects remain mere experiments and PoCs, then it is demanding for a company to move forward and apply AI to other processes within the organization.

Figure 20: From PoC to Production



Source: medium.com/predict/moving-ai-from-poc-stage-to-production-fc4b0908d0c4

From Theory to Practice

6.1 Potential Applications of AI across different productive sectors and processes 99
6.2 Selected UN cases of success 104
6.3 Selected private-sector cases of success 120

Chapter 6: From Theory to Practice

6.1 POTENTIAL APPLICATIONS OF AI ACROSS DIFFERENT PRODUCTIVE SECTORS AND PROCESSES

6.1.1 Agribusiness

Artificial Intelligence (AI) can improve the efficient and sustainable use of resources, increase productivity, and promote the integration of agribusinesses into regional and global value chains. However, there are barriers limiting the adoption and scale-up of AI technology, particularly in developing countries. Besides the lack of skills and infrastructure, there are other barriers like the limited availability of agronomic and manufacturing data that is needed for developing and deploying AI systems.

Table 3: SWOT analysis of the agro industry

Strengths	Weaknesses
• Improved efficiency of farm produce to markets through digital management and optimization. • Enhanced food security by minimizing food loss and helping to manage the Water-Energy- Food Nexus. • Reduced losses and increased yields by predicting crop diseases and plagues and automatic selection of seeds through image recognition. • Increased sustainability of farming practices by reducing fertilizer and pesticide use. • Reinforced food safety by facilitating the monitoring of food quality standards	• Applications and models concentrated on large-scale farming operations. • Seasonality of the sector increases the time needed for algorithms to learn and prove accurate input. • Predictions require abundant data from multiple sources. • Lack of accessible open data for farming and climate phenomena prediction. • Little advances in using AI to promote sustainable and healthy eating behaviours in the population.

Opportunities	Threats
• Value to the sector can help to address the increasing strain on global food supply owing to rising population. • Reduced food waste in production, currently estimated at one- third of total global output. • Reducing the yield gap (difference between a crop's potential yield and actual yield) estimated at more than 50 percent in many developing countries. • AI-based systems can provide early warning systems for disastrous situations.	• AI applications without solutions for risk anticipation may compromise global food security. • Increased asymmetries between small and large-scale farmers. • Incorrect predictions in low-scale business due to lower data availability. • Prevalence of business-as-usual agricultural practices contributing to climate change. • Potential appropriation, misuse, and abuse of data collected.

Source: Author's own compilation

6.1.2 Automotive

AI will alter not just the cars that are created, but also the entire business of how they are constructed. The usage of gadgets and sensors connected to IoT is increasingly supporting AI applications . Companies are rushing to use to high-value industrial operations like predictive maintenance and performance improvement. Original Equipment Manufacturers (OEMs) and suppliers are already manoeuvring and investing in autonomous vehicles and the AI that will power them.

Table 4: SWOT analysis of the automotive industry

Strengths	Weaknesses
• Lowering manufacturing costs while ensuring safer and faster operations through automation and assisted decision-making. • Streamlining the supply chain since OEMs and partner companies can automate processes like parts, tools, more accurately predict demand, reduce inventory, and improve logistics. • Reducing the probability of machine failure by enabling predictive maintenance in the body shop. • Enhanced quality of vehicles enabled by image recognition algorithms.	• The lack of integrated data platforms can be detrimental to the development and implementation of automated systems. • The implementation of AI across the automotive industry, particularly among Tier 2 and Tier 3, might require significant investments. • Lack of standards to validate digital 3D models for their use as digital twins. • Most traffic prediction systems currently disregard social context data.

Opportunities	Threats
• Reduce the costs for developing new products by improving verification and testing processes. • Mitigating human biases through the automation of manufacturing-production processes and monitoring functions. • Reducing emissions by optimizing routes and detecting parking spots. • Improving the driver's safety through autonomous driving. • Strengthened road safety by enabling driver recognition and alert systems to the driver.	• The high market concentration and low availability of open data in the industry can limit the capacity of companies from developing countries to develop their own AI systems. • AI-enabled automation might have negative economic impacts due to job-losses, particularly in developing countries. • Improved traffic management might increase use of private vehicles instead of mass transport. • Transparency and accountability issues related to the operation dynamics and changing nature of algorithms.

Source: Author's own compilation

6.1.3 Creative industries

The creative industry stands out as one of the early adopters of AI technologies. Already by 2016, an entire movie script was written, and a music album was produced by AI. However, there are several challenges to be considered such as the availability of large amounts of data resources for developing AI systems. AI creates predictions based on data that captures socio-cultural expressions expressed through music, films, photos, writing, and social interactions. Applications of AI in the creative industries have dramatically increased. However, AI is used more in games and for immersive applications, advertising, and marketing than in other creative applications.

Table 5: SWOT analysis of the creative industry

Strengths	Weaknesses
• AI can contribute at every level across all the creative value-chain, from creation and production to dissemination and consumption. • AI can incentivize creativity and reduce costs by automating common time-consuming and monotonous tasks that creators usually need to perform. • AI-based systems can automate tasks that were once thought only feasible by humans such as image discrimination and generation. • AI-based generative models can be applied to virtually all kinds of digital content, including music, text, images, or videos.	• Potential bias in algorithmic decision-making since the training of AI systems could be unrepresentative due to human selection criteria. • Data for training and improving AI systems is limited or exists in silos. • AI-tools require oftentimes a level of technical skill and experience that can represent a challenge for many creators. • Increasing costs associated with hardware acquisition and maintenance. • Interoperability and usability need further improvement.

Opportunities	Threats
• Reducing the dependency on external experts and sophisticated infrastructure (i.e., professional recording studios) by providing more affordable digital tools to creators. • Creating richer ways for users to navigate through cultural content and thus opening possibilities to develop new business models.	• AI-generated content challenges authorship, ownership, and copyright infringement. New exclusive rights on datasets must be designed to incentivise innovation and research. • The use of algorithms for creating content with minimum human intervention can contribute to significant job-losses. • The use of AI for developing content brings up issues regarding cultural and linguistic diversity.

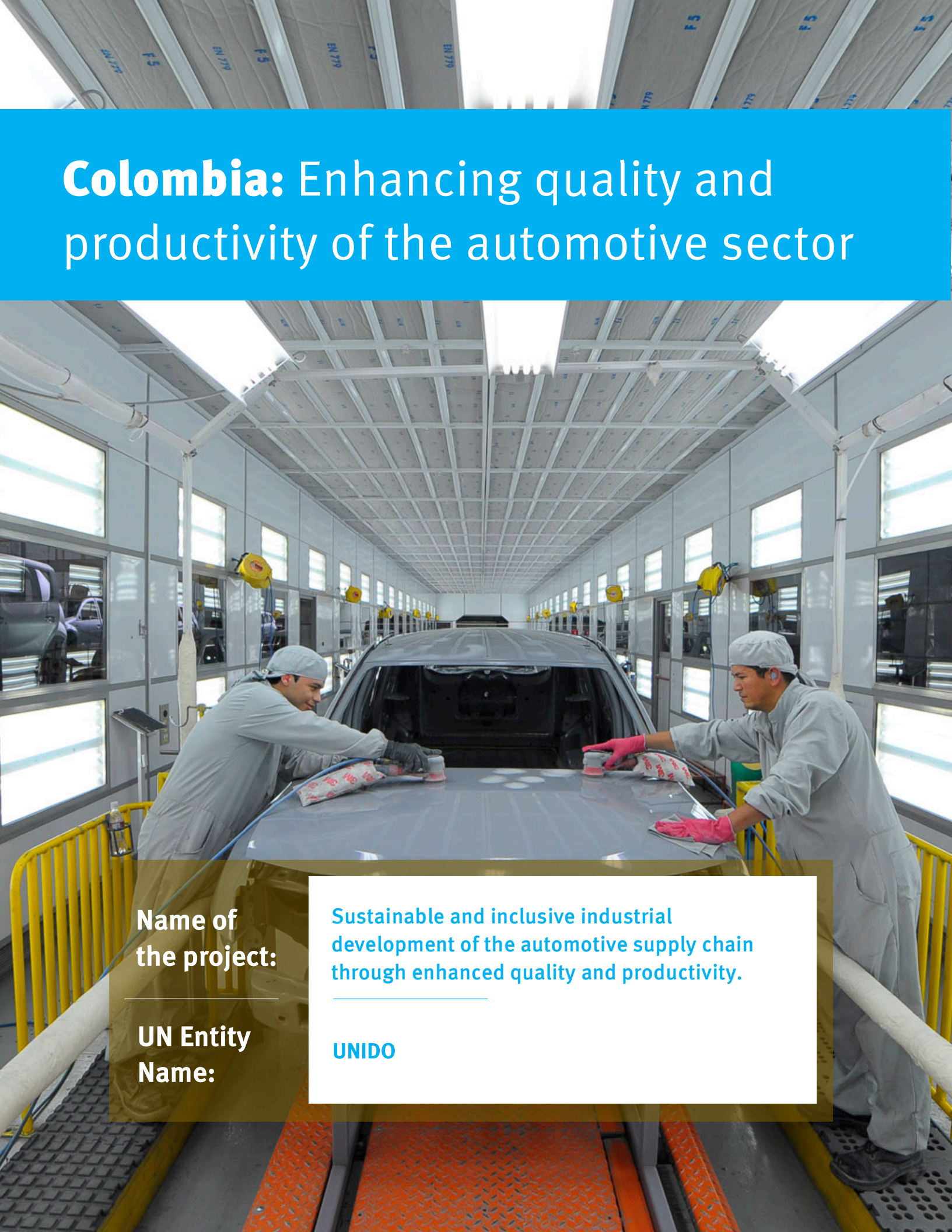
Source: Author's own compilation

6.2 SELECTED UN CASES OF SUCCESS

Several UN agencies are engaged in technical cooperation projects aiming at promoting AI as a way to achieve the SDGs. The present section provides the most significant examples of projects implemented in developing countries, leveraging the potential of AI to support SMEs. Additional projects might be encountered in the ITU Compendium ''United Nations Activities on Artificial Intelligence (AI) 2021''.[113]

[113] ITU, *United Nations Activities on Artificial Intelligence* (2021)

Colombia: Enhancing quality and productivity of the automotive sector



Name of the project:

Sustainable and inclusive industrial development of the automotive supply chain through enhanced quality and productivity.

UN Entity Name:

UNIDO

6.2.1 COLOMBIA: ENHANCING QUALITY AND PRODUCTIVITY OF THE AUTOMOTIVE SECTOR

Overview of the project

The overall objective of the sustainable and inclusive industrial development of the automotive supply chain through enhanced quality and productivity project is to foster Colombia's automotive industry integration into the regional and multilateral trading systems/supply chains, by enhancing its trade capacities, competitiveness, and performance. The project-specific objective aims at improving the quality and productivity of the automotive supply chain.

Colombia is the fourth largest producer of vehicles in the Latin American region. Its automotive industry represents 4.2% of the industrial GDP and employs 2.5% of its working population (about 25,000 direct employees in OEMs and Tier-1 suppliers and nearly 100,000 indirect employees). The automotive supply and manufacturing chain includes manufacturers and assemblers of light vehicles, buses, trucks, motorcycles, and auto parts manufacturers for OEMs and the aftermarket that sells in the local and international markets. But despite the good prospects and size of Colombia's automotive industry, it is currently at a critical point. Local auto parts manufacturers are struggling to compete against imported parts manufacturers due to different reasons, including low-quality performance, specifically in the form of a high level of Parts per Million (PPM). PPM means one defect (or event) in a million, and the Colombian auto parts PPM average is way higher than the international automotive industry standard requirements. Because of that, the industry urgently needs to apply 4IR tools like machine vision, data analytics and artificial intelligence to improve the quality of the products and reduce the PPM to international automotive OEM requirements levels (usually two-digit figures).

How AI is involved in the project

This process started in 2019 with the application of the following surveys to the Colombian automotive industry:

- ☑ Survey for the identification of opportunities for the adoption of Industry 4.0 tools in Colombia (83 participants);
- ☑ Survey for the identification of 4.0 solutions for the automotive industry (58 participants).

From these surveys it was possible to conclude that the most relevant and needed solution using 4IR tools for the Colombian automotive enterprises was: "To identify quality problems in early production stages to reduce costs associated with warranty repairs, increased process efficiency and increased customer satisfaction"

After identifying the most needed solution using 4IR tools for the Colombian automotive industry, it was defined an implementation plan with four steps:

1. Partner with local and government institutions and 4IR implementers that promote the 4IR technologies adoption in the country.
2. Identify the general 4IR knowledge within the companies (Companies Managers and production managers) and assess the adoption of state applications and solutions using 4IR technologies.
3. Define an academic agenda to fill the knowledge gaps and misinformation about 4IR applications.
4. Design a project for 5 Colombian automotive Companies to identify quality problems in early production stages applying 4IR technologies to reduce the PPM delivered to clients.

It was defined to use one customizable 4IR solution, for all five selected companies; all selected companies had different products and processes; the project included three automotive harness assembly companies, one brake lining manufacturing company and one fuel pipes and brake lines manufacturing company.
The project consisted in capture data of the 100% of the products, in an early production control point, by high-speed cameras using machine vision, then, the acquired data is analyzed and compared with predefined quality parameters to identify possible

deviations. All data is processed in real-time to generate reports and generate alerts when deviations and non-conformities occurs, and all the resulting information, quality problems and actions are stored and processed by AI Machine learning algorithms to retrain the system to improvement alerts and the defects and problems identification, to, at the end reduce the PPM delivered to clients.

This project not only uses AI to improve quality problems detection but also uses other 4IR technologies as IoT, Artificial Vision, Cloud Computing and data analysis.

How the project can impact on SMEs

One of the biggest problems of the Colombian automotive industry is that most of the industry is lagging in implementing and using state-of-the-art production processes because the companies tend to lean heavily towards traditional manufacturing processes. On the other hand, the global automotive industry is using 4IR technologies to improve quality, productivity and reduce costs beyond what is possible with traditional methodologies. In the long term, this situation could affect the competitiveness of Colombian industry, if it does not implement the same tools used by global industry.

This type of project can greatly impact SMEs because it was designed to be a multi-product and multi-company customizable application, to identify quality problems in early production stages applying 4IR technologies including AI, and this is one of the most common needed solutions, due to the high average level of PPM in Colombian industry compared to the international PPM requirements.

Result/ impact

The most important results and impacts on the selected SMEs for this 4IR/AI application project are:

- ☑ The reduction of costs associated with warranty repairs and parts reworks.
- ☑ The increase in customer satisfaction due to the reception of less defective parts.
- ☑ Meeting international automotive industry requirements in terms of PPMs, allowing the possibility to get to new international clients.
- ☑ Increased process efficiency.

Namibia: Promoting sustainable bush-processing value chains

Name of the project:

Promoting sustainable bush-processing value chains in Namibia.

UN Entity Name:

UNIDO

6.2.2 NAMIBIA: PROMOTING SUSTAINABLE BUSH-PROCESSING VALUE CHAINS

Overview of the project

In Namibia, the vast majority of the population is engaged in agricultural production as subsistence farmers, yet due to low productivity levels, only half of the country's food demand can be met through these activities, while the other half is met through imports. Since Namibia is one of the driest countries in sub-Saharan Africa, concerns about issues related to water management and shortages, waste generation and pollution are growing. In addition, the agricultural activities are threatened by bush encroachment, a form of land degradation that can be found worldwide, but much more frequently in arid and semi-arid rangelands. While bush encroachment constitutes an immense challenge, it also provides opportunities by utilizing biomass, making agricultural productivity storable, thereby strengthening the drought resilience of farmers. The project's aim is to strengthen important sources of food and income through processing and converting invasive bush species into animal feed and charcoal, utilizing it in agricultural, livestock and water management practices. Direct outcomes of the project encompass provision of 4IR and digital tools in supporting targeted, responsible and sustainable bush thinning and subsequent processing leading to value addition and job generation. In line with the Strategic Action Plan launched in 2020, a convergence of feasibility and market intelligence study, NGGP (National Green Growth Plan), a special purpose production plant, is being operationalized for manufacturing of high-value livestock feed, coal, chips, Arabic gum and other selected products utilizing Acacia species. Through these measures, higher levels of agro-industrial productivity will be achieved, resulting in a better local and regional supply of animal feed, energy, and other bush-based products, that will further facilitate improved competitiveness, import substitution and exports of food, relying, inter alia, on better quality meat and dairy products.

How AI is involved in the project

This project is especially valuable as an exploration of the applications of Artificial Intelligence and Machine Learning and the successful collaboration among several international organizations.

The project resulted in a novel Machine Learning algorithm, a resource that could be used in the future by further AI projects in Namibia and in regions facing similar bush encroachment and land degradation issues. The deployment of the technology has proven to be successful and the reliability of the Acacia-detection algorithms is high; the algorithms themselves could be training for other vegetation species and can be applied in other projects addressing issues related to sustainable biomass processing and detection of eligible species, improving agricultural productivity and strengthening drought resilience. This technological solution can produce a multiplier effect, in terms of providing a market-oriented sustainable business model to benefit from biomass for production of competitive higher value-added products, identification of market niches at local and external markets, thereby facilitating job creation.

How the project can impact on SMEs

The project follows a three-step strategy to ensure successful implementation:

1. Market Intelligence, to provide a detailed technical and economic feasibility study;
2. Technology Transfer, field testing, adaptation and demonstration;
3. Capacity Building, enhancing agro-industrial know-how for sustainability.

UNIDO's technical assistance in this project aims at stimulating productive value-added and employment generation activities based on bush value chain, which contribute to the sustainable development of the Walvis Bay Corridor and the whole logistics supply chain.

The project has the below direct effects on SMEs in the following sectors:

- ☑ Farming and Productivity: reducing land degradation will pave the way to more sustainable agriculture.
- ☑ Sustainable use of land: the proposed land use is indigenous to the region where no chemicals will be used.
- ☑ Renewable Fodder: during rainy seasons acacia leaves will be used as fodder resource.
- ☑ Job creation: the project will provide job opportunities for the men and women in Namibia as well as encouraging entrepreneurs in establishing their own enterprises.
- ☑ Enhance Experience: technical training will enhance human and institutional capacities.

Result/ impact

On an impact level, it is expected that innovative digital technologies and know-how for responsible harvesting are transferred, in particular the Machine Learning model for acacia species mapping that is based on remote sensing texture image analysis, satellite- and drone-supported imagery recognition for enhanced performance of the agricultural sector and related value chains.

Additionally, Machine Learning algorithm is expected to be fine-tuned to provide yield predictions. This will enable the NGGP to produce high quality bio charcoal and animal feed. A special-purpose animal feed recipe developed by the project experts will help farmers optimise livestock feeding. The main expected benefits include the following:

- ☑ sustainable use of land in harmony with natural processes;
- ☑ improved farming practices and productivity: reduced land degradation and diminishing invasive bushes pave the way towards enhanced agricultural activities;
- ☑ issues related to water management and shortages, waste generation and pollution are addressed;
- ☑ technological know-how, hands-on skills and ready-to-use business models facilitated by the project provide better opportunities for sustainable
- ☑ job creation among women and men, especially in rural areas.

China: Empowering SMEs through the Global Innovation Network on ISID

Name of the project:	Empowering SMEs through the Global Innovation Network on ISID
UN Entity Name:	UNIDO

6.2.3 CHINA: EMPOWERING SMES THROUGH THE GLOBAL INNOVATION NETWORK ON ISID

Overview of the project

The Global Innovation Network (GIN) Project's objective is to achieve inclusive and sustainable industrial development through technological advancement in Chinese manufacturing. A Shanghai Global Science & Technology Innovation Center (GSTIC) with increased capacity and the knowledge base for bringing in best practices and new and improved technologies to Chinese industries, as well as to those in other developing countries in the region and globally. The GIN project is supported by UNIDO and operated by the Shanghai Global Science & Technology Innovation Center. There are three main missions under the GIN project.

Firstly, the GIN project aims to promote the transformation of manufacturing factors and economic growth mode. Also, it will improve industrial competitiveness; accelerate technological upgrading and innovation; and promote sustainable economic development in the world.

Secondly, the GIN project aims to advance the SDGs by building risk-resistant infrastructure, promoting inclusive and sustainable industrial innovation and development, and creating equal employment opportunities for different genders.

Thirdly, the GIN project aims to create an international platform that helps expand the space of international cooperation, as well as to attract more international advanced technology to China and to be developed in China. At the same time, the project will transfer China's best technology and products to other developing and LDCs, through the United Nations multilateral cooperation mechanism, to promote the sustainable development of the global economy.

How AI is involved in the project

To achieve one of the goals of the GIN project, specifically promoting AI industrial development in China, Shanghai Global Science & Technology Innovation Center established a "Smart Food Service Center" in 2020, which combines AI technologies with agriculture and catering. The Center mainly provides smart devices with high technology such as 5G, Artificial Intelligence, Cloud Computing, Big Data, IoT, and Blockchain. The devices have been used in food raw material planting; logistics and distribution; operation management; and precision consumption – all with the objective of promoting food safety (reliability, nutrition and health) as well as convenient access to food services. The Center focuses on the development and utilization of smart edible engineering; accelerating the automation of food processing and production; and catalyzing the development of smart food production and consumption ecosystems in China.

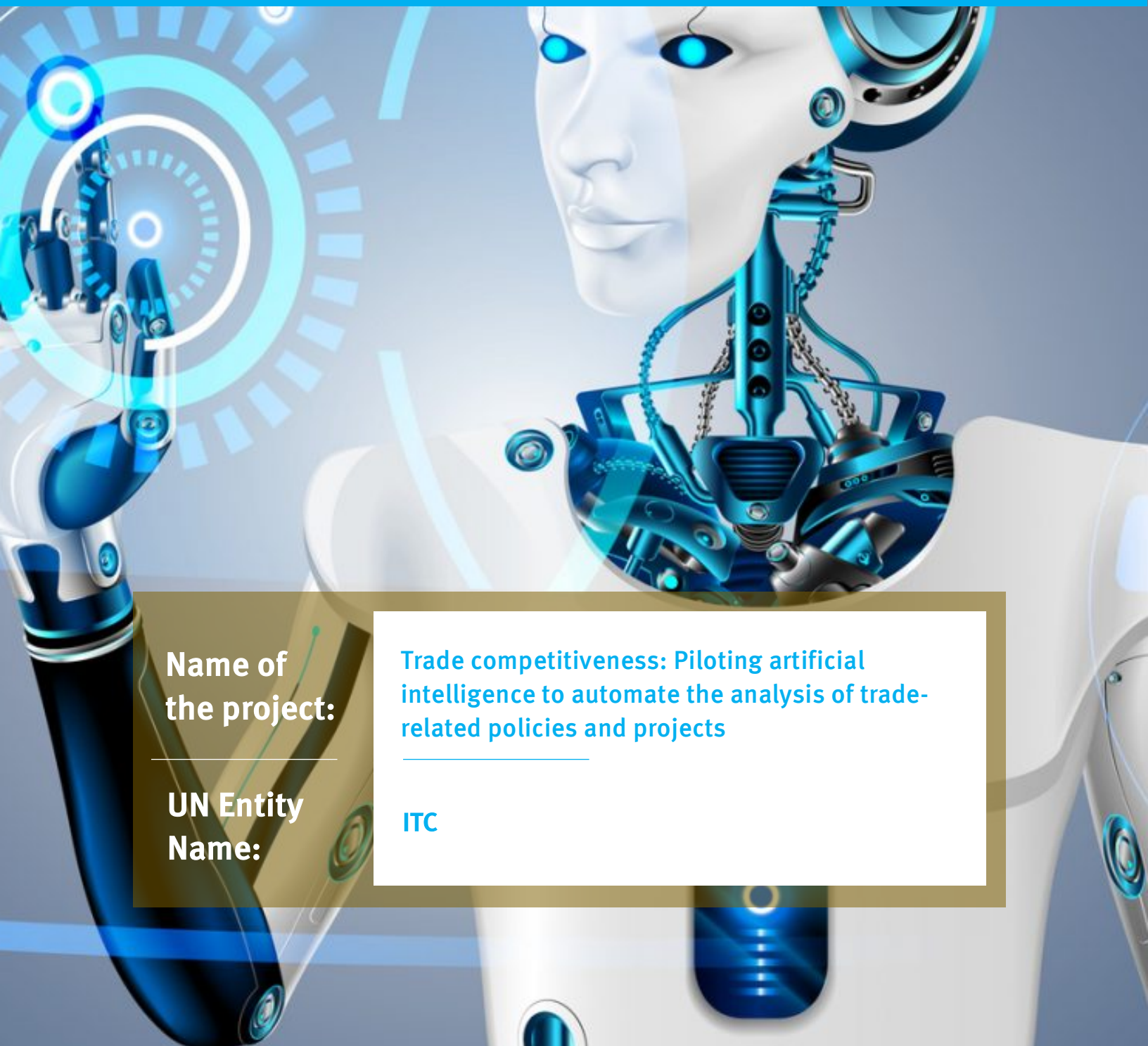
How the project can impact on SMEs

Sustainable food production and consumption is a key trend that needs to be considered as the international community combats challenges and negative impacts arising from climate change. The integration of digital technologies in agriculture and food service industry is an avenue through which this objective can be achieved. The "Smart Food Service Center" has been providing Chinese agricultural and food service SMEs with access to relevant technologies to promote production efficiencies and reduction of waste. The service center is also supporting SMEs to leverage these technologies to ensure that the agricultural produce and food products provided to their clients meet the highest health and safety standards.

Result/ impact

By applying and promoting the integration of advanced technologies within Chinese SMEs operating in the agriculture and food industry,the Center has contributed to an improvement in food management efficiency, convenience, and traceability across the country.

Global: Strengthening policy support for SMEs in developing countries using artificial intelligence



Name of the project:	Trade competitiveness: Piloting artificial intelligence to automate the analysis of trade-related policies and projects
UN Entity Name:	ITC

6.2.4 GLOBAL: STRENGTHENING POLICY SUPPORT FOR SMES IN DEVELOPING COUNTRIES USING ARTIFICIAL INTELLIGENCE

Overview of the project

The International Trade Centre (ITC) assists developing countries to take advantage of global trade opportunities. Its trade strategy programme provides SMEs, trade support institutions and policy makers in developing countries with policy solutions to address their trade competitiveness constraints. Designing a trade strategy requires gathering, processing and making sense of a fast-growing quantity of unstructured data. A significant amount of it is text data that until recently has largely been untapped.

In a world of abundant (and cheap) data, being able to effectively and quickly mine it for insights provides a competitive edge. Particularly, the analysis of vast (and only marginally exploited) text data can generate novel insights to inform trade and SME development policies. But is there an efficient way to screen vast amounts of potentially relevant text data? Can value extraction be automated? In seeking answers to these questions ITC has turned to AI. The project uses AI to automate the extraction of policy-relevant insights from a large body of ITC-facilitated trade strategies, with potential application to many other text-based documents. It aims to achieve three practical goals, namely:

- ☑ to automate the analysis of ITC's repository of more than 1,500 trade strategies;
- ☑ to enhance ITC's understanding of country needs and priorities;
- ☑ and to generate valuable intelligence for decision-making by ITC, its partners and beneficiaries.

The amount of relevant data that is available grows much faster than most organizations' and enterprises' capacities to analyze them. This calls for the smart use of artificial intelligence.

How AI is involved in the project

The project uses artificial intelligence to pinpoint potential policy solutions that can address the trade competitiveness constraints of a country. It uses algorithmic image processing, NLP information extraction techniques, and neural networks to find patterns in the data and new policy insights.

The project started in 2020 as a pilot to assess how the use of artificial intelligence could assist ITC to detect relevant information in vast quantities of trade policy documents. Using

supervised machine learning, a topic detection model was trained with the capability to automatically identify relevant content on 21 different trade-related topics with a 97% accuracy. A junior policy analyst used to spend days carrying out this task. She can now achieve similar (and consistent) results at the touch of a button. The time savings mean that more resources are available for higher value-adding tasks.

During 2021 the project has dived in ITC's vast database of national trade strategies. A combination of NLP methods, information extraction techniques, and neural networks are being used to analyze granularly the trade competitiveness problems that countries typically face, and the solutions that policy makers and experts tend to propose. The model found patterns of interest for trade strategy makers buried under thousands of pages of text data (often in tables!). When presented with a new trade problem, ITC's artificial intelligence model identifies similarities across thousands of trade policy constraints in its database and pinpoints some potential policy solutions. User interaction with the model is simple: plain English. A multilingual version is currently under development.

How the project can impact on SMEs

Initially, the project can impact SMEs by improving the quality and timeliness of policy recommendations for trade and SME development.

One of the crucial problems that SMEs face in developing countries is the weak policy support that they often receive. While artificial intelligence can improve the outlook, most countries tend not have the resources to develop their own tools. ITC's project can bridge this gap by making artificial intelligence available to policy makers, who can then gain insight into policy solutions to the benefit of SMEs.

The uses of the model are, however, multiple. Going forward, the project will explore ways in which SMEs can directly interact with ITC's artificial intelligence via a chatbot.

Result/ impact

ITC beneficiaries are very attentive to the opportunities that artificial intelligence can bring them.The project results show that artificial intelligence has a crucial role to play in trade and SME policy design. Automatically mining large amounts of trade-related text data generates valuable policy insights and new angles to known problems. Ultimately artificial intelligence can lead to better policies. Better policies will in turn benefit SMEs.

Innovative services based on artificial intelligence can boost SME competitiveness. Now is the time to develop them.

6.3 SELECTED PRIVATE-SECTOR CASES OF SUCCESS

AI has been applied extensively across different sectors and contexts[114]. The private sector offers countless examples on how AI can support businesses. This section provides some selected cases; additional examples are available throughout the publication.

6.3.1 YIELD IMPROVEMENT AND CONTINUED PROCESS VERIFICATION IN BIOPHARMA USING AI

Overview of the project

In the domains of life science manufacturing, the lifecycle of product development and validation of a manufacturing process starts with Process Design (PD), followed by Process Performance Qualification and Validation (PPQV).

This means that after the initial development of a new pharmaceutical compound or medicine, the production process undergoes qualification and validation before it can receive regulatory approval, after which it is put into industrial-level production. On this scale, the quality of each individual pill or bottle is ensured through Quality by Design (QbD): the guarantee of product quality through a deep process understanding, and a robust manufacturing process that follows good manufacturing practices (GMP) guidelines. One issue with this approach is that most of the required process understanding to achieve QbD is needed early on, yet most of the manufacturing data is available only after the transition to large-scale production.

For this reason, the Federal Drug Administration (FDA) issued the Process Validation Guidance in 2011 to introduce the concept of Continued Process Verification (CPV). CPV is a final stage in the product development lifecycle, a data-driven workflow to continue improving the efficiency and effectiveness of drug manufacturing, resulting in higher quality products produced at more affordable prices.

But its implementation is difficult in practice, requiring a multivariable procedure to link complex process parameters with product quality. Yet these are the ideal conditions for AI algorithms: a complexity that is too high for people, large datasets with many parameters to learn from, and clearly defined statistical goals. In this light, the Parenteral Drug Association (PDA) launched the "CPV of the Future" initiative with many industries and

[114] For more examples: www.big-data-value.eu/smes/; www.xavierhealth.org/aio-whitepaper-ai-in-action; www.proquest.com/docview/2031878627?pq-origsite=gscholar&fromopenview=true

academic partners with the goal of demonstrating the power of AI to realize CPV, and subsequently encourage the pharmaceutical industry to adopt AI for better and more efficient drug manufacturing.

How AI is involved in the projects

To achieve the successful implementation of AI to support CPV, a direct relationship needs to be established between the operating conditions of the manufacturing process, captured by Critical Process Parameters (CPPs), and attributes of the product at the end of the line. Artificial
Intelligence solutions provide a critical component in the pursuit of this process understanding, learning the complex dynamics from each iteration and applying this knowledge to the following batch.

This creates a connected chain of improvement as more products are being released, ultimately leading to an optimized and efficient way of manufacturing pharmaceuticals on a large scale.
In this project, a bioreactor was used to study the operating conditions of *Pichia pastoris*, a yeast that produces Candida rugosa lipase (CRL-1), which is a popular component in the food processing industry. The team deployed a series AI models that achieved two goals:

1. Finding the optimal operating conditions of the bioreactor to obtain maximal yields of CRL-1, while retaining high protein stability.
2. Preemptively identifying which batch had reduced efficiency during production, creating a predictive model to detect anomalies with an alarm system in place to correct deviations of an ongoing process.

How the project can impact on SMEs

The life science industry is a market dominated by large pharmaceutical companies, both for the development of new medicine and the manufacturing of pharmaceutical products. New Industry 4.0 technologies such as AI, Big Data and Cloud Computing are key enablers to boost the position of SMEs in this market, and increase their competitive power through technological innovation.

The principles of CPV go hand in hand with the fundamentals of AI, a data-driven approach to strive for the continuous improvement of a process. Its mindset is to learn from mistakes, to take a weakness like a low-quality batch, and turn this into an improvement to the production line. SMEs can be empowered in this competitive market by incorporating CPV and AI-based solutions as cost-effective and accessible tools in their existing business model, creating a disruptive force for smaller players in the market that don't have access to billion-dollar R&D facilities.

Result/ impact

The project has shown that AI can be used to create the ideal conditions for optimal drug manufacturing, providing a deep process understanding that helps guarantee product quality. The adoption of AI technologies into the workflow of pharmaceutical SMEs will help to reduce development costs of new drugs, enabling companies to design new medicines for local markets in developing

countries. This in turn can increase diversity in the pharma industry by supporting smaller enterprises to participate and pursue new business opportunities, leading to a global democratization of the manufacturing industry for medicinal products and therapeutics.

6.3.2 USING AI FOR THE DISCOVERY OF NEW PHARMACEUTICAL COMPOUNDS[115]

Overview of the project[1]

The goal of the pharmaceutical industry is to bring the best drugs to the patients for existing treatments, and continue the development of new medicines to address patient needs against untreated disease. For drug discovery and medicinal chemistry, the process revolves around identifying different drug targets and optimizing their working mechanism against disease profiles. But potential candidates are often selected from sets of hundreds or thousands of possible compounds, requiring extensive screening procedures.

AI can provide a valuable tool, if used correctly, to greatly accelerate this screening process and improve the design process of new drugs to treat diseases safely and effectively. One of the leading questions that R&D departments need to address is which chemical

[115] Sellwood M. A., et.al., *Artificial intelligence in drug discovery, Future Science* (2018)

structures will elicit the desired biological response profile. Iterative design loops that incorporate predictive AI models to simulate molecular combinations can provide a shortlist of candidate molecular designs that help identify chemical structures with high potential for prospective pharmaceutical solutions.

How AI is involved in the projects

One approach for this molecular design is to use a set of chemical building blocks from known synthetic organic chemistry, and use AI algorithms to select, align and replace these different elements in an iterative manner to propose new potential targets or optimize existing known chemical structures.

An alternative approach is to use AI-based generative models for molecules. These algorithms are trained on large data sets from the medicinal chemistry space, and learn the distribution over the molecules in the data. From this, AI models can sample novel combinations and propose potential new drug targets.

How the project can impact on SMEs

New drug discovery is an expensive and resource-heavy process, often reserved for major pharma companies in the industry. When comparing the biopharmaceutical sector with other main economic drivers, the drug industry has the highest global investment in R&D (€139 billion) in the year 2017-2018 [https://publications.jrc.ec.europa.eu/repository/handle/JRC113807]. SMEs often lag behind in terms of investment and access to R&D facilities, but Industry 4.0 technologies, and AI in particular, provide a catch-up mechanism that allow SMEs to benefit from technological innovation in drug discovery.

Final result/ impact

Incorporating AI solutions into drug discovery operations can greatly benefit the life science industry. Its implementation has the benefit of accelerating the clinical trial process, detecting adverse effects in advance by analyzing similar products and target patients. It furthermore decreases the overall costs that are associated with pharmaceutical compound R&D, enabling the development of a wider variety of drugs available to treat disease with a reduction in the final price of drugs for the patients and their insurer. Finally, the use of AI can support the process of Drug Repurposing (DR), also known as drug repositioning, in which previously developed drugs are used to treat a different set of common or rare diseases under an alternative purpose.

This leads to a more efficient use of available medication, bringing value to the population by offering more treatment options for disease that use less risky compounds on shorter development timelines.

6.3.3 AI IN PHARMACOVIGILANCE TO MONITOR DRUG TOXICITY AND SAFETY[116]

Overview of the project[1]

Drug safety is a critical component of the success of a new drug or medicinal product, alongside its effectiveness to treat diseases. But unexpected toxicities are a major concern for the health and safety of patients, where extensive research is required to prevent the occurrence of Adverse Events (AEs) or Adverse Drug Reactions (ADRs), in which unexpected side-effects can cause deterioration of morbidity or mortality.

Clinical trials are the major system in place to prevent AEs or ADRs before a drug's market release to ensure its safety for public health. However, these trials suffer a structural weakness in that they target the average patient, often with an underrepresentation of specific subgroups (cultural minorities, age or gender imbalances etc.). In response, comprehensive post-market monitoring programs are needed to detect the emergence of potentially dangerous numbers of AEs or ADRs.

The explosion of available databases of medical, chemical or pharmacological nature, combined with the access to electronic health record (EHR) systems provide the perfect conditions to implement AI solutions for pharmacovigilance and post-market monitoring of drug toxicity and safety.

How AI is involved in the projects

In the pre-market phase, AI technology plays an important role in determining the safety of drug usage and dosage. Despite extensive preclinical evaluations using traditional approaches, high toxicity is still a major contributor to drug failure. Predictive models based on AI provide the necessary tools to support toxicity estimates, reducing the cost and development time to bring a drug to market. Quantitative structure-activity relationships (QSAR) in particular can be used to model drug safety endpoints, including lethal dose values, tissue irritation and toxicity values.

In the post-market phase, data mining methods released on accessible databases and EHR systems can feed the necessary information to sophisticated AI models for pattern recognition of AEs and ADR among the ocean of health data available. This clinical data can furthermore be combined with existing knowledge of systems biology, creating AI applications of systems pharmacology that consider the effect of drugs on the entire biological system through *in silico* pathway simulations.

How the project can impact on SMEs

Pharmacovigilance using AI can support SMEs in the life science industry by reducing the burden of market-specific monitoring and testing in developing economies, creating favorable conditions for SMEs to bring new products to market. It furthermore enables new business opportunities for the development of safe medical devices as an emerging new market trend.

Final result/ impact

All drugs must be safe, effective and meet the specified quality in order to be delivered to patients. When a drug is not efficient enough, patients are adversely affected by receiving suboptimal treatment with an inadequate dosage of the active pharmaceutical ingredient (API). Pharmacovigilance plays an important role to detect a loss of efficiency, but in practice it takes a long time before trends are detected by people. Deploying AI for this task can improve detection rates of anomalies and help with the early discovery of major safety risks for public health.

EHR systems and medical databases provide a treasury of unstructured health data (images, comments and follow-up written by medical specialists, dosages, evolutive results, combination with other drugs, bios-psycho-social attributes of the patients, etc.), but its complexity can only be captured by advanced AI and analytical

tools. By continuously monitoring these systems, AI provides an objective mechanism that works without bias, active as a 24/7 unattended surveillance system to protect the health and safety of the public from unintended adverse treatment effects (e.g. dosages, drug interaction, external factors).

Conclusions and Recommendations

What to keep in mind?

The present work represents an attempt to clarify the most relevant characteristics of AI and answer to the commonly shared questions on the topic. Is AI simple to adopt and apply? How can the application of AI bring concrete benefits to my organization? Which are the challenges I should be aware of? Which are the steps to follow to adopt and apply AI?

I. Understand 'what' and 'why'

SMEs should understand what AI is, and why it is worth including it in a certain organization. Indeed, the benefits associated to the AI application are several, and they refers both to services and manufacturing. For instance, AI might be used to up-scale the supply chain management, including by predicting fluctuations in customer demand and efficiently scheduling distribution. It can support marketing activities, by tailoring the sales process, as well as predicting trends. AI can be also used in certain processes to identify unfamiliar problems and provide accurate resolutions, by analyzing a mass of contextual data on similar problems from other shifts or processes. The revolutionary future of business inevitably needs to embrace the use of AI, thus SMEs should first tailor their strategy by identifying how AI can better fit within their specific context.

II. Know well your context

Within the context of developing countries, there are some important elements which are driving the adoption of AI among SMEs. Having a good understanding of such factors allows SMEs to understand the environment they are operating in and, in some cases, redirect some conducts towards more recommended practices, to foster growth, competitiveness, and sustainability to the organization. Among the most relevant factors, it worth it to mention the use of AI driven by the need to increase the innovation within the organization, reach new markets, improve the productivity, meet the market demands.

III. Be aware of the challenges

Although there are some common challenges that SMEs of both developed- and developing-countries need to face, it is worth highlighting that, depending on the context, such barriers might be more negatively impactful. In other words, developing-countries-based SMEs might perceive more markedly the burden of certain barriers, thus being disadvantaged especially in the context of a globalized market. Among the most relevant are the lack of financial support to adopt AI in an SME, and the lack of a data acquisition infrastructure and process standardization. A good understanding of the multitude of

barriers is essential to build a good and sustainable response to such limitations.

IV. Understand the added-value of AI

There are a multitude of benefits associated with the use of AI, which might incentivize the adoption of this technology in the context of SMEs. From an economic perspective, AI contributes to increasing the competitiveness and long-term sustainability of an organization, inter alia by lowering costs associated to operations, improving the efficiency and the quality of production, as well as by accelerating the product development cycle (from design to commercialization). Several other AI-related benefits address social and environmental aspects. A good understanding of the added-value of AI allows an organization to justify the initial investment for the adoption of such technology in light of the return of investment that AI generates.

V. Know how to move from theory to practice

With the aim of accompanying SMEs throughout the process of adopting AI, this publication recommends five steps to follow:

1. Determine the SME readiness and ability, by examining the AI transformation processes and evaluating the AI Maturity level;
2. Build a AI strategy, which includes establishing legal framework, committing to resources, and setting up the standards;
3. Establish a proper data governance standard to deal with digital data, in light of the fact that AI systems are based on the availability of quality data in reasonable quantities;
4. Embrace AI data-driven decision making and minimize human bias and personal judgement in that process;
5. Start piloting the first AI project for your SME that can be used as a Proof of Concept (PoC); examine the knowledge gained in the previous stages; and analyze the new status of the SME in the AI adoption scheme.

VI. Get inspired

The ways, contexts, sectors, combinations and circumstances in which AI is deployed are almost countless. AI can be also applied to other advanced technologies to offer tailored experiences and responses to specific needs. The most effective way to disseminate and effectively show AI applications and its concrete potential to scale-up an organization is through case studies. Throughout this publication, several different scenarios have been proposed, and sections 6.2 and 6.3 has been dedicated to both UN-related- and private-sector success stories, with the aim at offering the reader the possibility to get inspired.

Glossary

3D-Printing

3D Printing is an additive manufacturing process that creates a physical object from a digital file. The process usually works by laying down thin layers of material in powdered plastic, metal or cement, and then fusing the layers.

Analytics translators

Analytics translation is the position that performs some of the essential functions in integrating analytics capabilities into an enterprise. They define the business problems that analytics can help solve, guide technical teams in creating analytics-based solutions to these problems, and integrate the solutions into business operations.

Artificial intelligence (AI)

The intelligence that is displayed or simulated by technological means. "Intelligence" in this definition is often assumed to mean: considered intelligent by the standard of human intelligence, the type of smart capabilities and behaviors displayed by humans. In addition, the term can refer to science or technologies, e.g., learning algorithms.

Artificial narrow intelligence (ANI)

Artificial narrow intelligence, or weak AI, is the only type of artificial intelligence that has been successfully achieved to date. Narrow AI is goal-oriented, designed to perform specific tasks, such as facial recognition, speech assistants, driving a car, or searching the Internet. It is highly intelligent at completing the particular job for which it is programmed.

Artificial general intelligence (AGI)

Artificial general intelligence, also called deep AI, is the concept of a machine with general intelligence that mimics human brightness and behaviors, with the ability to learn and apply its intelligence to solve any problem. AGI can think, understand and act indistinguishably from a human in any situation.

Artificial superintelligence (ASI)

Artificial superintelligence is the hypothetical AI that not only mimics or understands human intelligence and behaviour; ASI is when machines become self-aware and surpass the capacity of human intelligence and ability.

Artificial Neural Network (ANNs) / Simulated Neutral Network (SNN)

Artificial neural networks, neural networks or simulated neural networks, are a sub technology of machine learning and are the main enabler of deep learning algorithms. Its structure is inspired by the human brain, mimicking the way biological neurons communicate with each other.

Artificial Intelligence as a Service (AAaaS)

Artificial intelligence as a service refers to out-of-the-box AI tools that enable enterprises to deploy AI techniques at a fraction of the in-house AI cost.

Algorithms

It is a finite sequence of defined instructions, typically used to solve a class of specific problems or to perform a computation.

Bias

Bias is the discrimination against or in favour of certain individuals or groups. In the context of ethics, the question arises as to whether or not a particular bias is unfair.

Blockchain

A blockchain is a digital ledger of duplicated transactions and distributed throughout the entire network of blockchain computer systems. Each block contains several transactions, and each time a new transaction occurs on the blockchain, a record of that transaction is added to each ledger.

Chatbot

A chatbot is a computer program that simulates and processes a human conversation, allowing humans to interact with computers as if they were communicating with a real person.

Cloud Computing

Cloud Computing is the provision of different services over the web. These services include tools and applications like data storage, servers, databases, networks and software.

CAPTCHA

CAPTCHA is a type of test used in computing to determine whether or not the user is human.

Data science

It is a science that uses statistics, algorithms and other methods to extract meaningful and useful patterns from data sets, sometimes known as "Big Data." In addition to data analysis, data science is also concerned with data capture, preparation and interpretation.

Data Governance

Data governance includes the processes, functions, policies and standards that ensure the effective and efficient use of information within an organization to achieve its goals.

Data mining

Data mining is the process of analyzing a large batch of information to discern trends and patterns.

Data lakes

A data lake is a centralized archive that allows storing all the structured and unstructured data at any scale. It can store data as-is, without having to structure it first and run different types of analytics to guide better decisions.

Data stewards

A data steward is a position that manages the data governance function within an organization and is responsible for ensuring the quality and fitness-for-purpose of the organization's data assets, including the metadata for those data assets. A data steward may share responsibilities with a data custodian, such as data awareness, accessibility, publication, appropriate use, security and governance.

Deep Learning (DL)

Deep learning is a type of Artificial Intelligence that imitates the way humans acquires certain kinds of knowledge.

Explainable AI

Explainable AI can explain to humans its actions, decisions, or recommendations or provide sufficient information about how it arrived at its outcome.

Fourth Industrial Revolution (4IR)

The Fourth Industrial Revolution is the convergence of telecommunication, information and new production technologies, including nanotechnology, biotechnology, new materials, advanced digital production technologies, 3D printing, human-machine interfaces (HMIs) and Artificial Intelligence, with current general purpose technologies and new business models into industrial production processes that raise the concept of Industry 4.0, also known as Smart Factor.

General AI

General AI is the human-like intelligence that can be applied broadly instead of restricted AI, which can only be used to a specific problem or task. It is also referred to as "strong" AI as opposed to "weak" AI.

General Data Protection Regulation (GDPR)

The General Data Protection Regulation is a regulation in EU law on data protection and privacy in the European Union (EU) and the European Economic Area (EEA).

IT system

IT systems are all electronic systems for data processing, information, record keeping, communications, telecommunications, account management, inventory management and other computer systems.

Internet of Things (IoT)

The Internet of Things is the network of physical objects that have embedded sensors, software and other technologies to connect and exchange data with other devices and systems over the Internet.

Industrial Internet of Things (IIoT)

The Industrial Internet of Things refers to the use of the Internet of Things in industrial sectors and applications.

Machine learning (ML)

A machine or software that can learn automatically based on a computational and statistical process. The learning algorithms can detect patterns or rules in the data and make predictions for future data.

Natural Language Processing (NLP)

Natural language processing is the ability of a program to understand human language as it is spoken and written.

Positive ethics

Ethics is concerned with how we should live (together), based on a vision of the good life and the good society. It contrasts with negative ethics, which sets limits and says what we should not do.

Process standardization

Process standardization can be defined as improving operational performance, reducing costs by reducing process errors, facilitating communication, leveraging expert knowledge, and providing flexibility without sacrificing organizational controls.

Predictive analysis

Predictive analytics uses data, statistical algorithms and machine learning techniques to identify the likelihood of future outcomes based on historical data.

Proof of Concept (POC)

A proof of concept is an exercise in which the work is focused on determining whether an idea can become a reality. Thus, proof of concept determines the idea's feasibility or verifies that the concept will work as envisioned.

Parts per Million (PPM)

A lean manufacturing philosophy that measures defects recorded in every million products produced and can be a valuable benchmark of company performance and capability.

Responsible innovation

Approach to making innovation more ethically and socially responsible, usually involving incorporating ethics into the design and taking into account stakeholder views and interests.

The Singularity

The technological singularity or singularity is a hypothetical point when technological growth becomes uncontrollable and irreversible, resulting in unpredictable changes in human civilization.

Speech recognition

Speech recognition is a subfield of computer science and computational linguistics that develops methodologies that enable the recognition and translation of spoken language to text by computers.

Superintelligence

It is the theory that imagines the point where machines will surpass human intelligence. It is sometimes related to the idea of an "intelligence explosion" caused by intelligent machines designing even more intelligent machines.

Sustainable AI

It is the AI that enables and contributes to a sustainable way of life for humanity and does not destroy the Earth's ecosystems on which humans (and many non-humans) depend.

Symbolic AI

AI relies on symbolic representations of higher cognitive tasks, such as abstract reasoning and decision making. It can use a decision tree and take the form of an expert system that requires input from subject matter experts.

Trustworthy AI

AI that humans can trust. The conditions for such trust may refer to (other) ethical principles such as human dignity, respect for human rights, etc., or to social and technical factors that influence whether people want to use the technology. The use of the term "trust" concerning technologies is controversial.

References

Bibliography

Adobe (2021). Now your scanner is in your back pocket.

Airbus (2016). Pioneering bionic 3D printing. Airbus Newsroom. https://www.airbus.com/en/newsroom/news/2016-03-pioneering-bionic-3d-printing (18.11.2021)

Airbus (2021). Artificial intelligence – Capitalising on the value of data. Airbus. https://www.airbus.com/en/innovation/industry-4-0/artificial-intelligence (18.11.2021)

Allen, G., Chan, T. (2017). Artificial Intelligence and National Security. Belfer Center for Science and International Affairs, Harvard Kennedy School. https://www.belfercenter.org/sites/default/files/files/publication/AI%20NatSec%20-%20final.pdf (18.11.2021)

Allianz (2018). The Rise of Artificial Intelligence: Future Outlook and Emerging Risks. Allianz Global Corporate & Specialty. https://www.agcs.allianz.com/content/dam/onemarketing/agcs/agcs/reports/AGCS-Artificial-Intelligence-Outlook-and-Risks.pdf (18.11.2021)

Appen (2021). The State of AI and Machine Learning – AI Industry Accelerates Rapidly Despite Pandemic, Driven by Data Partnerships and Increasing Budgets. An Appen Whitepaper. https://resources.appen.com/wp-content/uploads/2021/06/Whitepaper-State-of-AI-2021.pdf

Ariker, M., Heller, J., Diaz, A., & Perrey, J. (2015). How marketers can personalize at scale. Harvard Business Review, 23.

Ataee, P. (2021). Artificial Intelligence, Unorthodox Lessons: How to Gain Insight and Build Innovative Solutions (Dance with Data)

Barrett, A. M., & Baum, S. D. (2017). A model of pathways to artificial superintelligence catastrophe for risk and decision analysis. Journal of Experimental & Theoretical Artificial Intelligence, 29(2), 397-414. https://www.tandfonline.com/doi/abs/10.1080/0952813X.2016.1186228 (18.11.2021)

Basile, A. O., Yahi, A., & Tatonetti, N. P. (2019). Artificial intelligence for drug toxicity and safety. Trends in pharmacological sciences, 40(9), 624-635. https://www.sciencedirect.com/science/article/pii/S0165614719301427 (18.11.2021)

Beck, R. (2021). Digital Twins and AI: Transforming Industrial Operations. Reliable Plant, Noria Corporation.. https://www.reliableplant.com/Read/31897/digital-twins-ai (18.11.2021)

Bitkom (2017). Artificial Intelligence Economic importance, social challenges, human responsibility. Bitkom.com. https://www.bitkom.org/sites/default/files/file/import/171101-PP-Artificial-Intelligence-ENG-Web.pdf

Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2015). Autonomous vehicles need experimental ethics: Are we ready for utilitarian cars? Cornell University. https://arxiv.org/pdf/1510.03346.pdf

Calipsa (2020). The Calipsa Video Monitoring Report 2020. https://www.calipsa.io/resources/video-monitoring-report-2020 (18.11.2021)

Capgemini Consulting (2012). Nike: From Separate Digital Initiatives to Firm-Level Transformation. https://www.capgemini.com/wp-content/uploads/2017/07/digital_transformation_at_nike_20-12_pdf.pdf (18.11.2021)

Cellan-Jones, R. (2014). Stephen Hawking warns artificial intelligence could end mankind. BBC news, 2(10). http://christusliberat.org/wp-content/uploads/2017/10/Stephen-Hawking-warns-artificial-intelligence-could-end-mankind-BBC-News.pdf (18.11.2021)

Chan, B. K. (2019). Why Data Governance is important to Artificial Intelligence, Mind Data. https://medium.com/taming-artificial-intelligence/why-data-governance-is-important-toartificial-intelligence-fff3169a99c (18.11.2021)

Chen S. (2017) The AI company that helps Boeing cook new metals for jets, Science, American Association for the Advancement of Science, Washington DC.

Colson, E., (2019). What AI Driven Decision Making Looks Like, Harvard Business Review. https://hbr.org/2019/07/what-ai-driven-decision-making-looks-like (18.11.2021)

Cybiant (2021). The challenges of AI implementation. https://www.cybiant.com/resources/the-challenges-of-ai-implementation/ (18.11.2021)

Data-Driven Innovation (DDI) (n.d.). Ecosystem. https://ddi-canvas.com/ecosystem/ (18.11.2021)

Data-Driven Innovation (DDI) (n.d.). DDI is Part of Internal Training@Siemens. ddi-canvas.com/ddi-is-part-of-internal-trainingsiemens/ (18.11.2021)

Data-Driven Innovation (DDI) (n.d.). Understanding the Obvious – That's the Purpose of our Activities Centered Around Data Driven Innovation. https://ddi-canvas.com (18.11.2021)

Datta, A., Tschantz, M. C., & Datta, A. (2015). Automated experiments on ad privacy settings: A tale of opacity, choice, and discrimination. Cornell University. https://arxiv.org/pdf/1408.6491.pdf (18.11.2021)

Davenport, T., Guha, A., Grewal, D., & Bressgott, T. (2020). How artificial intelligence will change the future of marketing. Journal of the Academy of Marketing Science, 48(1), 24-42. https://link.springer.com/article/10.1007/s11747-019-00696-0 (18.11.2021)

Deloitte (2019). Future in the balance? How countries are pursuing an AI advantage. https://www2.deloitte.com/cn/en/pages/technology-media-and-telecommunications/articles/how-countries-are-pursuing-an-ai-advantage.html (18.11.2021)

Eklahare, J. (2021). Safety in Manufacturing: the Role of AI, Efficient Manufacturing Web Magazine. Efficient Manufacturing. https://www.industr.com/en/safety-in-manufacturing-the-role-of-ai-2567803 (18.11.2021)

eMarketer (2020). US Ecommerce Growth Jumps to More than 30%, Accelerating Online Shopping Shift by Nearly 2 Years. Insider Intelligence. www.emarketer.com/content/us-ecommerce-growth-jumps-more-than-30-accelerating-online-shopping-shift-by-nearly-2-years/ (18.11.2021)

European Commission (2021a). Coordinated Plan on Artificial Intelligence Review 2021. https://www.eciia.eu/wp-content/uploads/2021/05/1_en_annexe_autre_acte_part1_v8_vf_C4B261EB-ABA4-5C30-1555482869410384_75787.pdf (18.11.2021)

European Commission (2021b). Regulation of the European Parliament and of the Council. Eur Lex. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1623335154975&uri=CELEX%3A52021PC0206 (18.11.2021)

European Parliament (2020). What is artificial intelligence and how is it used today? News European Parliament. https://www.europarl.europa.eu/news/en/headlines/society/20200827STO85804/what-is-artificial-intelligence-and-how-is-it-used (18.11.2021)

Food and Drug Administration (FDA) (2016). *Data Integrity and Compliance With CGMP Guidance for Industry*. U.S. Department of Health and Human Services. https://www.fda.gov/files/drugs/published/Data-Integrity-and-Compliance-With-Current-Good-Manufacturing-Practice-Guidance-for-Industry.pdf (18.11.2021)

Food and Drug Administration (FDA) (2021). Artificial Intelligence/Machine Learning (AI/ML)-Based Software as a Medical Device (SaMD) Action Plan. U.S. Food & Drug Administration, Center for Devices & Radiological Health. https://www.fda.gov/medical-devices/software-medical-device-samd/artificial-intelligence-and-machine-learning-software-medical-device (18.11.2021)

Glidden, J., (2021). Understanding What Artificial Intelligence Is, And What It's Not, Forbes Business Council, Forbes Business Council. https://www.forbes.com/sites/forbesbusinesscouncil/2021/04/14/understanding-what-artificial-intelligence-is-and-what-its-not/?sh=16d8993c48cd (18.11.2021)

Global Partnership on Artificial Intelligence (**GPAI**) (2020). The Role of Data in AI - Report for the Data Governance Working Group of the Global Partnership of AI. Digital Curation Centre Trilateral Research School of Informatics, The University of Edinburgh. https://gpai.ai/projects/data-governance/role-of-data-in-ai.pdf (18.11.2021)

Google (2020). Machine Learning Crash Course, Google Developers. developers.google.com/machine-learning/crash-course/generalization (18.11.2021)

Gopani, A. (2021). 78 AI Companies Around the World That Are Unicorns Today, AIM. https://analyticsindiamag.com/78-ai-companies-around-the-world-that-are-unicorns-today/ (18.11.2021)

Gunning, D., Stefik, M., Choi, J., Miller, T., Stumpf, S., & Yang, G. Z. (2019). XAI—Explainable artificial intelligence. Science Robotics, 4(37), eaay7120. https://www.science.org/doi/10.1126/scirobotics.aay7120 (18.11.2021)

Habermas, J. (1991). The structural transformation of the public sphere: An inquiry into a category of bourgeois society. MIT press.

Hernandez, D., Brown T. B. (2020). Measuring the Algorithmic Efficiency of Neural Networks. Cornell University. https://arxiv.org/pdf/2005.04305.pdf

Holzinger, A., Kieseberg, P., Weippl, E., & Tjoa, A. M. (2018). Current advances, trends and challenges of machine learning and knowledge extraction: from machine learning to explainable AI. In International Cross-Domain Conference for Machine Learning and Knowledge Extraction (pp. 1-8). Springer, Cham. https://link.springer.com/chapter/10.1007/978-3-319-99740-7_1

IBM (2021). How much does a data breach cost? https://www.ibm.com/security/data-breach (18.11.2021)

IBM Watson (2021). Global AI Adoption Index 2021. https://filecache.mediaroom.com/mr5mr_ibmnewsroom/191468/IBM%27s%20Global%20AI%20Adoption%20Index%202021_Executive-Summary.pdf (18.11.2021)

Impuls: Industry 4.0 Readiness Online Self-Check for Businesses. https://www.industrie40-readiness.de/?lang=en (18.11.2021)

International Organization for Standardization (2021). ISO/IEC JTC 1/SC 42, Artificial Intelligence Committee. https://www.iso.org/committee/6794475.html (18.11.2021)

ITU (2021). Accelerating the United Nations Sustainable Development Goals. AI for Good. https://aiforgood.itu.int (18.11.2021)

ITU (2021). United Nations Activities on Artificial Intelligence 2020. https://www.itu.int/dms_pub/itu-s/opb/gen/S-GEN-UNACT-2020-1-PDF-E.pdf (18.11.2021)

Johnson, K. (2020). CB insights: AI startup funding hit new high of USD 26.6 billion in 2019. Venture Beat. https://venturebeat.com/2020/01/22/cb-insights-ai-startup-funding-hit-new-high-of-26-6-billion-in-2019/ (18.11.2021)

Kupilas, K., Montequín, V., Alvarez, C., & Balsera, J. (2020). Industry 4.0 and Project Management and Engineering, Researchgate.

Lee, J., Singh, J., & Azamfar, M. (2019). Industrial AI: Is It Manufacturing's Guiding Light? Manufacturing Leadership Council. https://www.manufacturingleadershipcouncil.com/industrial-ai-is-it-manufacturings-guiding-light-9624/ (18.11.2021)

Lomas, C. (2018). The AI Business Model Canvas, LinkedIn. https://www.linkedin.com/pulse/ai-business-model-canvas-christopher-lomas/ (18.11.2021)

Machado, H. (2019). Cybercrime will cost the world more than USD 6 trillion annually by 2021, up from USD 3 trillion in 2015. NBCUniversal Media, LLC. https://www.nbcdfw.com/news/tech/cybercrime-to-top-6-trillion-in-2021-north-texas-security-firm-says/2636083/ (18.11.2021)

Manzano, T. (2020.)PDA Study Explores Role of A.I. in CPV, Parenteral Drug Association. http://www.pda.org/pda-letter-portal/home/full-article/pda-study-explores-role-of-a.i.-in-cpv (18.11.2021)

Marr, B. (2021). What Is The Impact Of Artificial Intelligence (AI) On Society? https://bernardmarr.com/what-is-the-impact-of-artificial-intelligence-ai-on-society/ (18.11.2021)

McCarthy, J. , Minsky, M.L. , Rochester, N. & Shannon, C.E. (1955). A proposal for the Dartmouth summer research project on artificial intelligence. http://www-formal.stanford.edu/jmc/history/dartmouth/dartmouth.html (18.11.2021)

McKinsey & Company (2019). Confronting the risks of artificial intelligence. McKinsey Quarterly. https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/confronting-the-risks-of-artificial-intelligence (18.11.2021)

McKinsey & Company (2018), Notes from the AI frontier – modeling the impact of AI on the world economy. McKinsey Global Institute. https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Artificial%20Intelligence/Notes%20from%20the%20frontier%20Modeling%20the%20impact%20of%20AI%

2oon%2othe%2oworld%2oeconomy/MGI-Notes-from-the-AI-frontier-Modeling-the-impact-of-AI-on-the-world-economy-September-2018.ashx (18.11.2021)

Mei, X., Lee, H. C., Diao, K. Y., Huang, M., Lin, B., Liu, C., ... & Yang, Y. (2020). Artificial intelligence–enabled rapid diagnosis of patients with COVID-19. Nature medicine, 26(8), 1224-1228. https://www.nature.com/articles/s41591-020-0931-3#citeas (18.11.2021)

Microsoft (2020a). Microsoft erklärt: Was ist Deep Learning? Definition & Funktionen von DL. News Microsoft. https://news.microsoft.com/de-at/microsoft-erklart-was-ist-deep-learning-definition-funktionen-von-dl/ (18.11.2021)

Microsoft (2020b). Microsoft erklärt: Was ist künstliche Intelligenz? Definition & Funktionen von AI. News Microsoft. https://news.microsoft.com/de-at/microsoft-erklart-was-ist-kunstliche-intelligenz-definition-funktionen-von-ki/ (18.11.2021)

Microsoft (2021). Use AI Insights in Power BI Desktop. Microsoft. https://docs.microsoft.com/en-us/power-bi/transform-model/desktop-ai-insights (18.11.2021)

Mindsync (2021). Is High Computing Power A Roadblock in the Path to AI Systems Deployment? Probably Not. https://medium.com/mindsync-ai/is-high-computing-power-a-roadblock-in-the-path-to-ai-systems-deployment-probably-not-6c7c5772e7e2 (18.11.2021)

Minonne, A. (2021). European Spending on Artificial Intelligence Will Reach USD 22 Billion in 2022, Supported by Strong Investments Across Banking and Manufacturing, Says IDC. IDC. https://www.idc.com/getdoc.jsp?containerId=prEUR148297521 (18.11.2021)

Monterio, B. (2020). 8 Steps to assess your ML/AI Maturity Model, Wordlink. http://insights.worldlink-us.com/blog/machine_learning_artificial_intelligence_maturity (18.11.2021)

National Safety Council (2021). Work Injury Costs and Time Lost. NSC Injury Facts. https://injuryfacts.nsc.org/work/costs/work-injury-costs/ (18.11.2021)

Nolan, A. (2021). Artificial intelligence, its diffusion and uses in manufacturing, Going Digital Toolkit Note, No. 12. http://goingdigital.oecd.org/data/notes/No12_ToolkitNote_AI&Manufacturing.pdf

OECD (2020). Artificial intelligence: Changing landscape for SMEs. https://www.oecd-ilibrary.org/sites/01a4ae9d-en/index.html?itemId=/content/component/01a4ae9d-en

OECD (2021). Studies on SMEs and Entrepreneurship. The Digital Transformation of SMEs. OECD iLibrary. https://www.oecd-ilibrary.org/industry-and-services/oecd-studies-on-smes-and-entrepreneurship_20780990 (18.11.2021)

Ongsulee, P., Chotchaung, V., Bamrungsi, E., & Rodcheewit, T. (2018). Big data, predictive analytics and machine learning. In 2018 16th International Conference on ICT and Knowledge Engineering (ICT&KE) (pp. 1-6). IEEE. https://ieeexplore.ieee.org/abstract/document/8612393

Osaruonamen, J. (2021). Consumer Perception in The Age of AI.

Pathak, R. (2021). How BMW uses Artificial Intelligence (AI)? Analytic Steps. https://www.analyticssteps.com/blogs/how-bmw-uses-artificial-intelligence-ai (18.11.2021)

Portugal, I., Alencar, P., & Cowan, D. (2018). The use of machine learning algorithms in recommender systems: A systematic review. Expert Systems with Applications, 97, 205-227.

Potember, R. (2017). Perspectives on research in artificial intelligence and artificial general intelligence relevant to DoD. MITRE Corporation MCLEAN United States. https://apps.dtic.mil/sti/pdfs/AD1024432.pdf

Presize (2021). Die perfekte Kleidergröße im E-Commerce – 100% digital. www.presize.ai (18.11.2021)

Prohorovs, A. (2020). Unicorn Exits as a Trigger for the Development of Small Countries' Startup Ecosystems Forbes, (Latvian edition) No, 14-19. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3726135 (18.11.2021)

PwC (2017). Sizing the prize What's the real value of AI for your business and how can you capitalize? https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf (18.11.2021)

PwC (2020). PwC's annual AI Predictions Survey 2021. www.pwc.com/us/en/tech-effect/ai-analytics/ai-predictions.html (18.11.2021)

Ransbotham, S., Kiron, D., Gerbert, P., & Reeves, M. (2017). Reshaping business with artificial intelligence: Closing the gap between ambition and action. MIT Sloan Management Review, 59(1). https://www.proquest.com/docview/1950374030?pq-origsite=gscholar&fromopenview=true (18.11.2021)

Rao, L. (2009). Google Acquires reCaptcha To Power Scanning For Google Books And Google News.

Richman, D. (2016). How Starbucks is using artificial intelligence to connect with customers and boost sales. Geekwire. https://www.geekwire.com/2016/starbucks-using-artificial-intelligence-connect-customers-boost-sales/ (18.11.2021).

Rieg, T., Frick, J., Baumgartl, H., & Buettner, R. (2020). Demonstration of the potential of white-box machine learning approaches to gain insights from cardiovascular disease electrocardiograms. PloS one, 15(12), e0243615. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0243615 (18.11.2021)

Sanyal, S. (2021). How much does AI cost in 2021?, Analytics Insight. https://www.analyticsinsight.net/how-much-does-artificial-intelligence-cost-in-2021/ (18.11.2021)

Sellwood, M. A., Ahmed, M., Segler, M. HS & Brown, N. (2018). Artificial intelligence in drug discovery, Future Science. https://www.future-science.com/doi/full/10.4155/fmc-2018-0212 (18.11.2021)

Senarathna, I., Wilkin, C., Warren, M., Yeoh, W., & Salzman, S. (2018). Factors that influence adoption of cloud computing: An empirical study of Australian SMEs. Australasian Journal of Information Systems, 22. https://journal.acs.org.au/index.php/ajis/article/view/1603 (18.11.2021)

Shanghong, L. (2021). Funding of artificial intelligence (AI) startup companies worldwide from 2014 to 2021, Statista. https://www.statista.com/statistics/621468/worldwide-artificial-intelligence-startup-company-funding-by-year/ (18.11.2021)

Shroff, R. (2020). Preparing Corporations for Artificial Intelligence Adoptions. Towards Data Science. https://towardsdatascience.com/preparing-corporations-for-artificial-intelligence-adoption-e67603a22037 (18.11.2021)

Srinivasan, P. (2021). AIaaS – Out of the box pre-built Solutions. Analytics Vidhya. https://www.analyticsvidhya.com/blog/2021/01/aiaas-out-of-the-box-pre-built-solutions/ (18.11.2021)

Synced (2019). The Staggering Cost of Training SOTA AI Models. https://medium.com/syncedreview/the-staggering-cost-of-training-sota-ai-models-e329e80fa82 (18.11.2021)

Tech Advisor (2019). How tech giants are investing in artificial intelligence. Tech Advisor Reviews. https://www.techadvisor.com/feature/small-business/tech-giants-investing-in-artificial-intelligence-3788534/ (18.11.2021)

UNESCO (2021). Recommendations on the ethics of artificial intelligence. UNESCO Artificial Intelligence. https://en.unesco.org/artificial-intelligence/ethics (18.11.2021)

UiPath (2021). Robotic Process Automation (RPA)–Automation software to end repetitive tasks and make digital transformation a reality. https://www.uipath.com/rpa/robotic-process-automation (18.11.2021)

USCF (2016). Big Data, Analytics & Artificial Intelligence The Future of Health Care is Here. General Electric Company. https://www.gehealthcare.com/static/pulse/uploads/2016/12/GE-Healthcare-White-Paper_FINAL.pdf (18.11.2021)

Uslu K (2020). *The Role of Cloud Computing in Artificial Intelligence. Towards Data Science*. https://towardsdatascience.com/the-role-of-cloud-computing-in-artificial-intelligence-507ffd68ca46 (18.11.2021).

Wang, J. (2020). The Cost of AI Training is Improving at 50x the Speed of Moore's Law: Why It's Still Early Days for AI, ARK Invest.

Wang, P., & Goertzel, B. (2007). Introduction: Aspects of artificial general intelligence. Artificial General Intelligence (AGI), 1-16. https://cis.temple.edu/~pwang/Publication/AGI_Aspects.pdf

Wang, Y. (2016). What are the biggest obstacles to growth of SMEs in developing countries?–An empirical evidence from an enterprise survey. Borsa Istanbul Review, 16(3), 167-176. https://www.sciencedirect.com/science/article/pii/S2214845016300539

Wichert, A., *Encyclopaedia of Neuroscience: Artificial Intelligence* (2021). Spektrum.de. https://www.spektrum.de/lexikon/neurowissenschaft/kuenstliche-intelligenz/6810 (18.10.2021)

Wiggers, K. (2020). AI training costs dropped 100-fold between 2017 and 2019, ARK Invest. https://venturebeat.com/2020/06/04/ark-invest-ai-training-costs-dropped-100-fold-between-2017-and-2019/ (18.11.2021)

Wilson, B. (1998-2012). The machine learning dictionary. CSE. http://www.cse.unsw.edu.au/~billw/mldict.html#activnfn (18.11.2021)

Wilson, F. (2018). The 5 Step Approach to a Successful Product Launch, Agile Zone Analysis, DZone. https://dzone.com/articles/the-5-step-approach-to-a-successful-product-launch (18.11.2021)

Wilson, G. (2020). Boeing reduces lead time and saves money by 3d printing aircraft parts. Manufacturing Global. https://manufacturingglobal.com/technology/boeing-reduces-lead-time-and-saves-money-3d-printing-aircraft-parts (18.11.2021)

Wise, J., de Barron, A. G., Splendiani, A., Balali-Mood, B., Vasant, D., Little, E., ... & Hedley, V. (2019). Implementation and relevance of FAIR data principles in biopharmaceutical R&D. Drug discovery today, 24(4), 933-938. https://www.sciencedirect.com/science/article/pii/S1359644618303039 (18.11.2021)

Wisconsin University (2021). How Much Is a Data Scientist's Salary? Data Science. datasciencedegree.wisconsin.edu/data-science/data-scientist-salary/ (18.11.2021)

World Economic Forum (2020). Global Gender Gap Report 2020. https://www.weforum.org/reports/gender-gap-2020-report-100-years-pay-equality (18.11.2021)

Xavier University (2019). Maturity Level Characterization of AI Capabilities for Self-Assessment Whitepaper, Xavier Health. https://www.xavierhealth.org/aio-whitepaper-maturity-level-characterization and https://static1.squarespace.com/static/58d0113a3e00bef537b02b70/t/5f46551350be76b443b84d3/1598444819754/AI_Poster_MaturityModel_2020.pdf