AI CUBE

GUIDELINES

AI & BD IN THE PROCESS INDUSTRY

ARTIFICIAL INTELLIGENCE AND BIG DATA CSA FOR PROCESS INDUSTRY USERS, BUSINESS DEVELOPMENT AND EXPLOITATION

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958402

DOCUMENT INTRODUCTION

The following document constitutes the AI-CUBE Guidelines compiling the main results of the AI-CUBE project and providing a guide for researchers, managers and operators in the implementation of AI and BD technologies in the process industry.

Specific guidance and recommendations for the implementation of AI and BD solutions in the process industry are included according to the main project results, such as:

- The current state of the AI and BD technologies implementation in the 10 SPIRE industrial sectors is presented (heatmaps and AI-CUBE survey results).
- AI-CUBE Maturity Model and the current status quo of the AI and BD technologies is included.
- The implementation path and the main barriers faced when implementing AI and BD solutions and how to overcome them are detailed.
- The value proposition of AI and BD solutions in the process industry is assessed.
- AI and BD-driven innovative trends and business models have been explored.
- Finally, the future of these technologies has been incorporated according to different future scenarios and other roadmaps initiatives.

AI-CUBE project intended to include information from all sectors of SPIRE to date, but as the project started before the incorporation of the Pulp & Paper and Refining sectors, some of the results and figures included in this guide do not cover all sectors.

This document is interactive with clickable links redirecting the user to different sections of the guidelines or webpages on the AI-CUBE website.

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By clicking on the INDUSTRY icon (found at the bottom of each page), the reader can easily navigate back to the status quo of the industry sectors.

By clicking on the BUSINESS MODEL icon (found at the bottom of each page), the reader can easily to the AI-CUBE business model.

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TODAY

THE AI-CUBE PROJECT IN BRIEF

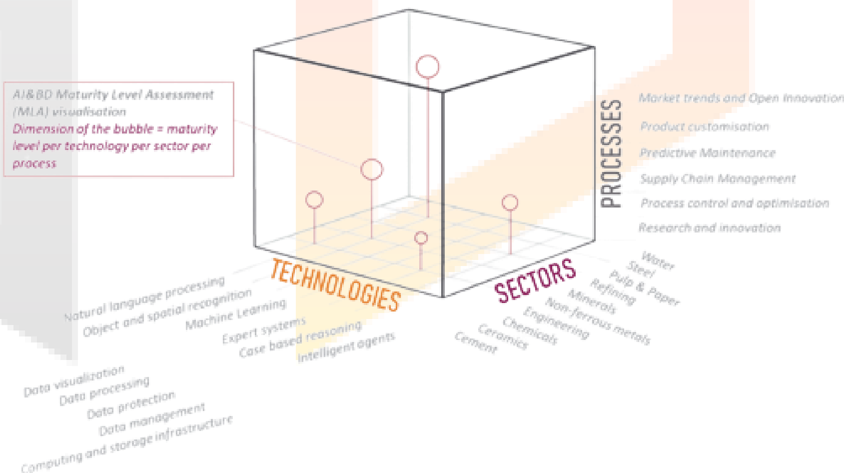
Funded under the Horizon 2020 Research and Innovation Programme.

Aimed at studing AI and BD status quo and harnessing and optimizing its potential in the European process industry (low adoption rates @23%, but 85% of business leaders believe!)

Resulted in these guidelines the 10 SPIRE industrial sectors, with specific recommendations on the application of AI and BD in the process industry, to guide researchers, managers, and operators in the implementation of these technologies.

THE AI-CUBE CONCEPT

The AI-CUBE concept is based on a tri-axial mapping of AI and BD technologies. It allows to map and visualize the status of AI and BD solutions use and penetration per SPIRE sector and macro-application process area.



Do you want to know more about AI-CUBE categories? CLICK HERE

To access all the AI-CUBE related documents, news and publications CLICK HERE

AI-CUBE OBJECTIVES

- **High-level study** on AI and BD technologies applied in the 10 SPIRE sectors
- Main **gaps and opportunities** for Artificial Intelligence & Big Data technologies in the process industry

- Preliminary set of **concerns, opportunities and barriers per sector** to be validated by experts in AI & BD technologies with experience in the process industry
- Expand the findings with **new Business Model opportunities and transferability** of AI & BD solutions

AI-CUBE PARTNERS

TO READ MORE ABOUT EACH OF THE PARTNERS CLICK ON THEIR LOGO ABOVE, OR

CLICK HERE

AI-CUBE MAIN RESULTS

MAIN FINDINGS FROM THE LITERATURE

SECTORS & TECHNOLOGIES

Here we see the number of references found in the literature searches for technologies with respect to sectors. It can be seen that the "hot" technology category is machine learning, with a particular concentration in the chemicals and minerals sectors. Categories with the least references are "data understanding and characterization", "data protection", and "computing and storage infrastructure".

	Data understanding & characterization	Natural language processing	Object and spatial recognition	Machine learning	Intelligent planning	Expert systems	Case based reasoning	Intelligent agents	Cyber-physical systems	Data visualization	Data processing	Data protection	Data manage-ment	Computing & storage infrastructure
Cement				4		3	1		1	2	2		1	
Ceramics			2	4	4	2	1	1	2	1	4		2	
Chemicals	8		1	10			1		1		2		3	3
Engineering	1	8		5	1	4	4	4	8	1		1	5	3
Minerals	2	1	4	14	4	1	1	2	1	1	1	1	3	2
Non-ferrous metals				7		2	1		1	1	3		1	
Steel		2	5	8		7	1	2	5		2		2	
Water		1	1	7	1			1	1	2	2		3	

HEAT MAP

>9	high
4-9	medium
0-3	low

Figure 1. "Heat map" sectors vs technologies.

PROCESSES & TECHNOLOGIES

Here we see the number of references found in the literature searches for technologies with respect to processes. It shows a particular concentration of references for machine learning, data processing, expert systems and object and spatial recognition. Likewise, the least references are found for data protection and natural language processing, for example.

	Data understanding & characterization	Natural language processing	Object & spatial recognition	Machine learning	Intelligent planning	Expert systems	Case based reasoning	Intelligent agents	Cyber-physical systems	Data visualization	Data processing	Data protection	Data manage-ment	Computing & storage infrastructure
(Model predictive) process control & optimization	2	1	10	25	7	11	5	1	8	4	12		6	3
Market trends & open innovation	4	2		5				1					1	1
Predictive maintenance		2	2	5		2	2	2	5				1	1
Product design/custom		3	1	10		4	2		4	2	2		3	
Research & innovation management, planning & design	5			8	1			1		1	2	1	7	2
Supply chain management (re) configuring & scheduling		4		6	2	2	1	5	3	1		1	2	1

HEAT MAP

>9	high
4-9	medium
0-3	low

Figure 2. "Heat map" processes vs technologies.

SECTORS & PROCESSES

Here we see that Process Control is the 'hottest' process (vertically), whereas Engineering and Minerals are the hottest sectors (horizontally).

	Market trends & open innovation	Product design / customization	Predictive maintenance	Supply chain management (re) configuring & scheduling	(Model predictive) process control & optimization	Research & innovation management, planning & design
Cement		5		1	8	
Ceramics		2		2	17	2
Chemicals	7			2	13	7
Engineering	4	12	10	10	6	3
Minerals	3	1	4	3	19	8
Non-ferrous metals		4		1	9	2
Steel		7	8	6	13	
Water				3	10	6

HEAT MAP

>9	high
4-9	medium
0-3	low

Figure 3. "Heat map" sectors vs processes.

KEY SURVEY RESULTS

The AI Cube online survey was conducted between July 2021 and May 2022. During this period, over 100 experts from the process industry were surveyed in a standardized manner as users and providers of AI or Big Data-based IT solutions. This results in over 50 concrete AI and BD use cases in the various sectors of the process industry, which describe different technologies in the 6 application areas. The experiences and lessons learned are described below. Most of the participants considered for this evaluation come from Germany, Spain, Italy, Austria, and Greece and represent both large companies (over 500 employees) and small and medium-sized enterprises.

USAGE OF AI AND BD TECHNOLOGIES IN THE APPLICATION AREAS OF THE PROCESS INDUSTRY

The mapping results of the applied solutions described in the survey show that despite existing variances in technology use among the different application areas, no process is completely disregarded in terms of AI and BD usage. However, in the recorded answer set, there is already a strong focus on the three areas of process optimization, research and innovation, and predictive maintenance as can be seen in the total sums per sector. The area of process control and optimization is by far the most AI and BD supported application area in the process industry across all sectors. At the same time, it becomes apparent that a lot of potential exists in supply chain management, product customisation and market trends as well as open innovation.

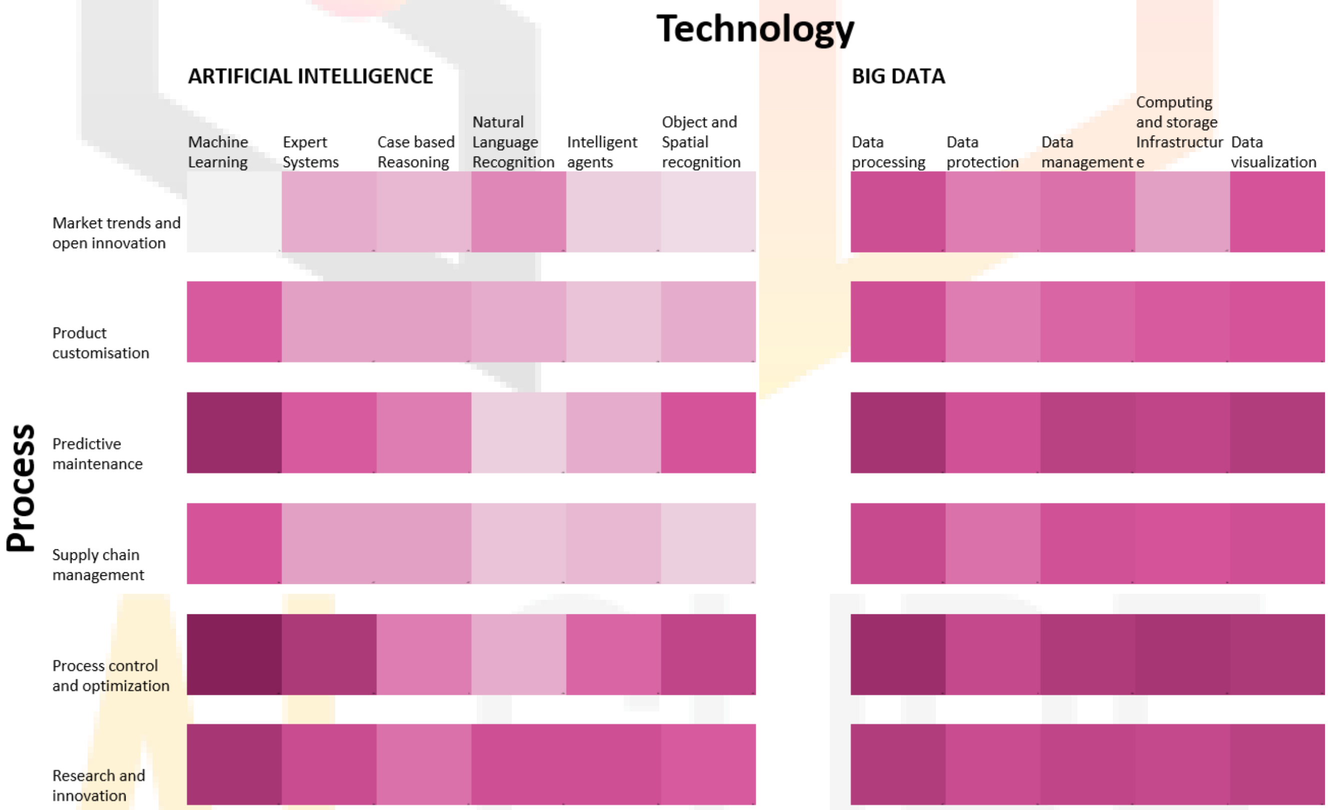


Figure 4. AI and BD technology used per process. Darker colour = more usage in process-internal comparison.

MATURITY OF AI AND BD SOLUTIONS

The analysis of the maturity of AI and BD solutions and implementations is collected and analysed within the framework of the developed AI-**CUBE Maturity Level Model**. The focus here is on company-specific aspects as well as technology-specific aspects. The results are structured based on 4 maturity levels in the categories of strategy, organization, people, technology and data, and collected using specific sub-dimensions. While strategy, organisational and people related maturity perspectives are measured on the company level, the technology and data related aspects are implementation specific.

Each single question and the summarised mean averages per category are described with levels of maturity. The levels are characterized as follows:

- Level 1 - little or no adoption of the practice: companies have little knowledge of the topic and the practice is not applied in the companies.
- Level 2 - experimenting the practice with limited use: companies are starting to experiment and test a certain practice along their processes.
- Level 3 - on the way of formalizing and adopting the practice: companies are at a good stage of implementation of a practice with high impact on the processes.
- Level 4 - full adoption and optimization of the practice: companies that are champions of a practice which is well established and recognised as important for their processes

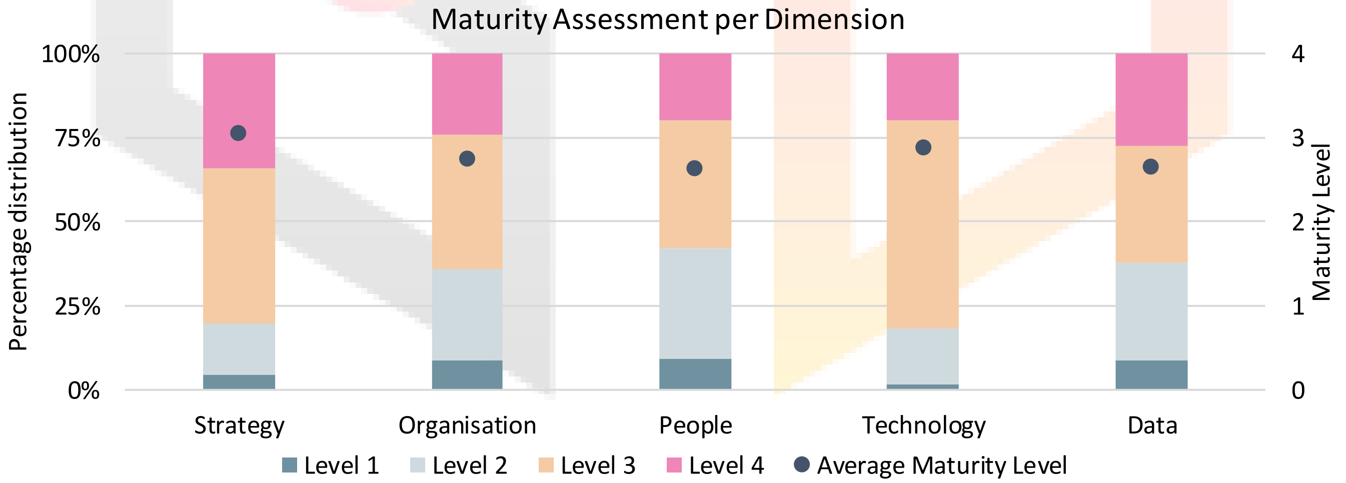


Figure 5. Maturity assessment per category in the process industry.

The category-based maturity assess for the user and provider participations in the online survey shows different maturities in the categories. While the strategy related and the technology-related aspects of AI and BD implementations are handled maturely (high percentage of Level 4 and Level 3), the data-related and the organisational aspects are not as mature as the other categories. The lowest maturity can be identified in the workforce-related category.

Especially the aspects of consideration of the importance of AI and BD in the corporate strategy, the attention to the corporate culture as well as the seen potential of AI and BD are very mature in levels 3 and 4. The latest has a very high has a very large share of level 4 evaluations, which indicates that adaptation in practice is already very pronounced. This maturity aspect marks the highest measured maturity level across the whole assessment marking the special status of this aspects. Consideration of ELSI factors and monitoring and control are mainly in the phases of experimentation or on the way to formalization and adoption (Phases 2 and 3) marking the lowest maturities in the strategy related aspects.

While the responsibilities in the organisational structure, the budget allocation and the handling of data privacy have higher maturity levels, the division of responsibility and the transparent governance have a higher portion of level 2 assessments and less level 4 level assessments. Overall, however, there appears to be a relatively uniform maturity level across the different aspects of this category in the process industry. Interestingly, while the industrial users think of integration of responsibilities in the organisational structure as the most mature aspect, the external providers see the budget allocation and the handling of data privacy more mature.

Looking at different aspects of the dimension of people, it can be seen, that especially the skill development hinders a higher overall maturity from the user viewpoint. From the perspective of the providers, the aspects of engagement of employees and the alignment to the technological evolution is seen with an even lower maturity level than the skill development in the companies of the process industry. In the evaluation of the provider ratings, many ratings in levels 1 and 2 were also identified here, which indicate sub-frames with low levels of implementation in these aspects.

The technology related aspects, which are assessed on an implementation level and not on a company level, the technology related aspects tend to have a comparable high maturity regarding the integration in processes and applications and the balance between technology and human intervention. Users and providers agree that in the data dimension, the updating of internal and external data and the processing of data are less mature than the other aspects. the basic quality and transparency of the data seems to have a higher maturity in the process industry. Especially from the user's point of view, however, there seems to be very little maturity in the processing of the data.

About the general maturity in the process industry, however, many aspects and categories seem to be well developed, at least among the participants of the survey. The technology-related aspects and the strategy-related aspects should be emphasised here. Especially in the workforce-related aspects, maturity is not yet as high as in the other categories.

ENABLING FACTORS OF AI AND BD IMPLEMENTATION

Concepts, processes, and factors that enable the use of AI were also identified and grouped based on literature surveys. The finally identified enabling factors are described and grouped by the three categories of strategy and company related factors, data and technology related factors and human related factors.

The overall evaluation shows that the aspects of the use of skilled personnel, the data-related aspects of accessibility, quality, and availability, as well as the domain know-how and the clear business objectives and scopes are decisive for AI and BD implementation projects. Summarised, the most important barriers and enabling factors can be analysed together to proactively define the best possible initial environment for a planned AI and BD implementation in the process industry and then actively respond to specific existing barriers. Based on the enabling factors presented here, companies in the process industry can, in addition to internal preparation and provision, also consider possible outsourcing if important factors cannot be provided satisfactorily purely internally.

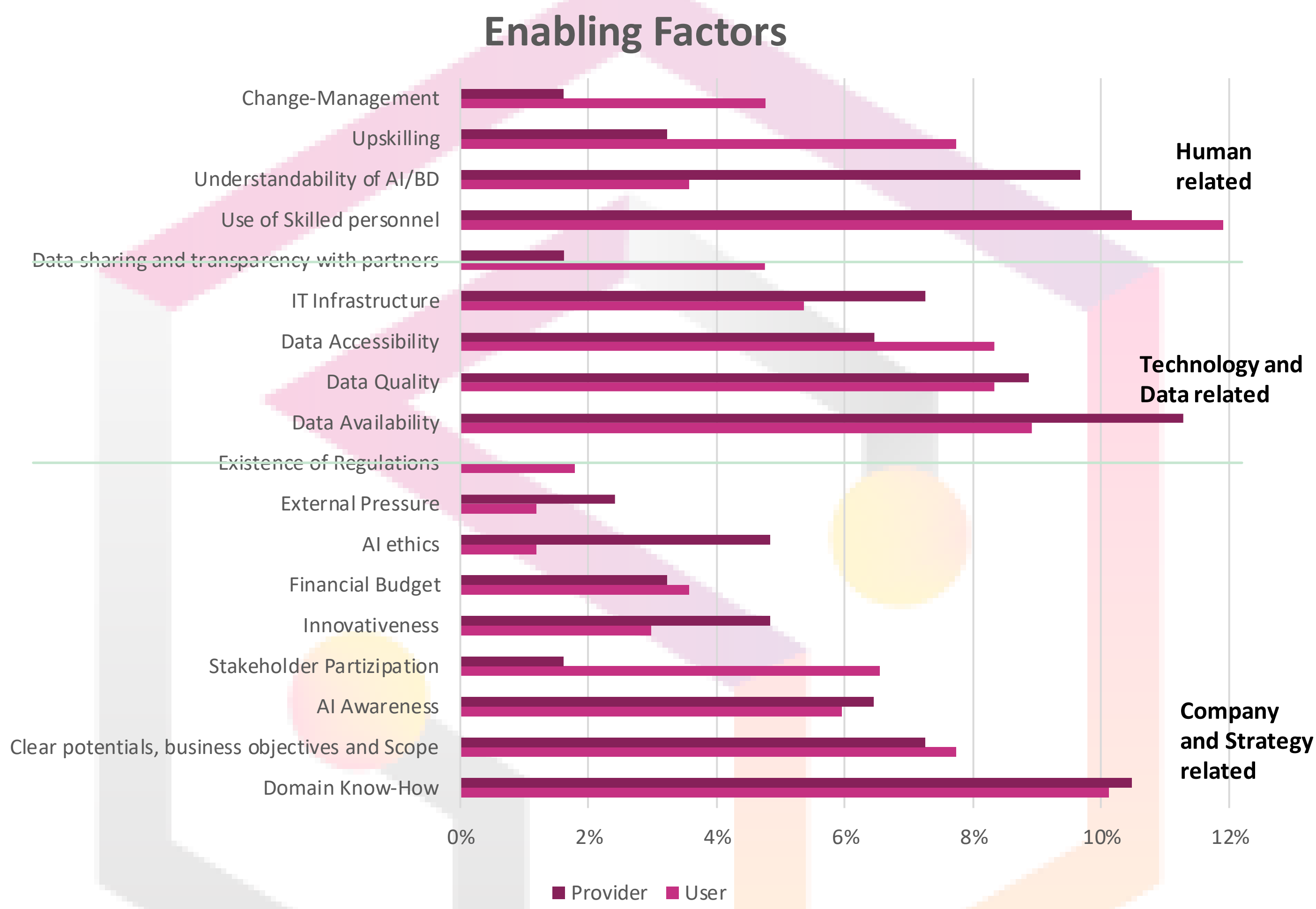
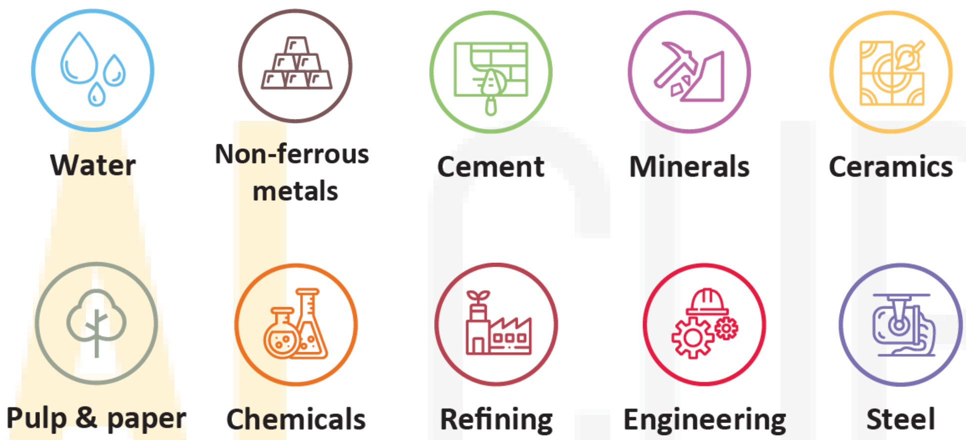


Figure 6. Enabling factors for the implementation of AI and BD solutions in the process industry.

STATUS QUO OF THE SPIRE INDUSTRIAL SECTORS

Are you looking for more information about your sector? Click on the related icon to see the content for each SPIRE sector below



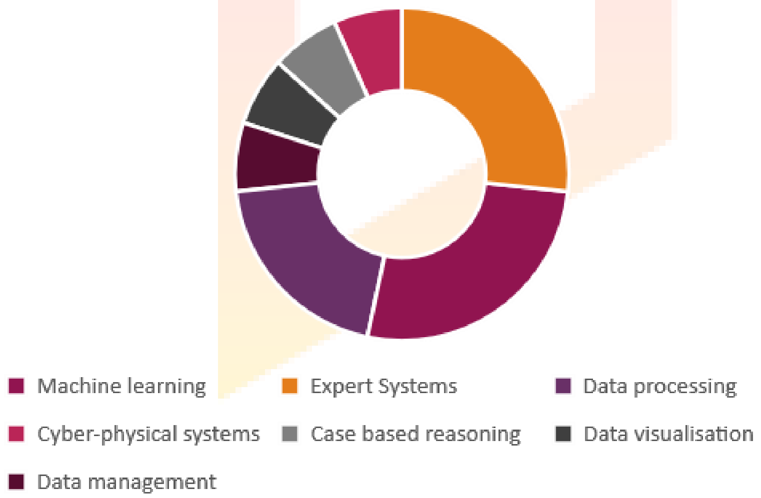
CEMENT SECTOR

Cement

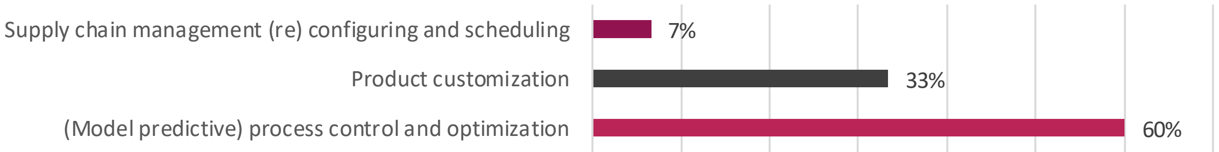
SECTOR OVERVIEW

Needs/Challenges	Main processes addressed by AI/BD technologies	Main AI/BD technologies applied	Business concerns
Needs: optimization of kiln, firing, material processing, predictive maintenance, predict process behavior, supply chain, remote operation, logistics, goods shipments tracking	Predictive maintenance	Machine learning	High energy consumption
	(Model predictive) process control and optimization	Cyber-physical systems	Predictive maintenance, remote operation
	Product design	Intelligent planning	Predict process behavior
	Research & innovation management, planning & design	Data understanding and characterization	Better understanding of value chain
Challenges: high energy consumption	Supply chain management		

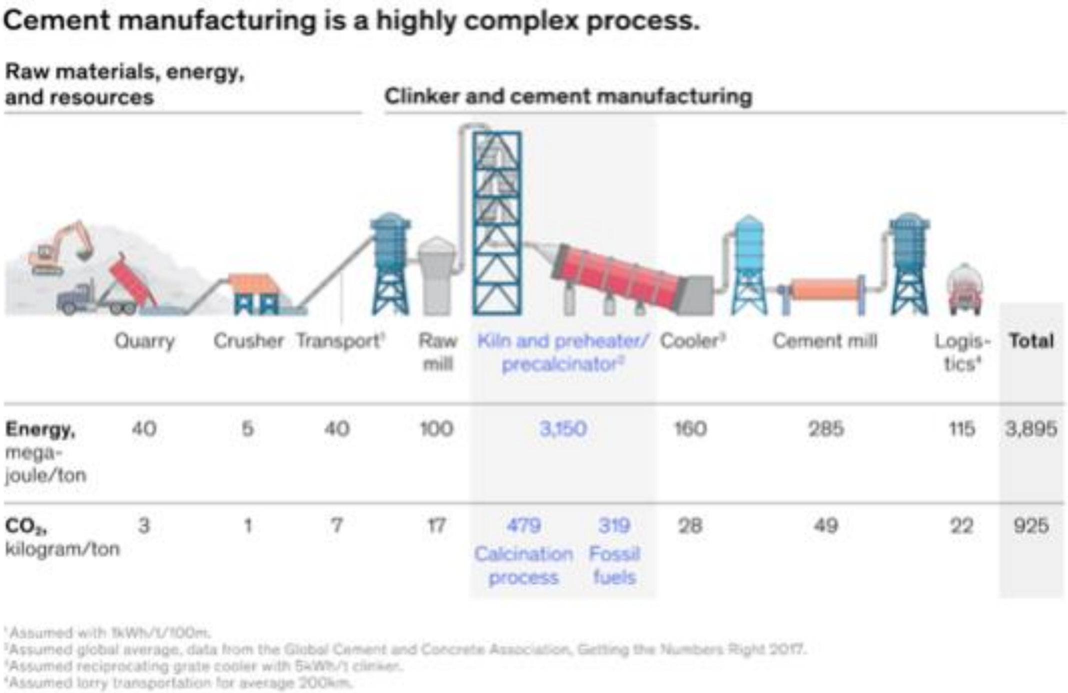
Main AI and BD technologies applied in the cement sector:



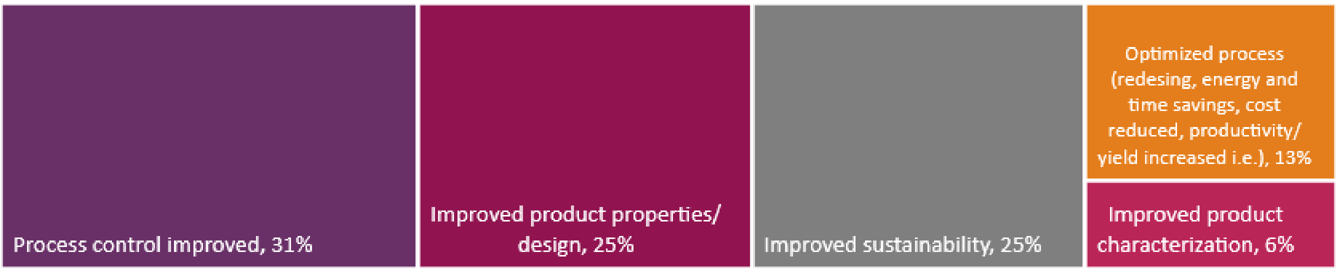
Main processes addressed by AI and BD solutions in the cement sector:



Cement production process:



Value proposition provided by AI and BD in the cement sector:



The argument is made for artificial intelligence for cement plants, citing the following possible application areas:

- Failure prediction (operative and corrective failures);
- Production processes optimization;
- Predictive maintenance;
- Remote operation; and
- Product design and quality; smart supply chain.

An example is given of how a global cement company has taken on board AI solutions. Cemex, a major building material company contracted a specialist AI company (Petuum) to implement the industrial AI products. The first product (Industrial AI Autopilot) claims to use Machine Learning and Deep Learning support complex process control to obtain a better optimization (superior to a human operator). The authors state the system uses deep learning neural networks trained with two years of plant information, including data from cement processes with associated timestamps.

The next AI product focuses on "Modeling for decision making", which models the variable inter-relationships over time. The historical operating models provide support for the current evaluation and future prediction of process performance.

Following on from the previous product, AI-based models are used to provide optimal settings, which are recommended for the plant. Plant data is analysed to optimize and predict process behaviour. For example, the AI system will recommend optimum settings for control variables in real-time, which are then validated by human operators before applying them.

The software "back-end" of the AI Autopilot product integrates historical process data via a data infrastructure, processing historical and streaming data, used to make the predictions.

Finally, some more examples of how the Peetum software is applied to specific steps and processes in the cement production process. It is said that the AI model used for cement uses smart factory principles to optimises the whole manufacturing process. This includes AI optimization for the cooler, ball mill, vertical mill, and the complete pyro process which includes pre-heater, cooler, and kiln. The AI model learns the dynamics of each of the industrial assets (cooler, ball mill, vertical mill, pre-heater, and kiln) and processes from historical sensor data, creating prescriptions by searching for the optimal values of critical control parameters, and closing the loop by sending prescriptions back to assets and processes to be activated.

REFERENCES

- Manufacturing process (cement), Lafarge, https://www.lafarge.com.eg/en/2_2_1-Manufacturing_process
- Leetham, D., The Cement manufacturing process, August 2015, ThermoFisher Scientific.
- Cement building material, extraction and processing. Britannica Encyclopedia.
- von Buchwaldt, A., Four challenges to achieving sustainability in the cement industry, Ernst & Young, Feb. 2020
- The 21st-century cement plant: Greener and more connected, Mc Kinsey, Sept. 2020.
- Rodrigues, F. A., Joekes, I. Cement Industry: Sustainability, Challenges and Perspectives, June 2010, Environmental Chemistry Letters 9(2):151-166, DOI: 10.1007/s10311-010-0302-2
- Artificial Intelligence boost for the Cement Plant. Artificial Intelligence News (Pye), Sept. 2020.
- AI Powering the future of cement, Cement World. May 2020.

Go back to all the SPIRE industrial sectors here.

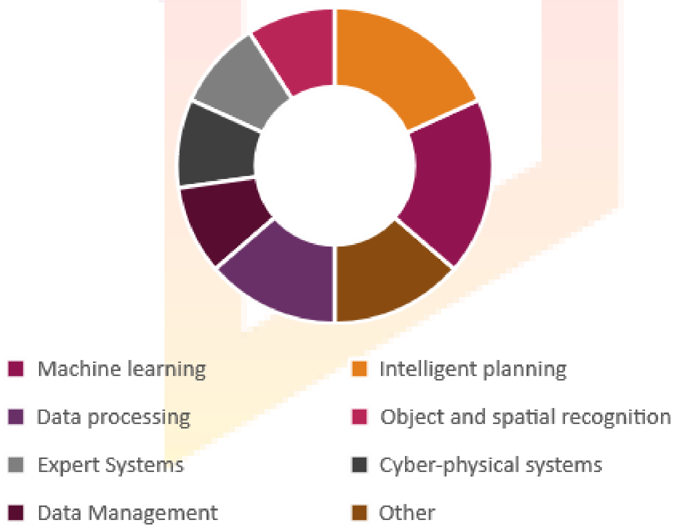
CERAMICS SECTOR

Ceramics

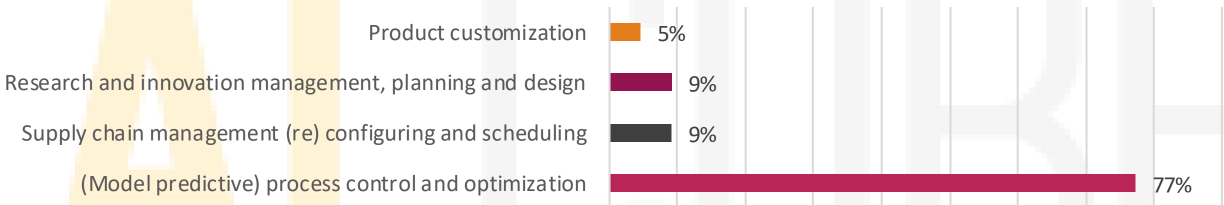
SECTOR OVERVIEW

Needs/Challenges	Process	AI/BD technologies	Business concerns
Needs: optimum raw material processing, firing, finishing.	Product customization/design	Machine learning	Material processing
	Supply chain management (re)configuring and scheduling	Data understanding and characterization	High energy consumption
Challenges: high energy consumption, reduction of defects (cracking/foaming)	Model predictive) process control and optimization	Intelligent planning	Reduce defects (cracking/foaming)
	Research and innovation management, planning and design		

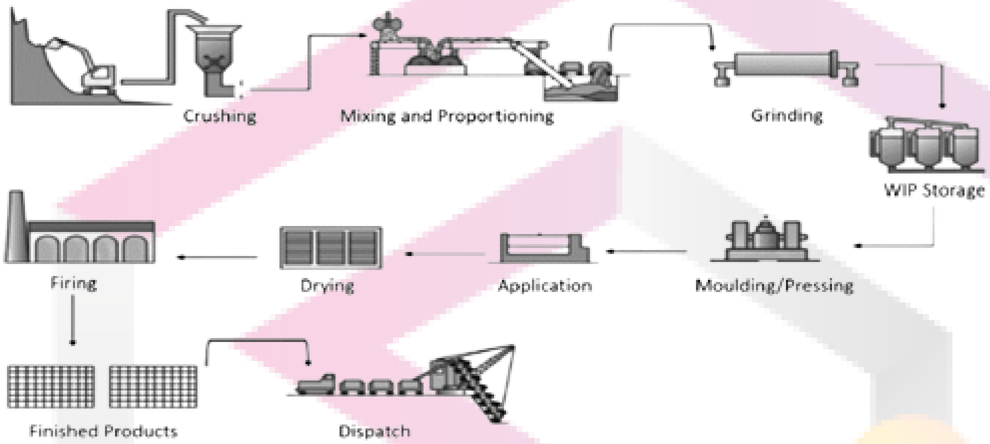
Main AI and BD technologies applied in the ceramics sector:



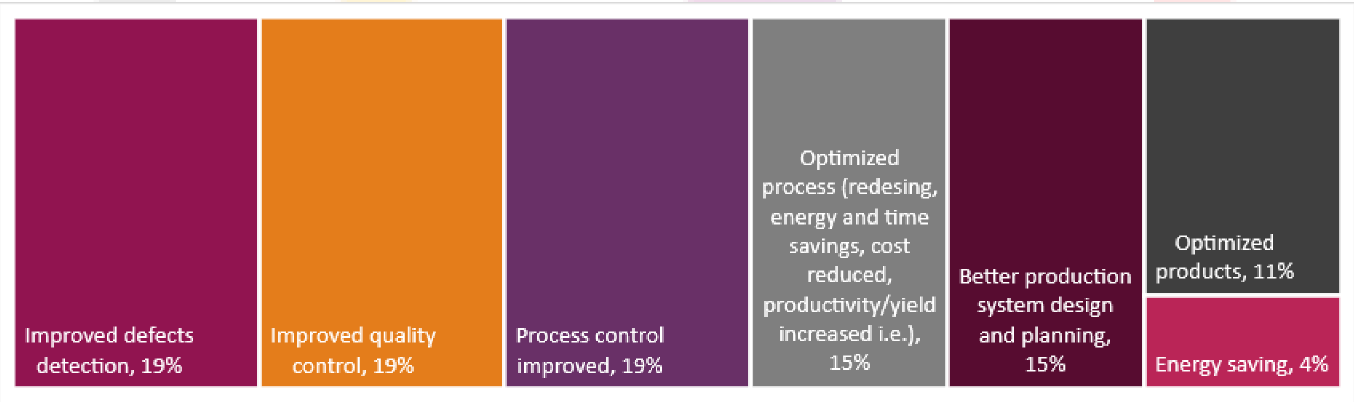
Main processes addressed by AI and BD solutions in the ceramics sector:



Ceramics production process:



Value proposition provided by AI and BD in the cement sector:



The role of AI and BD in the ceramics sector can be summarised as follows:

Machine learning algorithms are already being used in ceramic industry, especially in quality control processes. With various algorithms, it is possible to predict the behaviour of the material under extreme temperature conditions and to detect anomalies and deficiencies in the tiles. The studies being carried out with the help of Artificial Intelligence (AI) seek to predict the anomalous behaviour of materials during the manufacturing process, making it possible to control and use the components that meet better resistance conditions than those currently being manufactured. By recognizing incorrect patterns they are able to detect anomalies in products early, reducing shrinkage and increasing profitability. Nexusintegra already found companies that are working with this technology and are using it in this line or in others. They are, above all, companies in the ceramic, porcelain stoneware and flooring sectors.

Recent developments in AI&BD include real time monitoring, process optimization and programming, design improvement, quality control.

- Color Management software which allows ink savings and a quality improved designs thanks to mathematical algorithms (Digit-S)

- Data collection generated by advanced sensors, real time monitoring and remote monitoring of smart moulds for ceramics, optimization of warehouse management and freight transfer flows (DataRiver)
- Automated optical inspection designed to automatically find flaws in ceramic tiles before mass production (defect detection of the tiles to determine acceptance and rejection conditions (RSIP Vision)
- Real-time monitoring of production and sales performance

There is a growing interest in Big Data implementation among ceramic companies in their management and decision making processes. Research results show that the use of new information technology in ceramic companies is already in its infancy and is gradually growing. Today, special focus is on the process of production, sales, product development and maintaining and improving business turnover.

REFERENCES

- Sarkar, D. Ceramic processing: industrial practices. 2020. CRC Press, Taylor & Francis Group
- BAT BREF Ceramic Manufacturing Industry. European Commission
- Quinteiro, A., Dias, A., Arroja. Assessment of carbon footprint in different industrial sectors. Chapter: The Carbon Footprint of Ceramic Products. Springer Publications 2014
- Lean Manufacturing in the ceramic industry. MAPE 2019, volume 2, issue 1, pp. 457-466)
- The 4 industries that benefit the most from machine learning. Digital transformation - Nexus Integra / March 6 2020
- Digitization and Big Data in the Ceramic Tile Industry. 2019. Articels.
- Faisal, Md. and Katiyar, V. Identification of essential requirements of IOT and Big Data analytics to extend ceramic manufacturing. 2016. IJESRT 5(12).

Go back to all the SPIRE industrial sectors here.

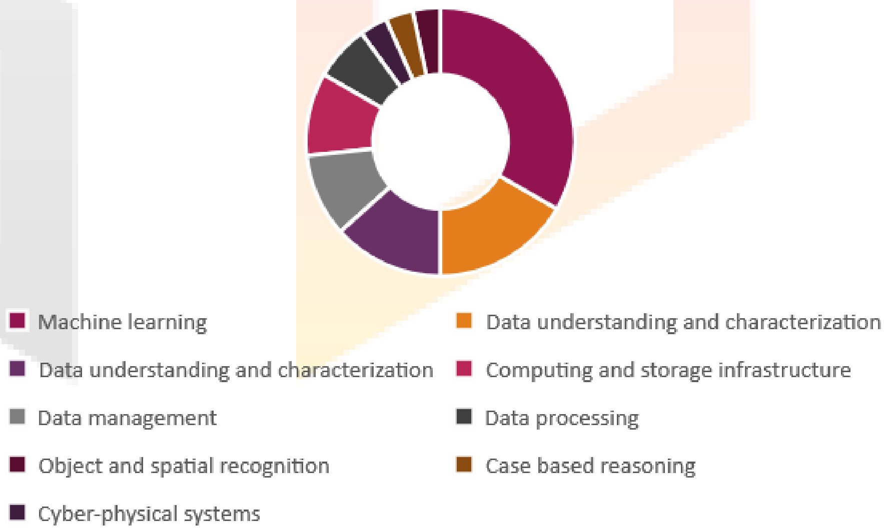
CHEMICALS SECTOR

Chemicals

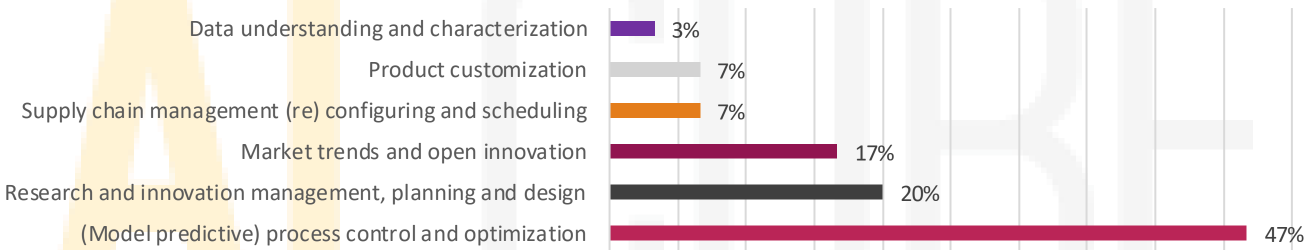
SECTOR OVERVIEW

Needs/Challenges	Process	AI/BD technologies	Business concerns
Needs: optimum conversion of materials. reliability, production planning, continuous sensor-based monitoring process control logistics, goods shipments tracking.	Supply chain management (re)configuring and scheduling	Machine learning Intelligent planning	Process control logistics, goods shipments tracking
	(Model predictive) process control and optimization	Cyber-physical systems	Continuous sensor-based monitoring
	Research and innovation management, planning and design	Data understanding and characterization	Security and human safety Conversion of materials
		Expert systems	Energy concumption
Challenges: waste avoidance, process complexity.	Supply Chain Management		Waste avoidance
			Process complexity, reliability, production planning (complex reaction mechanism identification, PAT data processing / identification)

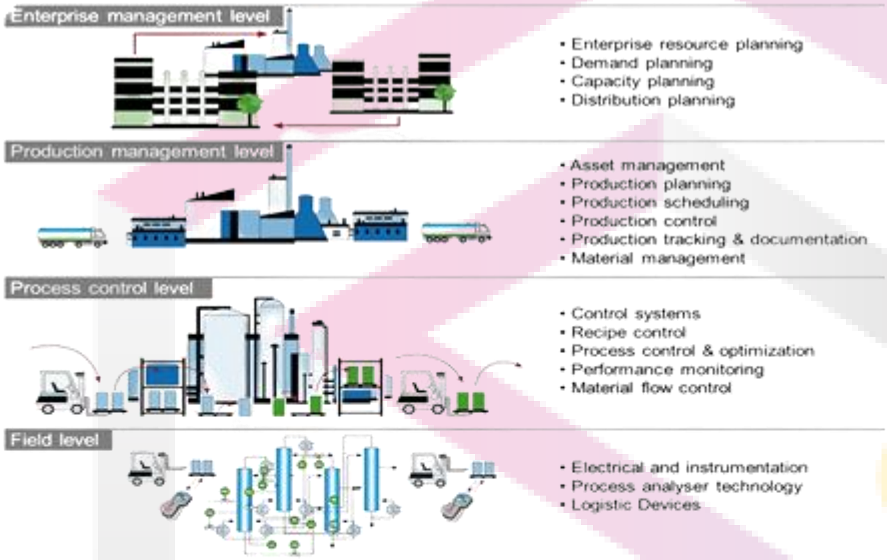
Main AI and BD technologies applied in the chemicals sector:



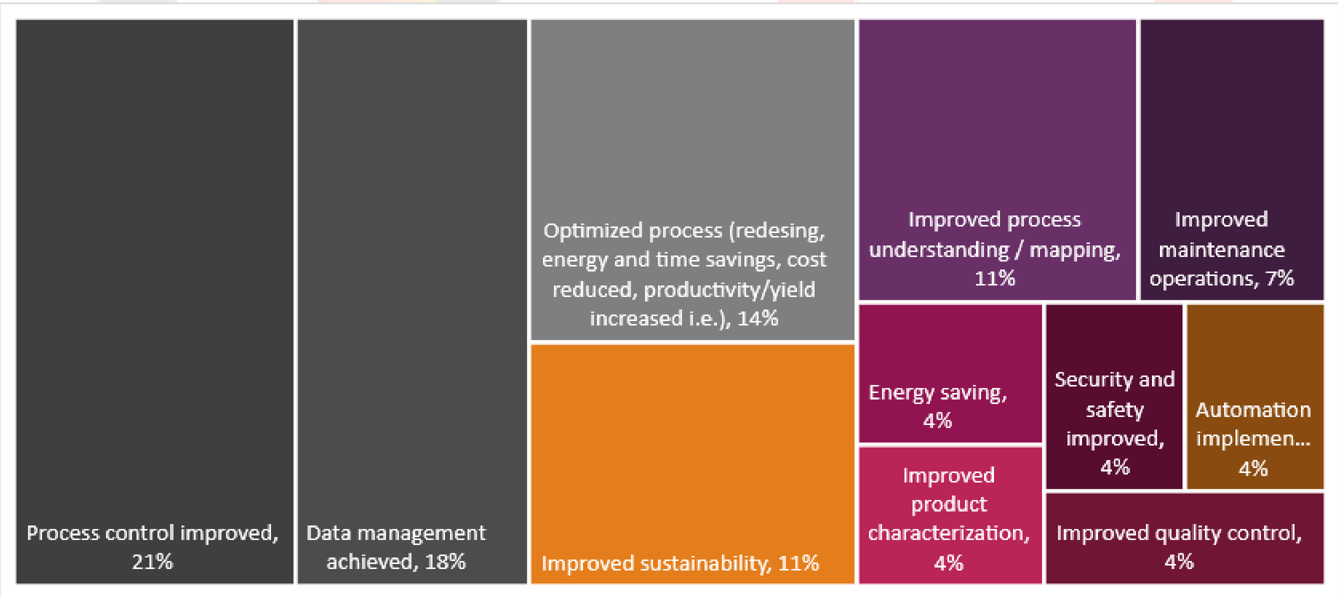
Main processes addressed by AI and BD solutions in the chemicals sector:



Chemicals production process:



Value proposition provided by AI and BD in the chemicals sector:



Research showed that digital technologies can contribute to future R&D improvements in the bioprocesses, and particularly through the development of:

- new process monitoring methodologies, thanks to microfabricated discrete sensors, real-time monitoring and digital imaging;
- new process control concepts, applying expert systems, artificial intelligence, neural networks, and principal component analysis.

Against the lack of data traditionally experienced in the biology experimentation, the XXI century witnessed astonishing technological improvements that made great quantity of data available in biology, generating the need for specific tools that could facilitate the analysis and interpretation of those data. In this context, predictive design and rapid evaluation are at the core of the bio-based approaches, along with the assembly of new materials through laboratory automation, high-throughput (HT) characterisation and post-production processing.

More in general, there are several processes in which the digital technologies can add value and improve the bio-based industry in particular, and in general any chemical or process industry. Some examples are given:

- Smart Design for extended products' life and improved recyclability
- Monitoring Systems based on automatic data flows for trend assessing, renewed production processes, emission calculation
- Stock exchange platforms for bio-based materials, digital marketplaces to increase bio-based materials availability, volumes, and improve quality assessment
- Advanced just-in-time delivery processes based on IoT or M2M communication for optimised delivery
- Decentralised production through 3D printing, enabling smaller modular manufacturing facilities, using Small Scale Intelligent Manufacturing Systems (SIIMS)
- Digital chains to connect supply chains across sectors based on horizontal and vertical integration through digital networks
- Consumer-centric and improved end-of-life usage through ingredient tracking
- Advanced computer-aided growth processes for growth processes' steering and tracking (e.g. input factors such as fertilizers, light, water)
- Augmented Reality (AR) training tools in human-machine collaboration
- Smart manufacturing enabling automatic control and steering of biochemical processes and communication across production entities

REFERENCES

- Birch H. Grüne Chemie. In: 50 Schlüsselideen Chemie. Berlin, Heidelberg: Springer; 2016.
- Nisser A, Malanowski N. Branchenanalyse chemische und pharmazeutische Industrie: Zukünftige Entwicklungen im Zuge Künstlicher Intelligenz. Düsseldorf, Forschungsförderung, No 166, Hans-Böckler-Stiftung; 2019.
- Verband der Chemischen Industrie e.V. Auf einen Blick Chemische Industrie 2019. Frankfurt am Main; 2019
- Segler M, Preuss M, Waller M. Planning Chemical Syntheses with Deep Neural Networks and Symbolic AI. Nature; 2018, vol. 555, pp. 604-610.
- Philp, J. and D.E. Winickoff (2018), "Realising the circular bioeconomy", OECD Science, Technology and Industry Policy Papers, No. 60, OECD Publishing, Paris
- https://www.oecd-ilibrary.org/sites/bd16d851-en/index.html?itemId=/content/component/bd16d851-en
- https://ec.europa.eu/jrc/en/science-update/future-bio-based-chemicals-eu-bioeconomy
- https://ec.europa.eu/growth/sectors/biotechnology/bio-based-products_en

- The Bio-based Industries Vision. Accelerating innovation and market uptake of bio-based products. BBI Consortium, July 2012 https://biconsortium.eu/sites/biconsortium.eu/files/downloads/BIC_BBI_Vision_web.pdf
- National Research Council (US) Committee on Biobased Industrial Products. Washington (DC): National Academies Press (US); 2000
- Klitkou, A., Bozell, J., Panoutsou, C., Kuhndt, M., Kuusisaari, J., & Beckmann, J. P. (2017). Bioeconomy and digitalization

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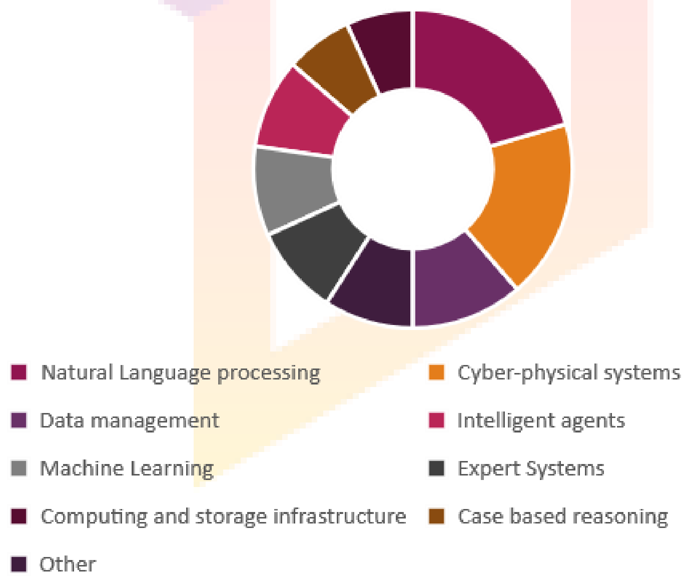
ENGINEERING SECTOR

Engineering

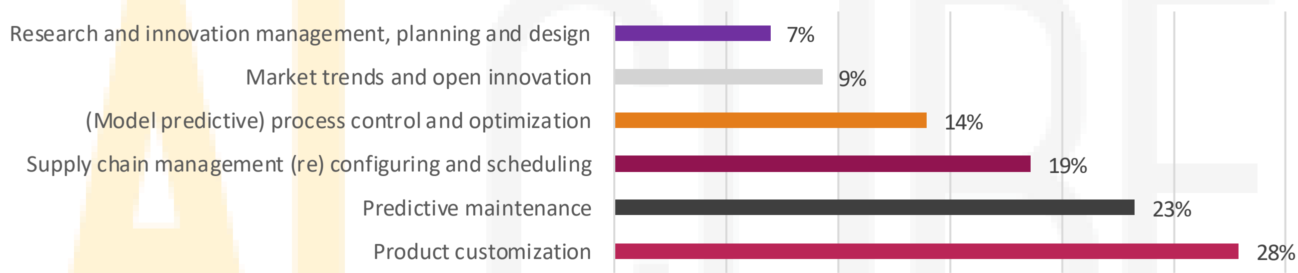
SECTOR OVERVIEW

Needs/Challenges	Process	AI/BD technologies	Business concerns
Needs: quality assurance, predictive maintenance, sensor data capture	(Model predictive) process control and optimization	Machine learning	Fault detection, quality assurance, rapid quality diagnosis
	Predictive maintenance	Intelligent planning	Predictive maintenance, data quality, sensor data capture
Challenges: fault detection, data quality	Supply chain management	Cyber-physical systems	Process optimization
		Data understanding and characterization	Degradation prediction and infrastructure monitoring (i.e. boiler fouling)
		Object and spatial recognition	

Main AI and BD technologies applied in the engineering sector:



Main processes addressed by AI and BD solutions in the engineering sector:



Value proposition provided by AI and BD in the engineering sector:

The role of AI and BD in the engineering sector:

The implementation of the AI engineering solutions in the process and manufacturing industries brings two main advantages: i) an effective and accurate information processing, and ii) a powerful data storage and calculation. AI technology builds production model through computer simulation system and makes comprehensive data analysis to make relevant precautious measures in case of emergency, which guarantees the orderly production system, reduces the possible capital loss of manufacturing enterprises, and also greatly improves the production efficiency and accuracy of manufacturing. Applications of artificial intelligence in manufacturing and process industries:

- Fault diagnosis. AI can automatically classify and categorize information to improve the accuracy of calculation, avoiding errors or failures and diagnosing.
- Quality inspection. Based on deep learning machine vision technology, AI detection makes quality inspection standards more unified, stable, and faster detection.
- Safer working places. AI recognizes the safety status of working places and warns the workers in case of emergency, set up visiting limitations of workers (image recognition), assess whether the workers on the spot are conforming to the safety regulations.
- In product development. AI (due to its powerful data storage and effective information processing) can help its clients find their desirable products and thus shorten the time for products design.
- In products manufacturing procedure, AI can help bring about most accurate products.
- In products rear service, AI provide far-distance equipment maintenance, spare parts management, routine or predictive equipment maintenance, fault warning and diagnosis, products upgrading, and etc.

Regarding the adoption according to the company size, independently of sectors, large companies tend to invest in AI faster at scale [37]. This is typical of digital adoption, in which, for instance, small and midsized businesses have typically lagged behind in their decision to invest in new technologies.

REFERENCES

- Eurofound: The Future of Manufacturing in Europe – Game changing technologies
- Marangell, F. (2019). Metal and plastic 3D printing: hype and the quiet revolution
- Seric, A. (2020). Managing COVID-19: How the pandemic disrupts global value chains
- Opportunities of Artificial Intelligence. European Union, 2020 (http://www.europarl.europa.eu/supporting-analyses)
- Palomar, S. Artificial Intelligence in Industry: New Services and Applications. (https://www.ennomotive.com/artificial-intelligence-industry/)
- Filipowiak, J. (2019). How can Virtual Reality (VR) be used for business?
- Seebo. (n.d.). Improving chemical production quality and yield by minimising process inefficiencies
- The Application of Artificial Intelligence in Mechanical Manufacture Industry. Yubo Wang 2019 IOP Conf. Ser.: Mater. Sci. Eng.688 033058
- Artificial intelligence: the next digital frontier? Mckinsey Global Insititute 2017

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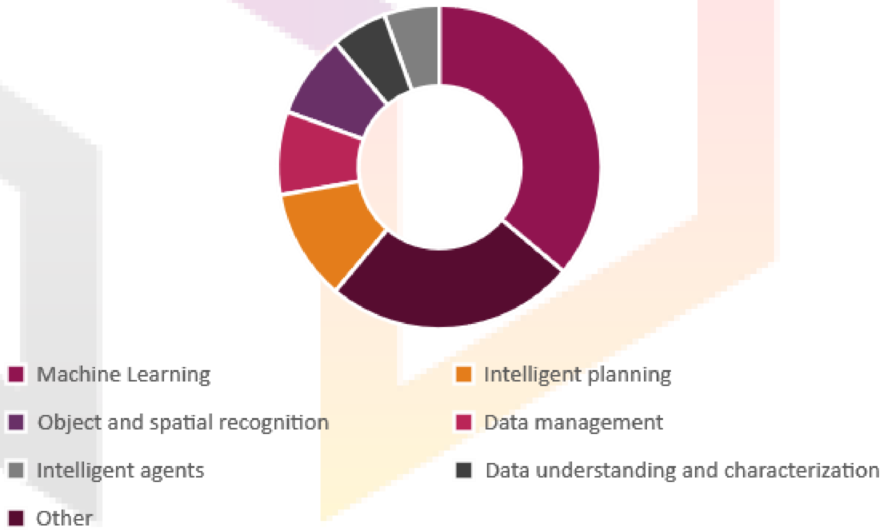
MINERALS SECTOR

Minerals

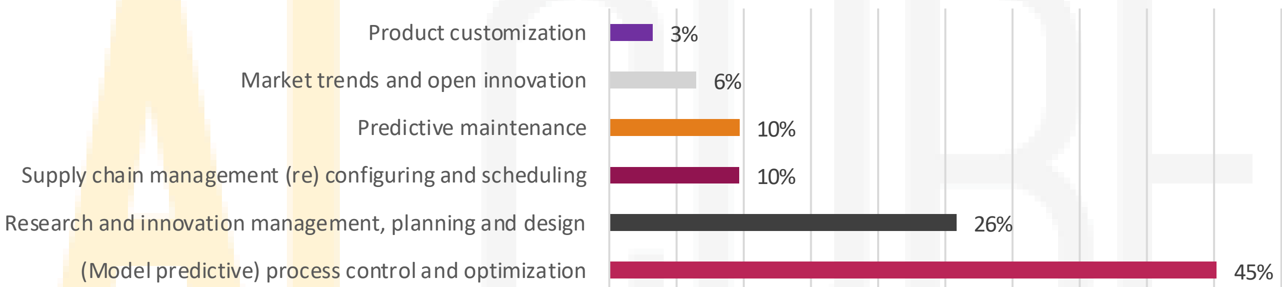
SECTOR OVERVIEW

Needs/Challenges	Process	AI/BD technologies	Business concerns
Needs: efficient milling of raw material, mining/extraction, scheduling/planning, security, automation, remote monitoring.	(Model predictive) process control and optimization	Machine learning Intelligent planning	Temperature control during the full process (since aggregated to the use)
	Predictive maintenance	Cyber-physical systems (SLAM Self Driving Vehicles)	Real time monitoring (control of raw materials)
Challenges: high energy consumption, security and human safety.			Scheduling/planning
			High energy consumption
			Security and human safety
			Automation, remote monitoring

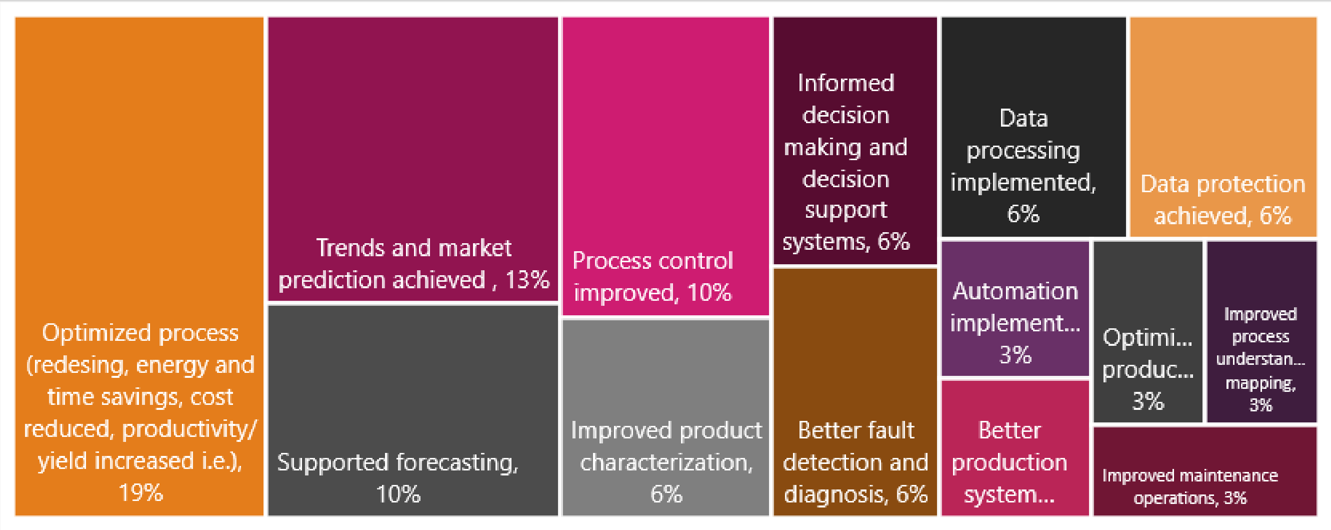
Main AI and BD technologies applied in the minerals sector:



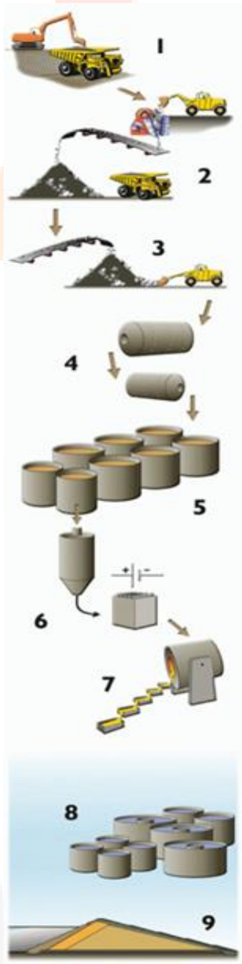
Main processes addressed by AI and BD solutions in the minerals sector:



Value proposition provided by AI and BD in the minerals sector:



Minerals production process:



The role of AI and BD in the minerals sector:

According to a survey of technological trends for the contemporary mining industry, five main areas are defined: (i) Spatial data visualisation. This is considered a disruptive technology; (ii) Geographic information systems; (iii) Artificial intelligence; (iv) Automated drones; (v) Use of renewable energy by the Mining Industry.

In the case of AI, it is cited as now taking a lead in decision-making for knowledge based companies. They use smart data and machine learning to improve operational efficiency, mine safety, and production workflow. It is stated that implementing artificial intelligence technology generates day-to-day data in half the time than what has been used previously in the field. Also, the mining industry evolves rapidly, so machine learning and AI impact the way mines today make choices for the future. The following are indicated as some ways the latest technology in artificial intelligence impacts the working mine:

Mineral processing and exploration: companies can find minerals more easily by using high-performance AI technology.

Autonomous vehicles and drillers: over the past decade, mining companies have been incorporating autonomous vehicles in their pit-to-pit operations. Self-driving trucks can easily navigate through narrow tunnels with AI (SLAM technology). Now, drilling systems are also simplified with a single operator that controls several drill rigs at once.

The overall objective is to obtain an optimal industry efficiency. As the mining industry attempts to reduce costs and lessen its environmental impact, techniques such as AI can help to ensure safety and reliability for both miners and the land that mines use.

Finally, different transformation technologies are discussed for the mining industry. They especially highlight: internet of things, robotics, plasma (to increase yields), 3d imaging technologies, automated drilling, remote operations control & monitoring.

REFERENCES

- The Mining Process. https://www.waihigold.co.nz/mining/the-mining-process/
- Key Stages in the Mining Process. https://www.cornwall.gov.uk/environment-and-planning/conservation/world-heritage-site/delving-deeper/mining-processes/key-stages-in-the-mining-process
- The mining industry, overview and trends. https://resourcegovernance.org/sites/default/files/nrgi_Mineral-Industry.pdf
- MOgroup process services. https://www.mogroup.com/products-and-services/services/?gclid=Cj0KCQiApY6BBhCsARIsAOI_GjZwIzKJrSN7JSMl3iyXcxvm97VV2k4Gy9W-7QcsYhQ4TOxTI3fb99oaAuLSEALw_wcB
- Challenges and opportunities for a successful mining industry in the future. https://www.researchgate.net/publication/332584218_Challenges_and_opportunities_for_a_successful_mining_industry_in_the_future
- Process control challenges and opportunities in mineral processing. https://www.controlglobal.com/articles/2015/process-control-challenges-and-opportunities-in-mineral-processing/
- Trends in Modern Mining Technology. https://www.angloamerican.com/futuresmart/stories/our-industry/technology/trends-in-modern-mining-technology
- Ten technologies with the power to transform mining. https://www.mining-technology.com/features/featureten-technologies-with-the-power-to-transform-mining-4211240/

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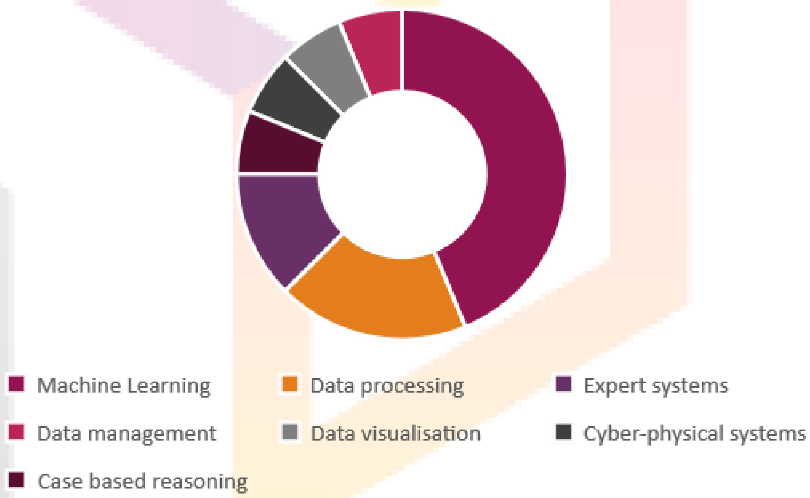
NON-FERROUS METALS SECTOR

Non-ferrous metals

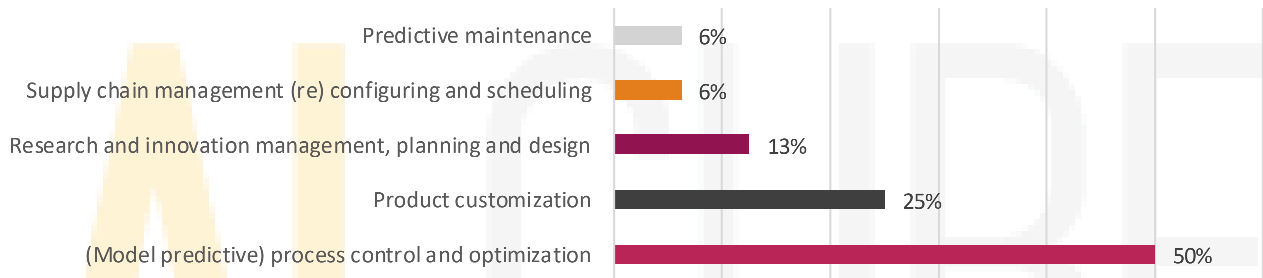
SECTOR OVERVIEW

Needs/Challenges	Process	AI/BD technologies	Business concerns
Needs: furnace, smelting, scrap quality control, logistics.	(Model predictive) process control and optimization	Machine learning	Waste water processing, clean water processing
	Predictive maintenance	Case based reasoning	Water management and quality
Challenges: high energy consumption, risk to humans,		Cyber-physical systems	Complex processing chain, large processing volumes, yield

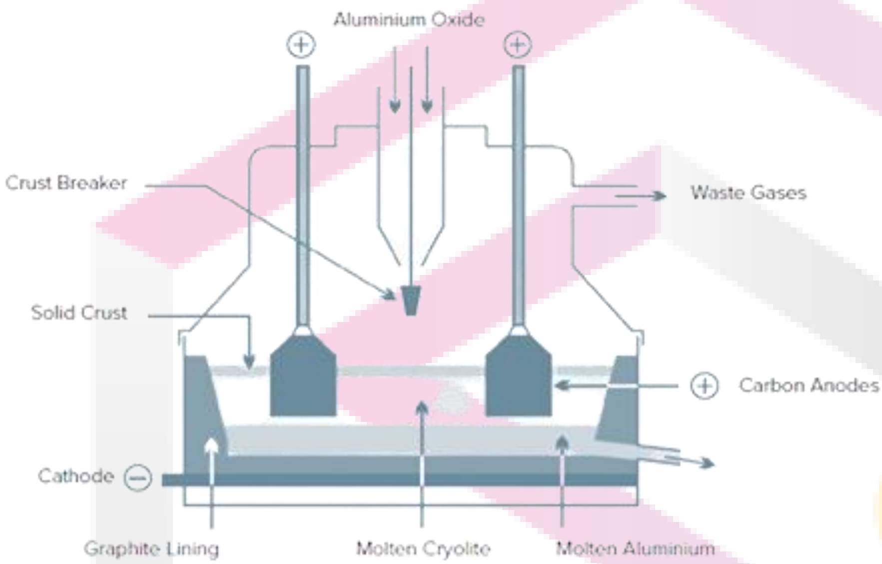
Main AI and BD technologies applied in the non-ferrous metals sector:



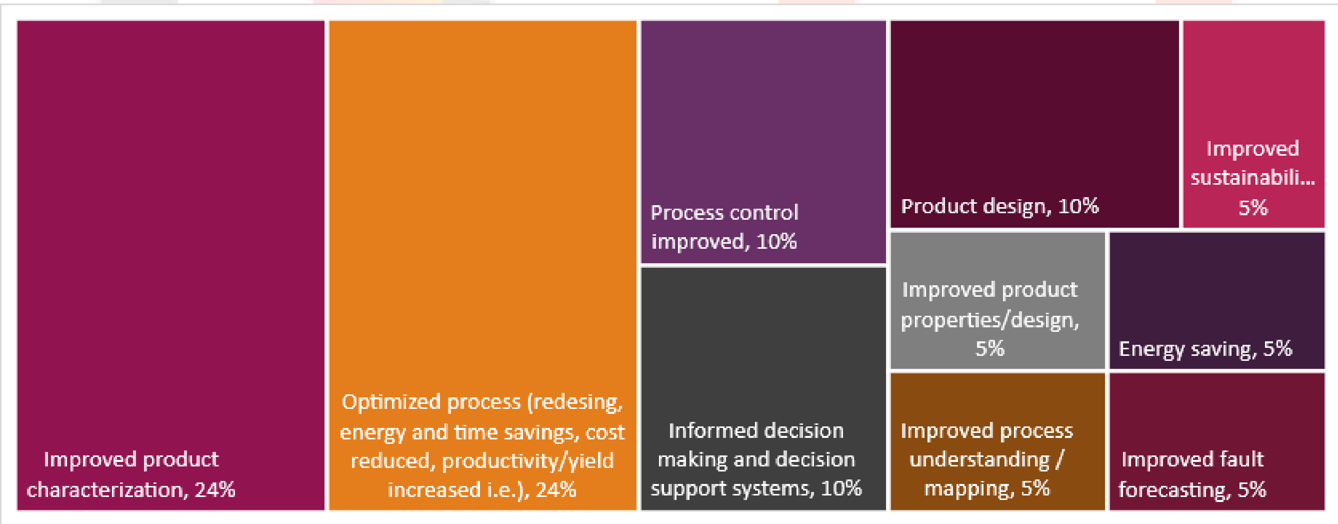
Main processes addressed by AI and BD solutions in the non-ferrous metals sector:



Non-ferrous metals production process:



Value proposition provided by AI and BD in the non-ferrous metals sector:



The role of AI and BD in the non-ferrous sector:

AI and BD have a profound impact on the aforementioned processes to reduce energy consumption. Therefore, new IoT solutions are required not only to measure the energy consumption for a single machine but also measure the energy consumed throughout the production process. Furthermore, an automated system for unifying the scrap quality classes prevents the additional processes and results in higher energy consumption for refining phases.

Unlike ferrous metals, the wide variety of product mixes and production processes in the non-ferrous sector results in unique AI solutions for each plant. Therefore, the role of the plant's production historical data is more dominant than the domain knowledge. This complexity emphasises the decision-support systems through machine learning techniques such as case-based reasoning. However, the uncertainty and randomness in the knowledge and experience should not be overlooked. Also, the adaptability of AI solutions highly depends on the collaboration of managers, engineers, and workers in a production plant. This complexity in the production process is also evident in the raw materials, where just a low proportion of them are the ores, and a high proportion consists of fluxes and other materials from different sources. Thus, the integration of the actors in the raw material provision from the suppliers to the plant requires timely and precise solutions. This aspect emphasises the role of decision-support systems in inbound logistics

REFERENCES

- Roudier, S., Sancho, L.D., Remus, R. and Aguado-Monsonet, M., 2013. Best Available Techniques (BAT) reference document for iron and steel production: Industrial emissions directive 2010/75/EU: integrated pollution prevention and control (No. JRC69967). Joint Research Centre (Seville site).
- Eurometaux, European non-ferrous metals association: https://eurometaux.eu/
- Wyns, T., Khandekar G., Metals for a Climate Neutral Europe: A 2050 blueprint. Institute for European studies (IES).
- del Campo, G., Calatrava, S., Cañada, G., Olloqui, J., Martinez, R., & Santamaria, A. (2018, June). Iot solution for energy optimization in industry 4.0: Issues of a real-life implementation. In 2018 Global Internet of Things Summit (GIoTS) (pp. 1-6). IEEE.
- Guo, S., Li, T., & Zhou, K. (2017, December). An improved case retrieval method for the production manufacturing process of aluminum electrolysis. In 2017 International Conference on Industrial Informatics-Computing Technology, Intelligent Technology, Industrial Information Integration (ICIICII) (pp. 16-20). IEEE.
- Li, L., Xie, Y., Chen, X., Yue, W., & Zeng, Z. (2020). Dynamic uncertain causality graph based on cloud model theory for knowledge representation and reasoning. International Journal of Machine Learning and Cybernetics, 1-19.

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PULP & PAPER SECTOR

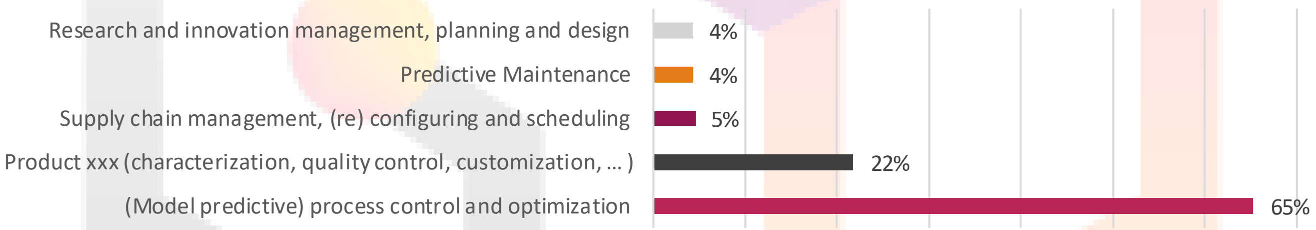
Pulp & paper

The Pulp & Paper sector joined A.SPIRE after the begining of AI-CUBE in 2020 so a more limited analysis was performed for the sector.

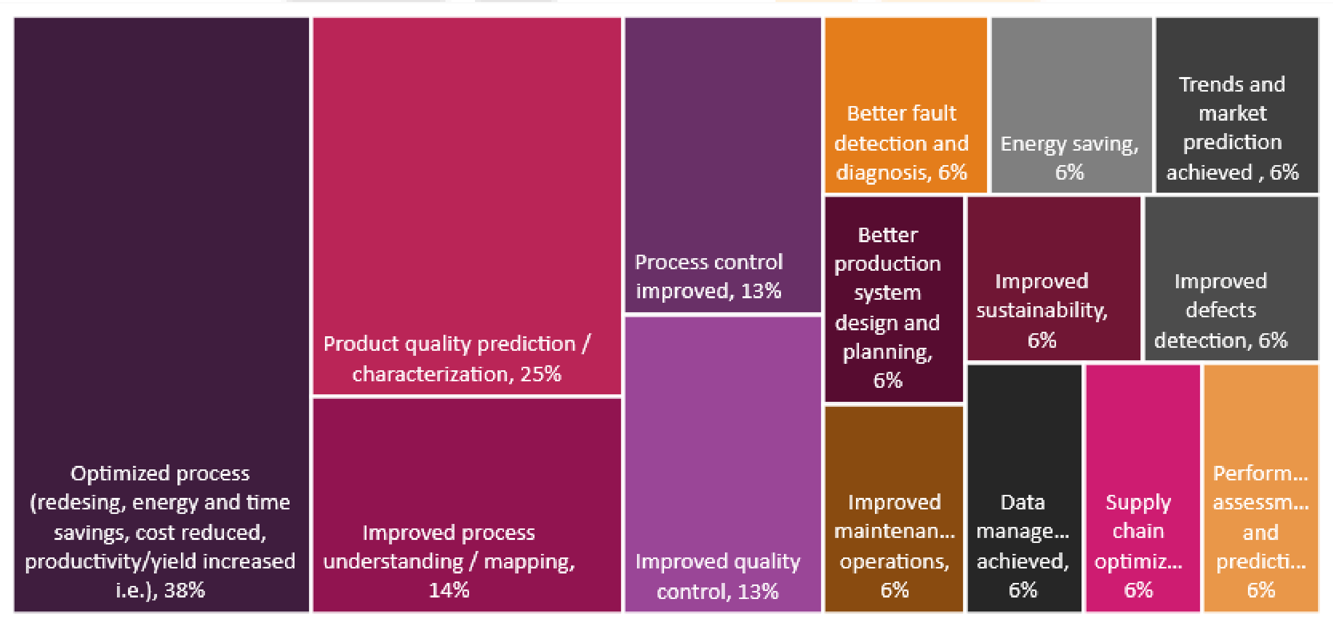
SECTOR OVERVIEW

Process	Business concerns
(Model predictive) process control and optimization	High energy consumption
	Water consumption
Product xxx (characterization, quality control, customization, ...)	Product quality
	Process efficiency and waste avoidance

Main processes addressed by AI and BD solutions in the pulp & paper sector:



Value proposition provided by AI and BD in the pulp & paper sector:



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REFINING SECTOR

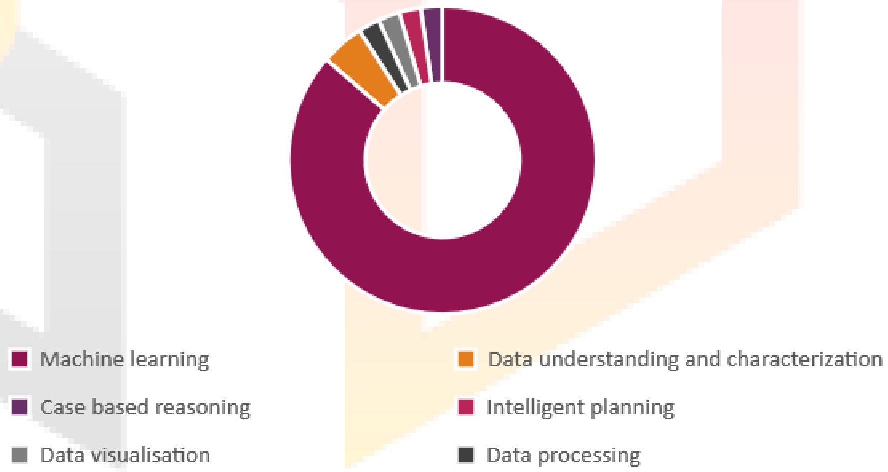
Refining

The Refining SECTOR joined A.SPIRE after the begining of AI-CUBE in 2020 so a more limited analysis was performed for the sector.

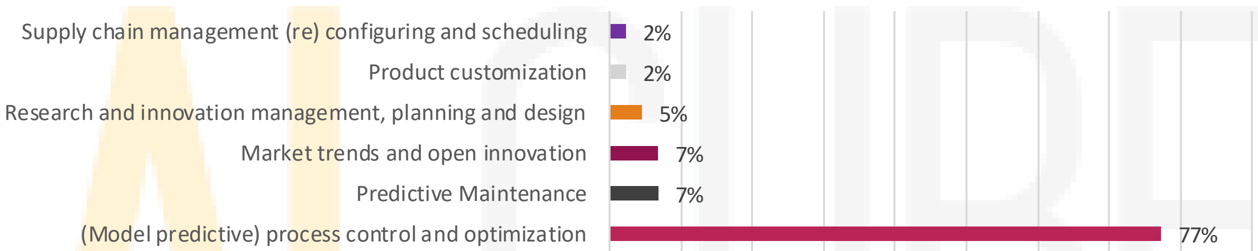
SECTOR OVERVIEW

Process	AI/BD technologies	Business concerns
(Model predictive) process control and optimization	Machine learning	Emissions minimizarion in the destilation process
Research and innovation management, planning and design	Data understanding and characterization	Proccess control and product quality assurance
Predictive Maintenance		Performance optimization
Market trends and open innovation		Corrosion, abrasión and fouling by exterme temperatures

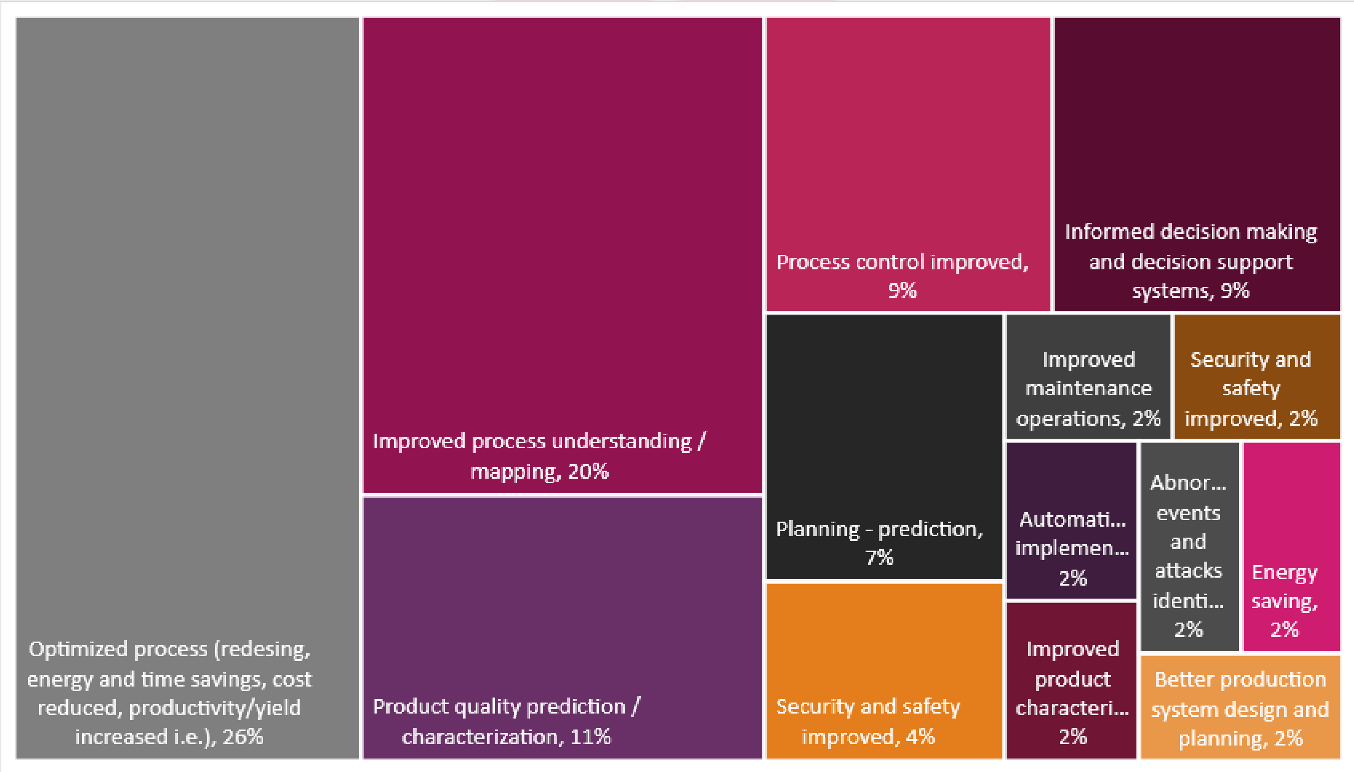
Main AI and BD technologies applied in the refining sector:



Main processes addressed by AI and BD solutions in the refining sector:



Value proposition provided by AI and BD in the refining sector:



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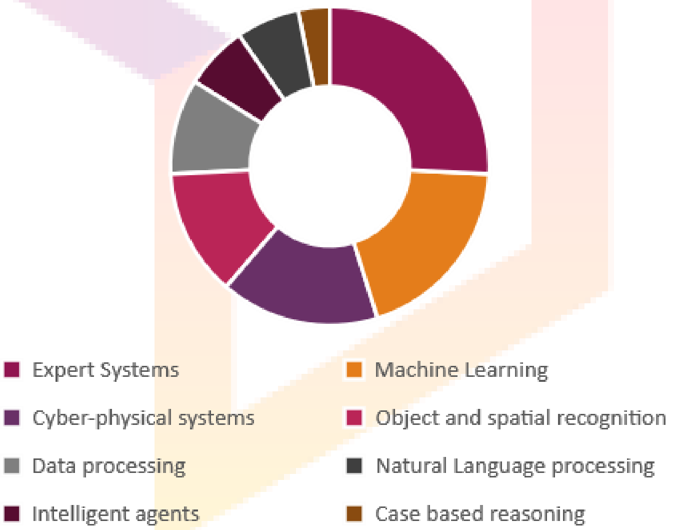
STEEL SECTOR

Steel

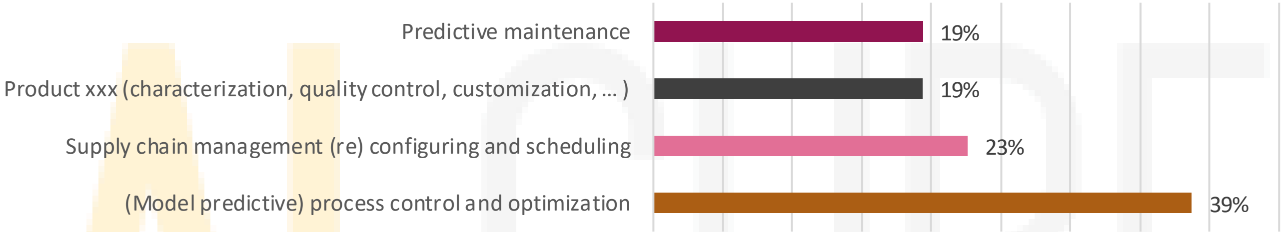
SECTOR OVERVIEW

Needs/challenges	Process addressed by AI & BD	AI/BD technologies	Business concerns
Needs: efficient furnace operation and smelting.	(Model predictive) process control and optimization	Machine learning	Process optimization and stable operation
Challenges: High energy consumption, risk to humans, quality control, logistics, Value Chain.	Supply Chain Management	Cyber-physical systems	Quality control
		Intelligent planning	Logistics, Value Chain
			Security and human safety
			Fossil free energy soruce (fuel switch – Hydrogen)

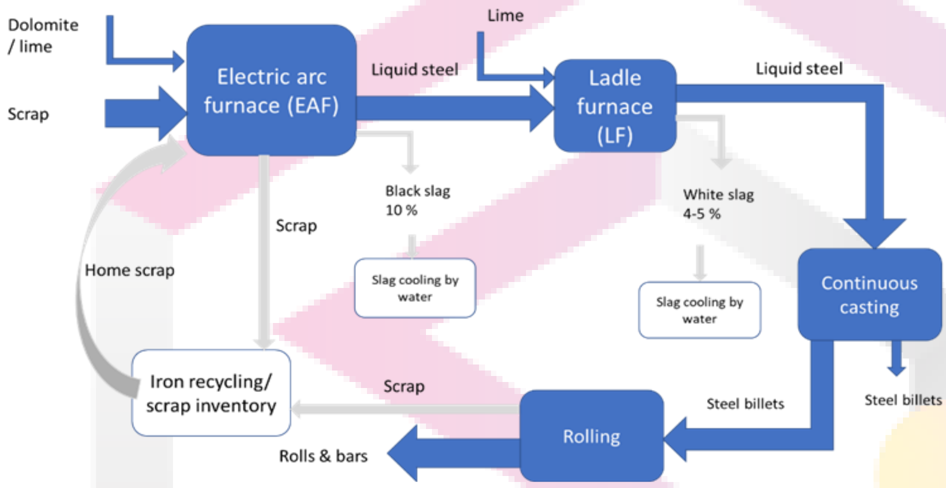
Main AI and BD technologies applied in the steel sector:



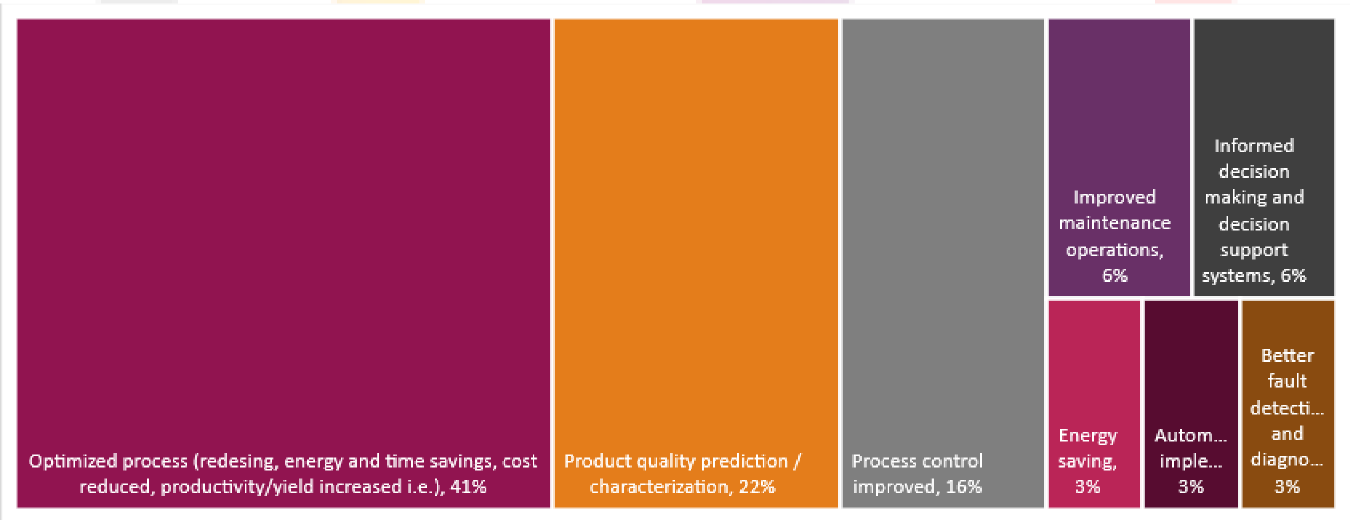
Main processes addressed by AI and BD solutions in the steel sector:



Steel production process:



Value proposition provided by AI and BD in the steel sector sector:



The role of AI and BD in the steel sector:

- Production process: steel production process can expose workers to dangerous working conditions. AI can support the real-time integrated control of the different production phases enabling cyber-physical systems by new way to formalize and treat BD collected along the process from machines, devices etc.
- Energy consumption: the utilisation of AI algorithms can assure flexibility in production. Innovative systems can help to smooth the energy consumption along the period by suggesting ways to reduce it in the peak periods, maximising the renewable energies, minimising the generation costs, and reprogramming the consumption profiles.
- Raw material quality control: in case of EAF, the scraps arriving to the plant can be classified with a high precision and timely manner thanks to advance sensing systems and AI algorithms.

Furthermore, these systems can detect the classified scrap in the inventory and provide a real-time monitoring of the inventory level for supporting production planning.

- Raw material handling: Intelligent robots enabled with AI can facilitate the scrap loading and transferring from the warehouse to the furnace avoiding human interaction in highly dangerous environments.
- Monitoring and planning: through automated in-house and external systems (such as GPS and laser sensors), the availability and timing of the materials can be tracked in real-time. The in-house monitoring consists the inventory level, position of the raw material and resources (e.g. internal transport modes) in the warehouse, operators' guide for timely picking and loading activities. Consequently, higher security for the employees is achieved in the workplace. The external monitoring consists of the real-time tracking of transport modes in the inbound and outbound flows.
- Disruption prevention in decision-support solutions: the process and supply chain of steel production encounter vulnerabilities due to several factors, such as suppliers delays and production disruptions. The current optimisation algorithms mainly focus on a single machine or a part of the supply chain. An integrated decision-support tool based on the optimisation of the whole value chain would be based on BD collected from different sources (machines, trucks, suppliers, warehouse) and can support event-management, and optimisation of the operations.
- Market analysis and forecasting: an online marketplace facilitates both the administrative and operative procedure to ensure a high-level collaboration with the other stakeholders in the value chain. An intelligent system for customer relationships management (CRM) and online monitoring and order management systems for the suppliers are among the prominent aspects in this criterion.
- Value chain integration for circular economy: an intelligent system that not only facilitates the forward flows of the raw materials and primary products, but also manages and integrates it with the reverse flows to the factory, waste management systems, and other value-added activities. To this end, it is critical to have the capacity to manage and analyse a huge amount of data.

REFERENCES

- World Steel Association. 2019. "Steel Statistical Yearbook 2019 Concise Version Preface." Worldsteel Association.
- Siderweb. 2018. "Il Rottame in 4D (The Scrap in 4D)." Milan.
- Çiftçi, Baris Bekir. 2018. "The Future of Global Scrap Availability." 2018. https://www.worldsteel.org/media-centre/blog/2018/future-of-global-scrap-availability.html.
- The European Steel Association (EUROFER). 2019. "Low Carbon Roadmap. Pathways to a CO2-Neutral European Steel Industry."
- Tello, P., Weerdmeester, R. "SPIRE Roadmap."
- ESTEP. 2017. "European Steel Technology Platform – ESTEP Strategic Research Agenda (SRA)."

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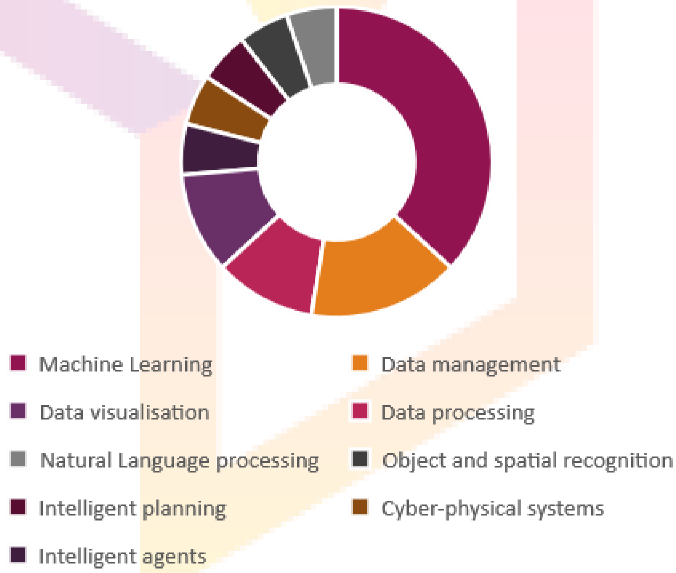
WATER SECTOR

Water

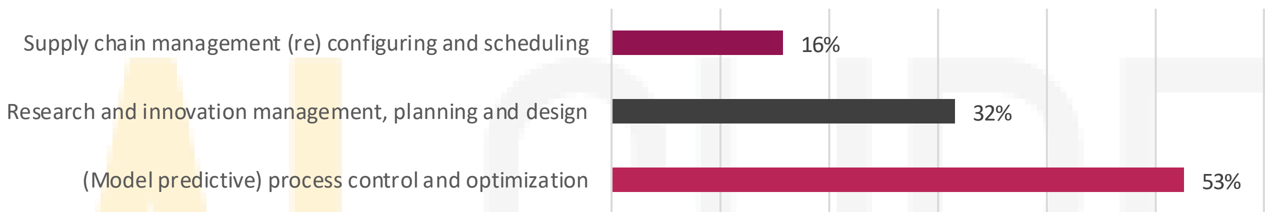
SECTOR OVERVIEW

Needs/Challenges	Process	AI/BD technologies	Business concerns
Needs: waste water processing, clean water processing.	(Model predictive) process control and optimization	Machine learning	Waste water processing, clean water processing
	Predictive maintenance	Expert systems	Water management and quality
Challenges: complex processing chain, large processing volumes, yield.	Research and innovation management, planning and design	Cyber-physical systems	Complex processing chain, large processing volumes, yield
		Data understanding and characterization	

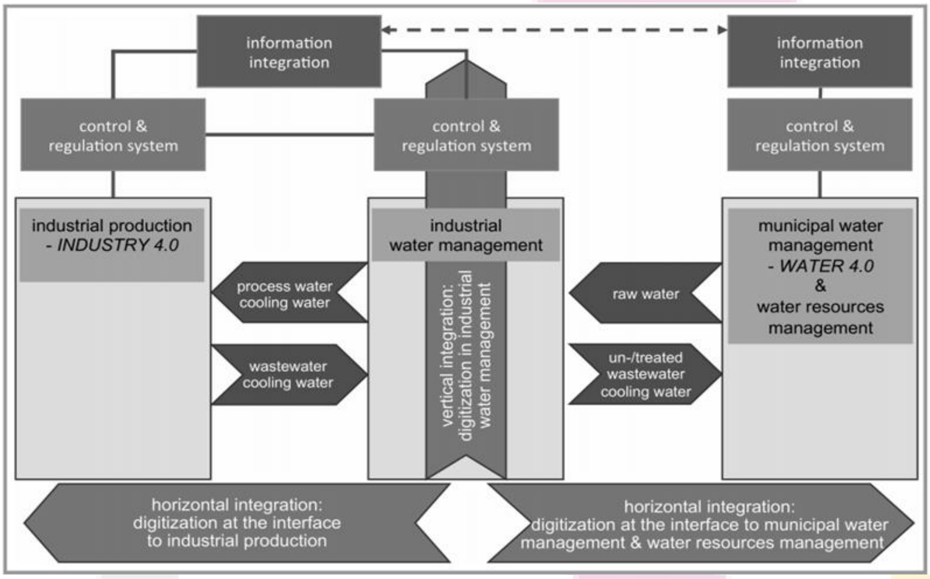
Main AI and BD technologies applied in the water sector:



Main processes addressed by AI and BD solutions in the water sector:



Water production process:



Value proposition provided by AI and BD in the water sector:

Industrial water treatment faces several major challenges, such as:

- The need for steady reassessment of contaminants and for a comprehensive chemical and toxicological analysis;
- Reducing the environmental footprint, mainly due to the disposal of the organic matter stripped from the wastewater;
- Reducing energy consumption, as filtering wastewater is an incredibly energy demanding endeavor;
- The need for new tools to empower workers to always make the best decisions in real time.

AI-enabled solutions have much to offer to the water industry in order to tackle the above challenges:

- AI-driven solutions can leverage data analysis to produce more effective water treatment processes;

- Automation and innovation have a critical role to play to make wastewater management leaner, less energy intensive, more sustainable and more easily predictable and controlled;
- Predictive maintenance, high-resolution remote sensing techniques, smart information and communication technologies can generate improvements not only in the detection of harmful microorganisms, but also in water-use efficiency;
- AI can play a pivotal role in the management of water resources also in connection with water utilities;
- Data driven decision making would allow for immediate control and prevention of hazardous situations, whenever possible.
- Use of AI and BD to anticipate/manage the impact of climate change (draughts and flooding). The use of weather predictions in combination with water management systems is also relevant here.
- Use of AI /BD for managing the governance of the full water cycle, including all stakeholders from Cities to industries and agriculture, predicting/planning the trade-off of water availability (different "qualities" of water to be used fit-for-purpose) in interdependent circular water systems for all types of users.

REFERENCES

- International Water Association and Xylem Inc, Digital Water, Industry leaders chart the transformation journey, 2019 report.
- Pal, P. Industrial Water Treatment Process Technology, Butterworth-Heinemann, 14 April 2017.
- Guyer, P., An Introduction to Industrial Water Treatment, CreateSpace Independent Publishing Platform, 1 July 2015.
- Aquatech, Industrial water: our essential guide to pollution, treatment & solutions, 29 May 2019.
- Villarína, M.C., Merel, S. Paradigm shifts and current challenges in wastewater management, Journal of Hazardous Materials, Volume 390, 15 May 2020, 122139.
- Froede, C. (DAIA — THE DECENTRALIZED AI ALLIANCE), Artificial Intelligence and Global Challenges — Clean Water and Sanitation, Medium, 3 April 2019.
- Becker, D., Jungfer, C., Track, T. Integrated Industrial Water Management – Challenges, Solutions, and Future Priorities, Chem. Ing. Tech. 2019, 91, No. 10, 1367–1374.
- Ante, A., et al., Industriewasser 4.0 - Potenziale und Herausforderungen der Digitalisierung für die industrielle Wasserwirtschaft, Positionspapier DECHEMA e.V., Frankfurt am Main, DECHEMA, ISBN 978-3-89746-210-6, 2018.

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MATURITY OF AI AND BD IMPLEMENTATIONS IN THE PROCESS INDUSTRY FROM DIFFERENT PERSPECTIVES

THE MATURITY LEVEL ASSESSMENT (MLA) MODEL

Maturity Level Assessment (MLA) Models have proved to be essential instruments to support the positioning of organizations in a specific comparative framework and help find better solutions for change. MLA Models have become a well-established tool also in the area of digitalisation to support corporate management in complex and novel technology transformation processes and to help understand the gaps in the digitalisation path.

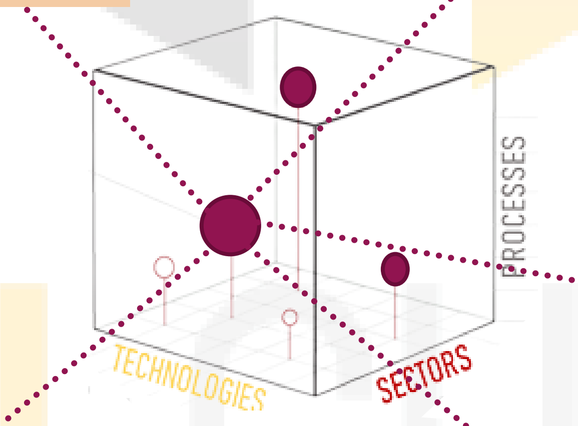
AI-CUBE MLA model is conceived as a multi-stage model to capture patterns in developing organizational capabilities along different dimensions. For each maturity level, the MLA model describes corresponding development steps for relevant dimensions. These steps to full implementation of AI and BD have been logically connected and generalizable to identify the correct maturity level of an organization.

The MLA model was implemented and distributed through an **online survey** to process industry companies. This online survey was available for users and providers of AI and BD technologies that want to test the maturity level of their company or provide an opinion on the maturity of the sector.

THE 5 DIMENSIONS OF THE AI-CUBE MLA MODEL

Strategy → the strategic alignment of a company towards the AI/BD application. A clear AI/BD strategy should be integrated with the corporate level, and committed by the top management. AI/BD are considered as a competitive advantage for successful companies aligned with the ethical, legal, and social issues.

Data → Features of the data in terms of richness, transparency, frequency, quality, formatting, capabilities to process unstructured data.



Organisation → the role of AI/BD experts and AI/BD governance capabilities within the company and its organisational structure. These aspects can affect the financial status and companies' capabilities to handle their AI/BD applications internally.

Technology → availability of AI/BD technologies within the different processes of a company, level of usage, human-interaction.

People → role and approach of employees towards AI/BD, training level, skill development, training aligned to the AI/BD objectives of the company.

The MLA model is organised along 5 dimensions. For each of them, there are some sub-dimensions that companies can investigate to understand their level of maturity in implementing AI and BD technologies. The ethical and social dimension is considered in this model with questions related to people and the level of interaction between people and technologies.

MAIN FINDINGS

During the AI-CUBE project, several companies have been involved in the self-assessment to collect a preliminary perspective on the sector’s maturity in implementing AI and BD technologies. In particular, based on the results collected from the preliminary set of contacts, the implementations of AI and BD technologies in the process industry already have a high maturity. On average, the highest maturity is in strategic considerations meaning that the sector is perceiving that the implementation of these technologies needs to be based on a solid commitment from the management of the company.

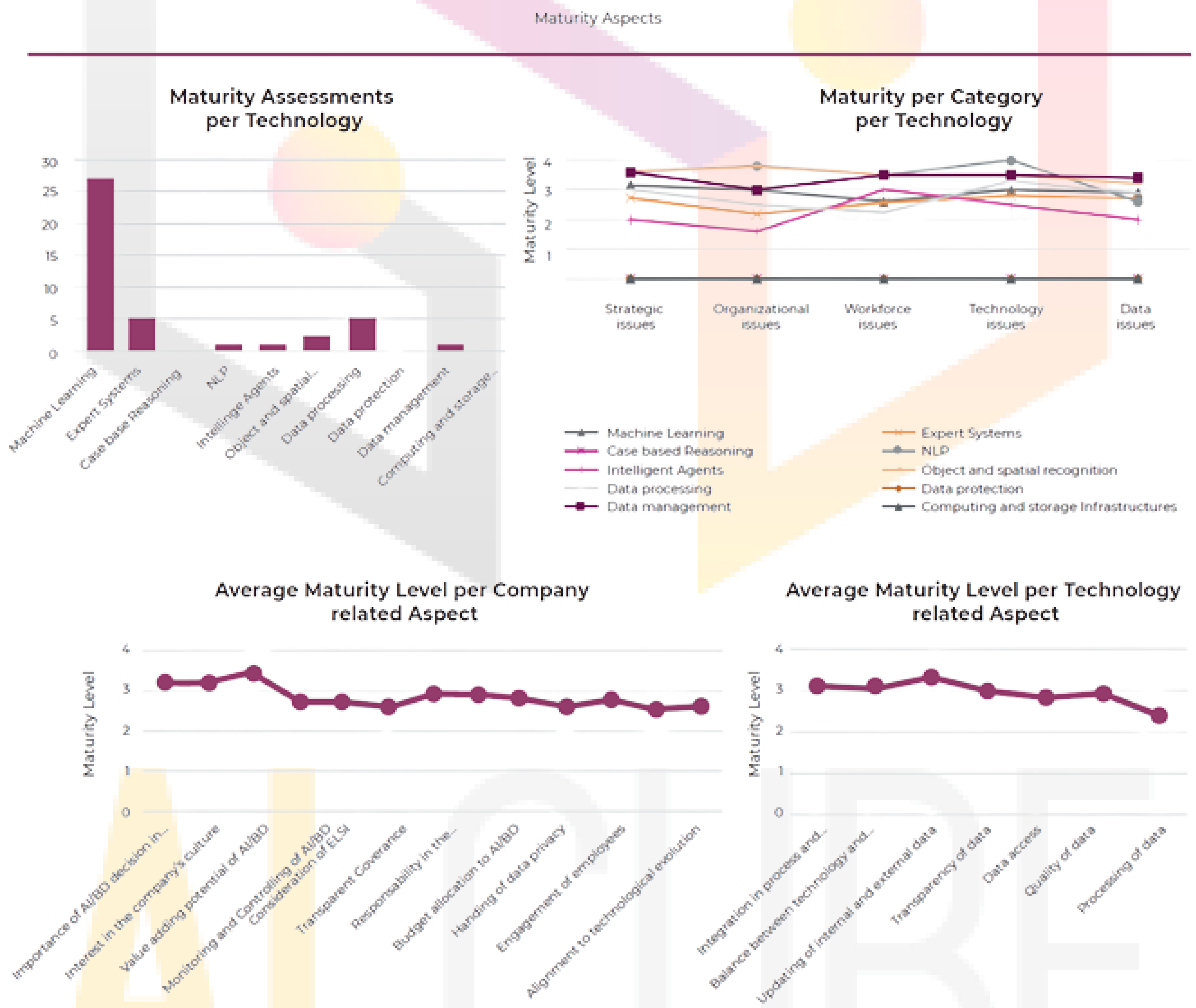


Figure 7. Maturity assessment per category.

Some of the main findings on the maturity assessment performed by AI-CUBE include:

- The results from the dimensions of workforce involvement show that there is a lower level of implementation of practices.
- High amount of Machine Learning technologies throughout the whole process industry and the individual sectors
- In principle, current implementations of AI and BD technologies in the process industry already have a high maturity.
- In particular, the personnel and data-related maturity aspects and governance topics are currently less pronounced than others.
- On average, the highest maturity is in strategic considerations.

UNDERSTAND THE MATURITY LEVEL OF YOUR COMPANY

The following statements per dimension can be used to know the maturity level of your company towards the implementation of an AI or BD solution. Read carefully the evaluation key point and assess a level (from 1 to 4) to the maturity of AI and BD in your company.

The results can be checked in the following section devoted to **Implementation** that includes the main barriers for the implementation of AI and BD technologies, this will provide with an insight in the barriers causing a low implementation level and how to overcome them. The last part (**here**) or the following section will allow you to understand more specifically the maturity level according to your identified barriers.

The maturity level of Strategy can be evaluated based on: • **Company strategic alignment**, i.e. alignment of AI/BD with other business goals • **Cultural attitude** of the company towards AI/BD, i.e. interest in AI/BD initiatives, data-driven culture, and the approach to change management • AI/BD are perceived as contributor to create **added value** in a company, i.e. competitive advantage deriving from AI/BD applications for the company and stakeholders • **ELSI** (Ethical, Legal, Social Issues) strategies	STRATEGY Level 1 - little or no adoption of AI/BD strategy Level 2 –AI/BD strategy is at early stage of definition. Level 3 - AI/BD strategy is at early stage of implementation. Level 4 - Full adoption and optimization of AI/BD strategy.
The maturity level of Organisation can be evaluated based on: • **AI/BD governance**, i.e. transparency and incorporation of governance roles (CDO/CTO) at corporate level and association to company KPIs. • **AI/BD responsibilities** are tied to the organisational structure of a company, i.e. AI/BD responsibilities centralisation, existence of appropriate data scientists, and top management support. • **Financial and economic budget** handled specifically for AI/BD development and monitoring, • **Privacy management strategy**, with respect to the governance of data access, privacy protection, and regulation alignments. • Development and maintenance of the **AI/BD projects** managed internally or outsourced	ORGANISATION Level 1 - little or no adoption of organisation practices Level 2 - experimenting practices with limited use. Level 3 - on the way of formalizing and adopting practices. Level 4 - full adoption and optimization of practices.
The maturity level of People can be evaluated based on: • **Employees engaged** in the AI/BD initiatives, i.e. their skills level and ability to develop AI/BD projects and solve relevant problems, and top management support • **AI/BD skill development** associated within the corporate and functional levels • **AI/BD responsibilities** between corporate level and functions are clearly defined for AI/BD management • **AI/BD skill level** in the company, i.e. staff awareness and alignment with the fast-paced technological evolution • **Collaboration** between Digital Experts & other Employees (traditional works) effective	PEOPLE Level 1 - little or no adoption of these practice Level 2 - experimenting some practices with limited use. Level 3 - on the way of formalizing and adopting some practices. Level 4 - full adoption and optimization of all practices.
The maturity level of technology can be evaluated based on: • **Human interaction** in AI/BD applications • **Level of usage and integration** of AI/BD within the different steps of each process • **Level of flexibility** assured by AI/BD to unforeseen situations • **Degree of decision-support** by AI/BD at process level	TECHNOLOGY Level 1 - little or no adoption of these practices Level 2 - experimenting the practices with limited use. Level 3 - on the way of formalizing and adopting this practices. Level 4 - full adoption and optimization of all the practices.

The maturity level of Data can be evaluated based on:	DATA
• **Richness** of available data concerning internal and external data • **Transparency** on available data of internal and external data • **Frequency** of data updates related to real time data gathering • **Data quality** measured as completeness of data collected in terms of frequency, missing data, formatting, unique identification of source • **Capabilities** to process unstructured data by AI/BD	Level 1 - *little or no adoption of these practices* Level 2 - *experimenting some practices with limited use.* Level 3 - *on the way of formalizing and adopting these practices.* Level 4 - *full adoption and optimization of all the practices.*

IMPLEMENTATION OF AI AND BD TECHNOLOGIES

BARRIERS TO THE IMPLEMENTATION OF AI AND BD TECHNOLOGIES

Generally, different barriers and challenges hamper the implementation of new technologies to new areas of application. By examining the individual challenging aspects in detail in the research, it was possible to identify three overarching categories of barriers (all the descriptions of the barriers identified in AI-CUBE can be consulted in the GLOSARY section of our website, **here**). These core barriers are strategy and company related barriers, data and technology related barriers and human and culture related barriers. Awareness of these general and the particularly relevant challenges represents a first necessary step for the establishment of new technologies in the process industry. The most mentioned barriers in the AI-CUBE online survey were the unclear business case or strategy, insufficient data quality and insufficient data access, and the lack of the needed talent. Less important challenges stated by the industry are the lack of available tools, the complexity of data, time constraints or missing trust.

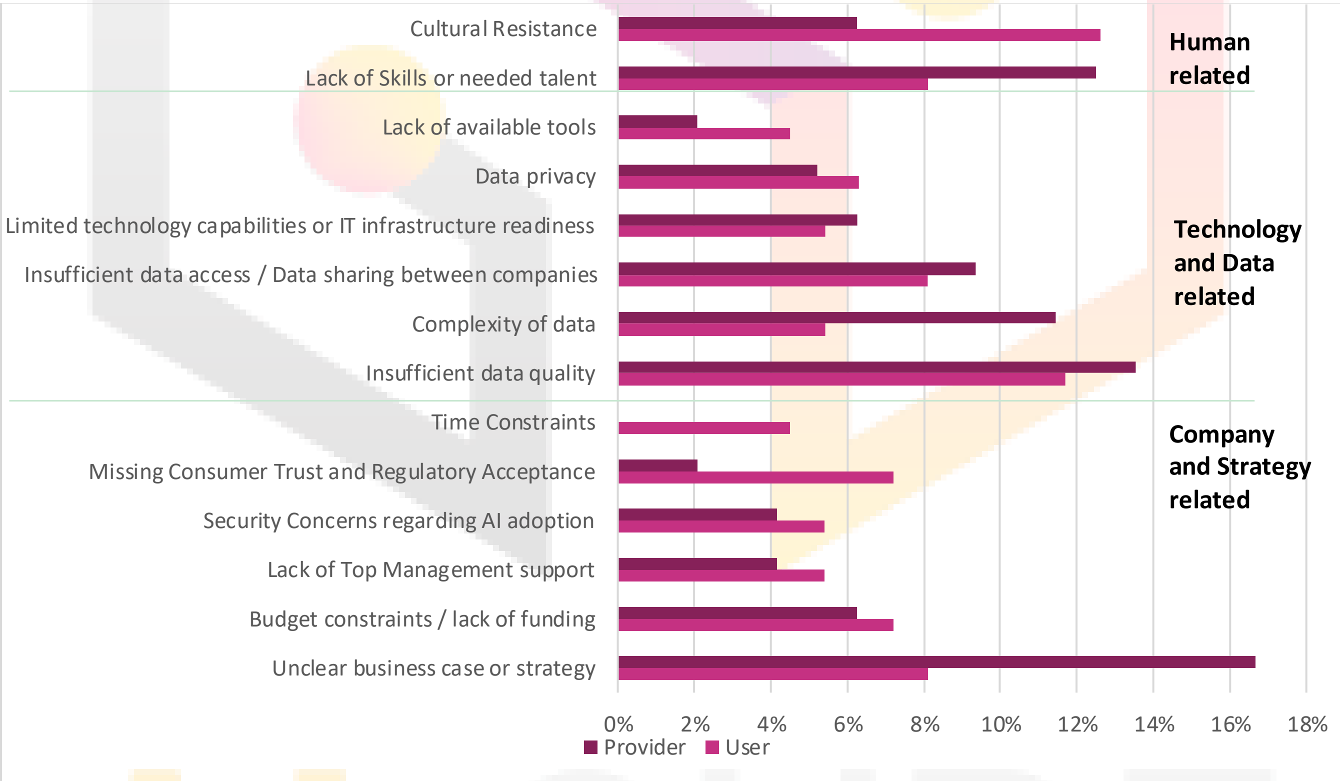


Figure 8. AI-CUBE barrier to the implementation of AI and BD solutions.

From an organizational view, mainly the missing business cases or unclear strategies, existing budget constraints and the lack of top management support represent the barriers to AI implementation that need to be handled most importantly. While existing security concerns and the missing consumer trust are often mentioned as relevant, time constraints are not that important in the process industry. This shows that it is, above all, the internal related to the c-level and strategy that need to be addressed first. External barriers exist only to a much lesser extent. When looking at the technology and data-related challenges that impede implementation, the most significant barriers are insufficient data access, insufficient data quality and data complexity. Less important aspects of limited infrastructure capabilities and data privacy concerns are still important factors that should be observed in an AI or BD implementation project. Challenges like the availability of tools do not strongly influence AI and BD solutions in the process industry. Once the underlying conditions of data availability, privacy and infrastructure are in place, the actual control and use of data are not a constraint. Regarding the human-based barriers, both cultural resistance and the lack of skills in the process industry are among the most severe challenges of the entire list. Successful implementation without taking this category into account does not seem to be possible.

Barrier	Unclear business case or strategy	Budget constraints / lack of funding	Lack of Top Management support	Security Concerns regarding AI adoption	Missing Consumer Trust and Regulatory Acceptance	Time Constraints	Insufficient data quality	Complexity of data	Insufficient data access / Data sharing between companies	Limited technology capabilities or IT infrastructure readiness	Data privacy	Lack of available tools	Lack of Skills or needed talent	Cultural Resistance
User	8%	7%	5%	5%	7%	5%	12%	5%	8%	5%	6%	5%	8%	13%
Provider	17%	6%	4%	4%	2%	0%	14%	11%	9%	6%	5%	2%	13%	6%

MAIN RESULTS: Barriers per Sector

By breaking down the barriers to the individual sectors of the process industry, sector-specific statements can be determined in addition to the overall statements about the situation in the process industry.

The barriers of unclear business cases, data quality and lack of skills and talent, which were identified as particularly significant, were also rated as especially important in all individual sectors. For example, in the Non-ferrous metals sector, in the Water sector and in the Pulp & Paper sector, the basic IT infrastructures appear to be a major challenge. Consumer trust, on the other hand, is rated as particularly important in the refining sector. In line with this, data privacy is also a major challenge in AI and BD adaptation in the refining sector.

Regarding barriers, whose overcoming results in increased economic value, the very pronounced barriers can be named here above all since they strongly impede or prevent a fundamental implementation. Without a basic sufficient data quality or a handling of the data complexity, no positive economic impact can be achieved. In addition to these basic requirements, however, the strongly rated barriers of unclear business cases, data sharing between companies and the necessary skills probably have the strongest influence on increased economic value. The lack of a business case or a corresponding strategy, which is a major obstacle, is the most important one. However, approaches for standardized data sharing are also indispensable for economic improvement. And the development of the necessary talent must also be focused on here to leverage economic potential.

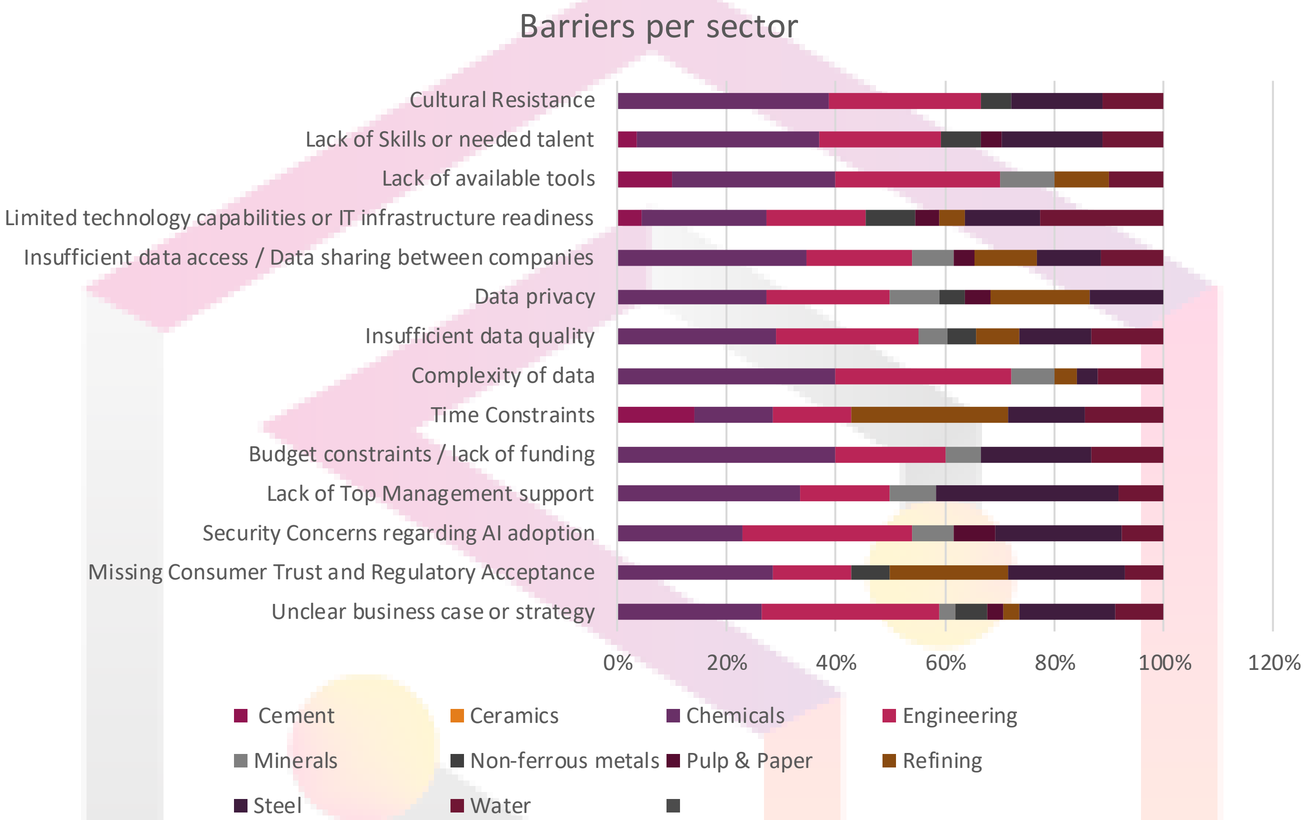


Figure 9. Barriers found per sector.

LOOKING FOR A WAY TO OVERCOME YOUR BARRIERS? CONTINUE TO FIND OUT HOW!

Barrier	Strategy for Overcoming the Barrier	Description
Unclear business case or strategy	Definition of Success Stakeholder Integration (internal and external) Use of Roadmaps Proactive Planning	An unclear business case hampers the whole integration project or the solution development due to missing objectives and metrics. When modelling the business case, it is necessary to define what success means with regard to AI implementation. Success may range from simply delivering the wished results as acceptable costs to increased performance and explicit impacts on the ROI. Through workshops with all relevant internal and external stakeholders for the implementation project, the business case can be defined, strengthened, and challenged. A more strategic approach for implementing the single solution into a broader scope can be achieved through the development of roadmaps for future visions of the adaptation.
Missing Consumer Trust and Regulatory Acceptance	Clarity of Responsibilities Transparency Certification Open Communication	One crucial requirement for overcoming the missing trust of consumers or customers is the presence of essential government regulations leading to clarity and responsibilities. The newly created algorithm-based decision making often sparks mistrust or fear that needs to be lifted by regulation, transparency, and certification. When the process of data preparation is openly discussed, consumer trust may rise, and mistrust based on misunderstandings can be lowered.
Security Concerns regarding AI adoption	Predictive Risk Management Fall back scenarios Security rules Security Infrastructure External certification	The traditional security concerns regarding the real-life consequences of AI based decisions as well as cyber- and data security related concerns need to be seriously addressed before and while implementing new technologies. Often security related aspects are not appropriately addressed in the implementation process leading to low acceptance ratings of the outcoming solutions. Security concerns regarding the outcome of decision processes need to be lowered by implementing fallback scenarios in case of malfunction and basic security rules and intervals. When huge amounts of data, especially personal information, are stored and processed, a robust security infrastructure is required. Through external monitoring and certification, achieved security levels can be communicated and concurrently reviewed.
Lack of Top Management support	Creation of Awareness Anchoring the AI strategy in the corporate philosophy proactive Analysis of potentials	The creation of awareness in top management can improve the support from the c-level in terms of budget, support and cultural change. Strong support by the leadership improves the rate of successful AI implementations. A potential analysis preceding the implementation projects with the analysis of efforts, potential benefits and alternatives can highlight relevant changes and benefit signals in a management summary.
Budget constraints / lack of funding	Focussing on Core issues (Scope Reduction, POC) Transfer of existing solution Collaborative projects Public Funding	By reducing this scope and focusing on a core issue, the required budget can be reduced, and a proof of concept can still be fully realised. By implementing solutions that have already been applied in comparable application areas and are transferable, partial implementation efforts can be reduced, even if further efforts are still necessary. Apart from the methods to reduce the necessary funding requirements, public funding or collaborative projects are also possible budget sources.

Barrier	Strategy for Overcoming the Barrier	Description
Time Constraints	Use Case Reduction for POC Focus on Value Creation Expansion Roadmap	A prototypical implementation can be a less time-consuming alternative to complete interface processing due to manual data maintenance. This can be integrated into subsequent expansion stages to enable a complete and automated procedure.
Complexity of data	Dimension reduction Data transformation Complexity reduction methods Complexity management through tools	The optimum of the data-induced complexity lies between the respective extremes of an underfitting and an overfitting. The ideal complexity that can still be accepted also depends on the quality and quantity of the existing data sets. Another strategy can be transformation processes to adapt data formats. Each of the complexity drivers of Big Data can be reduced or managed to a certain point through various methods. However, some basic complexity must be accepted for successful implementation.
Insufficient data quality	Data Cleaning Methods Consistent standardized approaches Data Augmentation	The main strategy for dealing with insufficient data quality is the targeted use of data cleaning methods. Depending on the type of data quality-impairing characteristics, the affected metadata can be analysed and corrected using standardized approaches. Suppose the quality problem is that the number of data points is too low or there is insufficient data after cleaning. In that case, the number of data points can be increased, for example, by using data augmentation methods.
Data privacy	Secure Data Interfaces External assessments and certifications Focus on necessary data Reduction of personal data	On the technical level, the design and implementation of secure data interfaces is the basis for ensuring data privacy. These interfaces as well as the internal security of data storage, data access and data processing can be ensured and communicated transparently through external assessments and certifications. The use of dimension reduction methods and the associated focus on the decisive data attributes helps to only use the necessary data and thus reduce the amount of privacy-related data.
Insufficient data access / Data sharing between companies	Internal Communication Contractual agreements safe interfaces Unified information models Open source data sets	While insufficient data access within a company often has technological or organisational causes, access to shared data by other companies has a legal and economic cause besides the already mentioned. Company internal data sources in other subsidiaries or divisions need to be accessible by the relevant AI or BD experts. This may require the effort of higher management levels to communicate the overall advantage in sharing this data. When sharing data between companies, the legal and organisational aspects can be addressed by contractual agreements for securing the steady flow of data. This can be supported by assessing the value of the data exchange for every participating company leading to other aspects of agreement besides monetary compensation. The technical aspect of cross-company data sharing needs safe data interfaces, protecting the data from external and internal malicious access or manipulation. Unified information models for shared information such as the OPC UA improves the integration and eases the bilateral connection between partners. Initiatives like the International Data Spaces Association with its purpose-related data precision or the European GAIA-X project can lay the technological foundation for enhanced cooperation in this field. The increasing number of Open Source data by governments, non-profit organisations or researchers can grow into valuable alternatives of supplements for generating the necessary data input for AI or BD projects.
Limited technology	Focus on most important aspects	Theoretically, the greenfield planning of the underlying IT infrastructure leads to the optimum in enabling AI and BD technologies. In established and updated

Barrier	Strategy for Overcoming the Barrier	Description
capabilities or IT infrastructure readiness	Cloud computing Requirement identification through POC	companies with historically grown legacy IT structures, this restart is not possible, leading to integration efforts of new structures in existing landscapes: When planning to implement AI or BD solutions in a supporting infrastructure the specific capabilities of data storage, networking and scalable computing power are the most important ones. These capabilities enable generation and storage, the quick accessing, processing, and transporting of data, as well as working with the necessary data. One possible quick, affordable and scalable way is the use of cloud computing for improving the necessary main capabilities due to its low entry barriers, pay-per-use business models and unlimited resources.
Lack of available tools	Open Source Frameworks Implementation of existing tools Use Case simplification	A lot of libraries and frameworks for AI are Open Source leading to a huge availability of up-to-date tools. These libraries and further tools for affordable or free prizing simplify usability and testing. Furthermore, already developed AI building blocks for special tasks like text or picture recognition are easy to implement in new solutions, streamlining the application domain specific efforts. In the case of no appliable tools, a simplification of the use case can help to increase the range of applicable tools or solutions.
Lack of Skills or needed talent	Separation in Primary and Secondary skills Internal upskilling Collaboration with educational institutions	The skills necessary for developing, deploying, and monitoring an AI or BD tool can be separated into primary and secondary skills. While the primary skills describe knowledge in AI and BD technologies, frameworks and platforms, secondary skills focus on the underlying basic skills, such as math, statistics, decision-making models or data visualisation. Looking at the primary skills, especially those of AI specialists and business analysts (abstract AI or BD understanding combined with domain know-how) are identified as missing skills. One possible long-term solution for this challenge is the collaboration with educational or research institutions with the intention to align their curriculum with the industrial requirements and challenges. The upskilling of existing personnel describes the interdisciplinary improvement of the employee's skillsets in the relevant fields of knowledge, regarding primary and secondary skills. This invest in upskilling becomes more and more obligatory when looking at the labour market in these fields.
Cultural Resistance	Change Management Transparent communication Participation development of overall vision Top Management support Explainable AI	Reasons for cultural resistance towards the implementation of AI or BD solutions lie in employees' lack of understanding, threatening the acceptance of AI based systems, privacy concerns among the public and the fear of job loss due to increased automation through intelligent solutions. Transparency and an open communication from the start can help lowering barriers and misunderstandings and increase the understanding of the new technologies. A clearly communicated and documented vision combined with top management support and derived effects on single processes or roles can help support this change. AI adaptation can trigger a company-wide cultural change with the goal of becoming more innovative. One building block of open communication is the concept of explainable AI, trying to lighten the black box of the applied algorithms. New AI solutions are often easier to interpret and traceable, reducing the complexity for the existing employees and helping them understand the solutions.

DO YOU WANT TO KNOW HOW TO SUCCESSFULLY IMPLEMENT AI & BD TECHNOLOGIES? HAVE A LOOK AT OUR IMPLEMENTATION PATH

Especially the aspects and solutions to cultural resistance, lack of skills, insufficient data access and quality, lack of Top Management support and unclear business cases need to be included in an implementation path for the process industry. To implement successful AI or BD solutions, the different challenges and barriers must be addressed with a holistic, **socio-technical approach** transforming the organisation, the overall strategy and the technological base of a company.

The **most challenging barriers from the company related and the human related categories** need to be addressed before starting the concrete development or implementation. The barriers related to insufficient top management support, lack of skills and the cultural resistance towards AI implementation must be addressed before starting the technical or business case related aspects of an implementation model. The solutions of implementing trainings, clarifications and change processes can be summarized and performed in a preparation phase before the implementation. Particularly in companies with little experience, these internal processes are time-consuming and only eventually lead to a final decision for or against implementation. Further, less important barriers like limited capacities or budget restrictions need to be analysed and planned in a project planning phase. In this phase, a project plan with defined budgets and approval of the decision-making bodies must be the result.

For tackling the challenges of **limited access to the relevant data with the necessary data quality** characteristics, the organisational data acquisition and the technical data collection must be given a prominent place in the process model. The quality assessment is another important requirement that must be taken seriously with regard to the overall results and performances of the final solutions. When planning an implementation process, it is necessary to guarantee a defined minimum of quality regarding the used data and following the system. For this reason, the data preparation becomes more important and leads to considerable efforts, meaning it needs to be planned and executed with high importance. The results or pre results must be very clearly visualised for the project team, the data experts and the professional users that will work with the solution. Furthermore, continuous performance monitoring and reporting become important after the go-live in order to keep quality high. At the same time, the input data may change over time and further improve the solution continuously.

By considering **lessons learned** from other industries and the overall technical field, the potential of AI and BD solutions in the process industry can be realised faster and more efficiently through upstream preparation of these enabling factors. The approaches for solving the different challenges with a focus on solving the barriers most relevant in the process industry represent knowledge that must be included in the processes of implementation, development, or transfer. This holistic view of technology implementations helps the process industry to sharpen its understanding of the scope and importance of AI or BD adaptations. From these descriptions, initial conclusions and conditions can also be outlined for the necessary underlying ecosystems in the process industry regarding skills, infrastructure and data.

ASSESS THE MATURITY OF YOUR COMPANY ACCORDING TO OUR BARRIERS

Not sure if your company is ready to implement AI & BD solutions? Assess the maturity of your company according to our barriers

Maturity Category	Maturity Dimension	Question
Strategy related	Importance of AI / BD decisions in the company's strategy	Decisions regarding AI/BD are part of your company's strategy and are treated as an important contribution to your business goals.
	Interest in the company's culture	Within your company's culture there is a strong interest in AI/BD. (i.e. you run AI/BD initiatives, you implement a data-driven approach that guides your decision making, and AI/BD is taken into consideration in your change management activities.)
	Value adding potential of AI/BD	AI/BD is considered to add value and to help reaching competitive advantage.
	Consideration of ELSI	Strategies to face ELSI (Ethical, Legal, Social Issues) with regard to AI/BD are transparently defined and communicated.
	Monitoring and Controlling of AI/BD	The monitoring and controlling of ELSI for AI/BD are part of your company's strategy.
Organisational	Transparent Governance	AI/BD is transparently governed at corporate level. (i.e. specific tasks are formalized in governance roles ()
	Responsibilities in the organisational structure	Responsibilities to enhance AI/BD are well tied to your organisational structure and supported by top management.
	Budget allocation to AI/BD	Part of the overall budget is specifically allocated to AI/BD projects.
	Handling of data privacy	Your company has a well-defined governance structure for handling privacy of data in AI/BD applications (i.e. monitoring of data access, data protection, and regulation alignments).
	Division of responsibilities	In your company, the division of responsibilities of AI/BD management between corporate level and operations is transparent and well defined.
Workforce related	Engagement of employees	Employees are engaged in the AI/BD initiatives, they have the skill level and ability to develop and manage AI/BD projects.
	Skill development	The AI/BD skills development is associated to specific formal training programmes and is also reflected in job descriptions.
	Alignment to technological evolution	The staff in your company is aligned with the fast-paced technological evolution brought by AI/BD.
Technology related	Integration in processes and applications	In the specific process under consideration, AI/BD is used throughout different steps and is integrated with other applications.
	Balance between technology and human intervention	The algorithms and tools applied in this process are flexible enough to balance the AI/BD and human intervention in dealing with risks (cyber security and ELSI).
Data related	Data access	The AI/BD technology has access to the needed data sets.
	Transparency of data	Data related to the process is handled in a transparent way.
	Updating of internal and external data	Internal and external data handled by the AI/BD technology is updated in real-time.
	Quality of data	Data handled by the AI/BD technology has the right quality for the process in terms of frequency of collection, completeness of data, formatting, unique identification of source.
	Processing of data	The AI/BD technology has the capability to process all forms of unstructured data (e.g., text analysis) necessary for the decision to be taken.

AI & BD VALUE PROPOSITION

Almost 300 scientific and technical publications from 2016 onwards were analysed to understand the main applications and results achieved by implementing AI and BD solutions in the SPIRE industry. The significant results achieved provided us with the value proposition provided by AI and BD solutions to industries grouped according to different fields. The first field in the table related to DATA is common to all the processes and other fields to be achieved due to the necessity of the data for AI and BD technologies implementation.

Table 1. Main contribution of AI and BD technology to the process industry (results achieved / application in the form of value proposition) from the literature review.

FIELD	AI & BD contribution (value proposition)	PROCESS
DATA	Data management achieved	ALL
	Data processing implemented	
	Data protection achieved	
	Data exploitation	
SECURITY	Security and safety improved	
	Abnormal events and attacks identification	
MARKET	Trends and market prediction achieved	Market trends and Open Innovation (MT & OI)
	Supported forecasting	
	Improved customer needs identification	
DECISIONS	Informed decision making and decision support systems	Research and innovation management, planning and design (R&I)
PLANNING	Planning – prediction	
DESIGN	Product customization (customer driven)	
	Improved product properties/design	
PRODUCT	Optimized products (final properties/characteristics improved)	Process control and optimization (PC & O)
	Improved product characterization (prediction and identification of final properties)	
	Product quality prediction / characterization	
PROCESS	Improved process understanding / mapping	
	Performance assessment and prediction	
	Optimized process (redesign, energy and time savings, cost reduced, productivity/yield increased etc)	
	Process control improved	
AUTOMATION	Automation implemented	
ENERGY	Energy saving	
SUSTAINABILITY	Improved sustainability	
QUALITY	Improved quality control	
	Improved defects detection	
SUPPLY CHAIN / PRODUCTION	Better production system design and planning	Supply chain management (SCM)
	Supply chain optimization	
MAINTENANCE / FAULTS	Better fault detection and diagnosis	Predictive maintenance (PM)
	Improved fault forecasting	
	Improved maintenance operations	

The higher contribution is obtained for the field on PROCESS followed by PRODUCT, in terms of processes this corresponds to PC & O. The lower contribution is obtained for planning, security and automation.

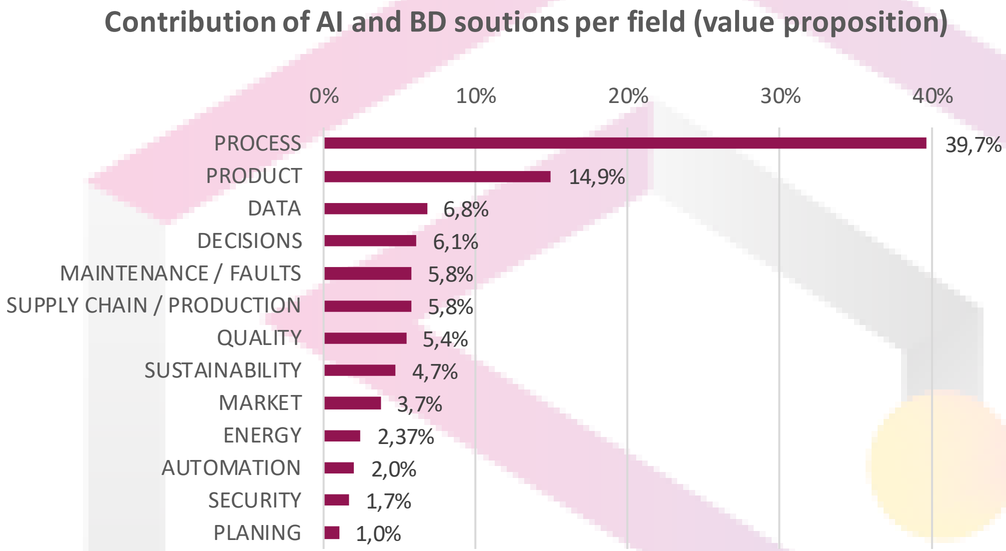
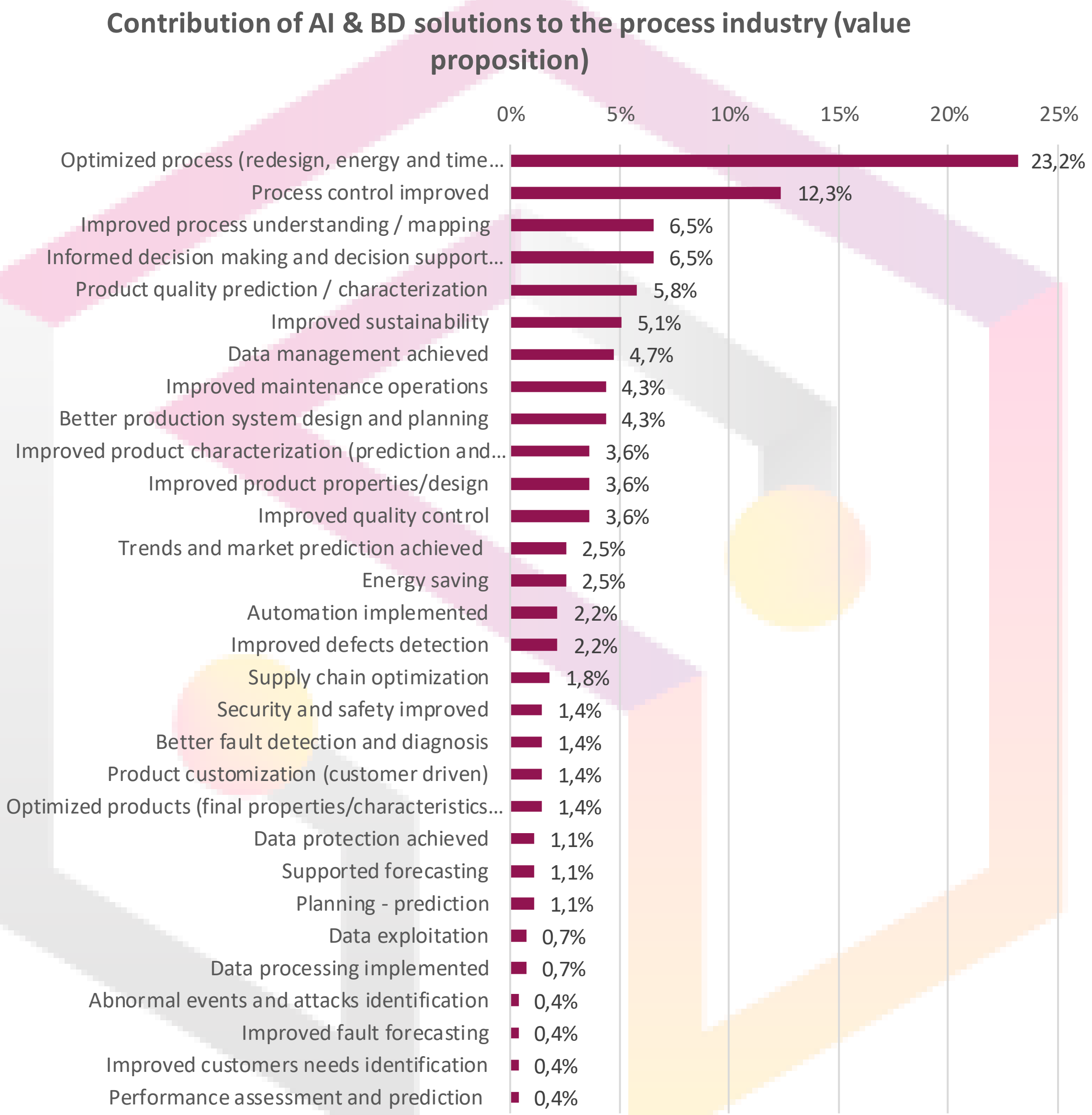


Figure 10. Contribution of AI & BD solutions to the process industry (value proposition).

According to the number of studies addressing each of the specific contributions, we observed that the main value provided by AI and BD solutions is the Optimization of Processes, with 23% of the publications reporting an Optimized Process in terms of redesign, with possible results on energy or time saving, cost reduction, or productivity/yield increase among others. The second main contribution or AI and BD technologies to the process industries is the Improvement of Process Control with 12% of the publications reporting a Process control improved. The results achieved and applications are obviously interrelated. For example, improved process control might be a prerequisite for optimized processes in many cases.

However, we remind the reader that our classification in is based on what is mentioned as the main focus/contribution (keywords) of AI & BD applications in the process industry, without analysing in detail the interactions among results achieved and applications.



** "Energy saving" has been considered as an application/result separated from "Optimized process" for specific papers aiming at saving energy through different AI and BD applications not as results of optimized processes and providing specific values.*

Figure 11. Contribution of AI & BD solutions to the process industry (value proposition).

According to the results achieved by the application of AI and BD technology in the different industrial sectors from the literature review, we have identified the main gaps according to the business concerns detected in each sector. For this, we have compared the results achieved per sector with the specific business concerns of that sector, if there was no result for concern, then there is a gap.

To know about the sector-specific business concerns go to the status quo of the sector, here.

Once the gaps were identified, we searched for results in different sectors which could fill that gap by transferring AI and BD solutions between sectors.

MAIN GAPS IDENTIFIED AND TECHNOLOGY SECTOR TRANSFER

The following table shows the three main gaps identified (business concerns not addressed by the results/applications found in the literature review), all the sectors with the same gap and the transferability from other sectors to cover the gap.

LITERATURE		TRANSFER		
GAP	SECTOR	RESULT	SECTOR	SOLUTION
Better understanding of value chain	Water	Supply chain optimization	Engineering	supply chain mapping of structures to increase their visibility
	Steel	Supply chain optimization	Pulp & paper	green supply chain 4.0 multi-level hierarchical model is established by considering the eleven green practices
	Non-ferrous metals			
	Cement			
High energy consumption	Minerals	Energy saving	Chemicals	ANN and related solutions (e.g. neuro-fuzzy) within different control loops such as network predictive control regarding energy savings
	Cement	Optimized process (redesign, energy and time savings, cost reduced, productivity/yield increased i.e.) – Energy saving	Steel	optimization of heat losses - Energy saving
		Energy saving	Water	ML and other techniques applied to improve energy and resource efficiency in the water distribution systems
		Energy saving	Ceramics	framework of data-driven sustainable intelligent/smart manufacturing based on demand response, improved the energy efficiency of ball mills
		Energy saving	Pulp & paper	BD analysis techniques to identify savings through the analysis of historical process data, power and compressed air generation had the greatest potential for achieving energy savings
		Energy saving	Refining	novel approach based on a multi-output ANN model was devised to cope with variations (uncertainty) in crude composition to save energy in the CDU operation
		Improved process understanding / mapping – Energy saving	Non-ferrous metals	measure energy consumption in factories
Security and human safety	Steel	Security and safety improved	Chemicals	safety production information management platform for the daily supervision and emergency rescue of chemical industrial parks
	Minerals	Security and safety improved	Refining	accident causation model for repair and maintenance related accidents at oil refineries and proposes the best model for early accident prediction through the integration of artificial neural networks, fuzzy systems, and metaheuristic algorithms
	Non-ferrous metals	Security and safety improved	Refining	AI Technology Assisted Emergency Management in Oil Industry

The first result in the table is the necessity for a Better Understanding of the Value Chain found for the Water, Steel, Non-ferrous metals and Cement sectors. With regard to the transfer opportunities from other sectors, the Engineering and Pulp & Paper sectors have solutions oriented to gain this understanding.

The second main gap found in the literature is related to the High Energy Consumption of the process industry. This is a common concern for most sectors, but it has been detected that not all of them have applied AI and BD technologies to improve it. The Minerals and Cement sector have no reported applications devoted to Energy saving, however, for the other 7 sectors, we found that AI and BD solutions achieved a reduction in energy consumption or results related to it.

The last main gap detected is Security and Human Safety. Minerals, Steels and Non-ferrous metals sectors have this business concern, and no literature was found addressing this challenge. However, the Chemicals and Refining sectors have AI and BD applications achieving improvements in the security and safety of humans in the industry.

Of course, each of the proposed solution transfers in the table is meant to cover a gap (a business concern in a sector which no solution in that specific sector). Still, the solutions can be transferred to any other sector with the same business concern or that specific need some time.

BUSINESS MODEL TO MAXIMISE A VALUE PROPOSITION

If you know the value proposition you want to achieve from AI and BD technologies, check the related proposed business model to help to get the maximum benefit of the solution and go to the next section.

VALUE PROPOSITION	*BUSINESS MODEL*
DATA	Applicable to all the AI-CUBE business model
SECURITY	Applicable to the HUMAN FIRST business model
	Applicable to the DATA USE / CONTROL & QUALITY FOR SC business model
MARKET	Applicable to the HUMAN FIRST business model
DECISIONS	Applicable to the DATA USE / CONTROL & QUALITY FOR SC business model
PLANNING	Applicable to the DATA USE / CONTROL & QUALITY FOR SC business model
DESIGN	Applicable to the HUMAN FIRST and CUSTOMIZATION business models
	Applicable to the SUPPLY CHAIN business model
PRODUCT	Applicable to the PROACTIVE & PREDICTIVE business model
PROCESS	Applicable to the DATA USE / CONTROL & QUALITY FOR SC business model
	Applicable to the PROACTIVE & PREDICTIVE business model
AUTOMATION	Applicable to the DATA USE / CONTROL & QUALITY FOR SC business model
ENERGY	Applicable to the SUSTAINABLE business model
SUSTAINABILITY	Applicable to the SUSTAINABLE business model
QUALITY	Applicable to the DATA USE / CONTROL & QUALITY FOR SC business model
SUPPLY CHAIN / PRODUCTION	Applicable to the DATA USE / CONTROL & QUALITY FOR SC business model
MAINTENANCE / FAULTS	Applicable to the PROACTIVE & PREDICTIVE business model

**The previous table is an indicative application of the business models, all the business models can be used for the different value propositions defined (even a combination of several business models).*

AI & BD DRIVEN BUSINESS MODELS IN THE PROCESS INDUSTRY

BUSINESS MODELS TRENDS

A deep literature analysis was performed in AI-CUBE to identify the primary business models driven by AI and BD technologies applied to the process industry. Different publications, roadmaps, books and other material were found and analysed.

Keeping in mind for the selection of the business models their applicability to the process industry, four different categories were created according to the main outcomes to achieve as follows: environmental outcome, human outcome, operations-logistics outcomes and commercial outcome. 11 different trends for innovative AI and BD-driven business models were identified within the previous categories.

Table 2. AI and BD driven business models trends.

	BM TREND	DESCRIPTION	VALUE
ENVIRONMENTAL OUTCOME	SUSTAINABLE BM	Linear model + environmental dimension + human dimensión	Resource efficiency for sustainability and competitiveness. Profitable and resilient activities that benefit society and the environment.
	CIRCULAR BM	Sustainable BM turns circular + company ecosystem	Preserving value in the form of energy, labour, and materials. This means designing for durability, reuse, remanufacturing, and recycling to keep products, components, and materials circulating in the economy.
	SYMBIOTIC BM (industrial symbiosis and collaborative BM)	Circular BM + industrial collaboration + local ecosystem	Collaborative approach concerning the physical exchange of materials, energy, and services between partnering firms and utility, sharing of related infrastructures (creating value from waste).
HUMAN OUTCOME (workforce)	HUMAN CENTERED BM	Human-machine collaboration, human-in-the-loop Application: decision making, problem-solving Technology: ML	AI that learns from human collaborations and is based on systems that are nurtured and constantly improved thanks to human input, therefore allowing better communication between robots and humans. Better Informed Decision-Making Processes / Reliable and Successful Products / Improved and Personalized Customer Experience
OPERATIONS / LOGISTICS OUTCOME	PROACTIVE PREDICTIVE CM (Proactive monitoring and maintenance BM)	Application: predictive maintenance Technology: sensors, automation, ML, BD	A proactive and predictive approach helps companies plan better, make smarter decisions, run smoother and improves productivity. Increased reliability, efficiency and satisfaction and competitive advantage.
	HYPERCONNECTED SC BM	Supply chain communication Technology: automation, robotics, digital twins	Agile, dynamic supply chains that flex to changes in demand through seamlessly integrated planning and execution. SC optimization and understanding
	QUALITY ASSESSMENT BM (Improved product / service quality // quality check BM)	Technology: high-resolution cameras, acoustic and visual sensors	Increases customer confidence, company credibility and competitive advantage while improving work processes, efficiency, and competitiveness. Increased customer satisfaction providing competitive advantage and reducing production costs.
COMMERCIAL OUTCOME	AI-AS-A-SERVICE (Servitization BM)	Outcome as a service / aftersales or advance services like maintenance - MaaS, consultancy or data selling	Meeting customers' demands, leading ultimately to greater customer retention. Manufacturer builds a profitable business from constant streams of additional, incremental revenue. Manufacturer can gain useful insights into future R&D processes by analysing the

	BM TREND	DESCRIPTION	VALUE
		Technology: IoT and sensors	performance of a product sent to a customer and using this information to strive towards continuous product improvement. Customers pay a fixed fee per unit of service consumed, while the ownership of the system remains with the technology provider, who remains responsible for all operating costs. This strongly incentivises the service provider – to think long-term when designing and selecting the technology.
	CUSTOMER-DRIVEN BM	Customer behaviour Application: Patterns and prediction Technology: BD	Prioritizes the customer experience above all else and uses customer needs to guide every facet of operations, from the marketing plan to product development. Customer understanding and market prediction
	INTELLIGENT CUSTOMIZATION BM (customization / design BM)	Technology: ML	Tailoring business streams and aligning strategies with customer value. Customer loyalty, competitive advantage
	COLLABORATIVE BM	Collaborative thinking Technology: ML	Collaborative network sharing resources

BUSINESS MODELS

The AI-CUBE trends were combined to obtain 7 AI and BD-driven business models and one common thread typing them together, the HYPERCONECTED trend, which is an overarching trend in all of them. These BMs can be applied to all the sectors alone or combined with others due to their mainstreaming character.

Table 3. AI and BD driven business models and mainstream.

	DESCRIPTION	BUSINESS MODEL	TREND
ENVIRONMENTAL IMPACT	Profitable and resilient activities that benefit society and the environment.	SUSTAINABLE	HYPERCONNECTED Agile, dynamic supply chains that flex to changes in demand through seamlessly integrated planning and execution.
	Preserving value in the form of energy, labour, and materials. This means designing for durability, reuse, remanufacturing, and recycling to keep products, components, and materials circulating in the economy.	CIRCULAR	
	A collaborative and hyperconnected approach to the physical exchange of materials, energy, and services between partnering firms and utility sharing of related infrastructures in dynamic SCs, creating value from waste across the network.	COLLABORATIVE SYMBIOSIS	
HUMAN IMPACT	AI serves humans by learning from human collaborations and is based on systems that are nurtured and constantly improved thanks to human input, therefore allowing better communication between robots and humans. The AI keeps improving itself thanks to human beings and facilitates what they are doing by optimizing their role in the factory, and enhancing and giving value to their knowledge. Focussed on the human experience, it prioritizes the customer experience as well and uses customer needs to guide every facet of operations, from the marketing plan to product development, tailoring business streams and aligning strategies with customer value.	HUMAN FIRST	

	DESCRIPTION	BUSINESS MODEL	TREND
OPERATION & LOGISTICS IMPACT	A proactive and predictive approach helps companies plan better, make smarter decisions, run smoother and improves productivity	PROACTIVE & PREDICTIVE	
	Increases efficiency and effectiveness of the production and management of the manufacturing and key processes in the organisation through the analysis and exploitation of data and process control.	DATA USE / CONTROL & QUALITY FOR SC	
COMMERCIAL IMPACT	Customers pay a fixed fee per unit of service consumed, while the ownership of the system remains with the technology provider, who remains responsible for all operating costs. This strongly incentivises the service provider – to think long-term when designing and selecting the technology.	AI-AS-A-SERVICE	

To know more about each AI-CUBE business model click on the business model name. General information on AI-driven innovative business models has been also included to understand how AI can transform the industry and the business model in an organization.

AI DRIVEN INNOVATIVE BUSINESS MODELS - GENERAL

- SUSTAINABLE BM
- CIRCULAR BM
- COLABORATIVE SYMBIOSIS BM
- HUMAN FIRST BM
- PROACTIVE & PREDICTIVE BM
- DATA USE / CONTROL & QUALITY FOR SC BM
- AI-AS-A-SERVICE BM

IS IT WORTH THE INVESTMENT IN AN AI AND BD SOLUTION IMPLEMENTATION?

By following the following steps towards digital transformation with the support of AI, contact centre leaders can maximise the benefits from AI integrations, strengthen business operations, and provide a better foundation for business continuity. Companies can use a seven-step process to optimise their AI deployments (https://smartcitiestech.io/2021/07/seven-steps-to-maximise-benefits-from-artificial-intelligence/):

1. Conduct a cost-benefit analysis

The first step in a digital transformation journey is conducting a cost-benefit analysis of potential tools and technologies. Not all contact centres will experience the same benefits from AI, so it's essential that business leaders conduct a cost-benefit analysis to understand their company's unique positioning and how they may benefit from AI deployments.

2. Align IT with business needs

To truly realise the benefits of AI deployments, business leaders must align their IT departments with business objectives. This ensures the IT team understands areas of the business that need enhancement and focus and can help to identify AI and other technologies to facilitate success in these areas.

Data is essential for contact centres in terms of managing and optimising customer experience (CX). While it's not the IT department's responsibility to manage data integration and analysis, aligning IT with business objectives ensures the IT team can understand where there is potential to leverage AI capabilities for better results and insights.

3. Assess and ensure compliance and data security

Good data security and compliance are essential. Understanding how AI will be used across the organisation will inform the type of data that needs to be collected, and what regulations may impact on its collection and use.

4. Identify opportunities for AI enhancement

Conducting a cost-benefit analysis provides an opportunity for contact centre leaders to understand what the end goal is by implementing AI. At this stage, business leaders must also consider what areas should have AI capabilities integrated to help achieve those objectives to subsequently realise the benefits.

5. Integrate education and training

AI capabilities can be used to enhance the agent experience, rather than replace human agents in contact centres. However, agents will require education and training on how best to use AI technologies to empower them to fully realise the benefits.

AI solutions can be leveraged to provide real-time guidance and feedback to agents, essentially acting as a digital twin on calls. However, agents will require training and education on how to leverage AI during customer interactions. Additionally, AI capabilities can be leveraged to improve and build on training programs to ensure agents always have access to the most up-to-date training information.

6. Regularly assess AI activities

AI can provide many benefits to businesses, though it's essential to have a clear benchmark to assess against to ensure these are still meeting business needs and requirements. Contact centres must develop relevant benchmarks to regularly assess AI-enabled activities.

7. Regularly assess AI for enhancements or adjustments

AI technologies leverage machine learning among other things to improve performance and optimise contact centres for streamlined efficiencies. However, these capabilities can adjust and change over time.

It's essential to regularly assess AI tools to ensure they are still operating correctly and to help identify any changes that need to be made.

COST-BENEFIT ANALYSIS

In the past, enterprises struggled to generate value from investments in artificial intelligence. That trend seems to be shifting. One survey found that 92% of firms are now achieving ROI from data and AI investments, with 26% saying they have AI in widespread production. Another survey found that 56% of companies use AI in at least one business function, with more companies attributing a greater share of their earnings to AI as well[1].

However, success depends in large part on AI and machine learning models transitioning from research to production. That isn't happening as quickly, as a third survey suggests that half of AI models aren't yet deployed in production environments.

A cost-benefit analysis can help to make the right decision for investing in AI and BD technologies.

When identifying and quantifying the costs and benefits of an AI and BD solution we need to take into account non-monetary benefits and specific intangible and competitive characteristics implicit in the technology. A holistic assessment of the company's value chain and where AI can bring value (new revenue, cost savings, time savings through efficiency or process automation) is necessary for companies to adopt AI at scale and to realize business value of embedding AI in its value chain.

Cost-Benefit Analysis is a systematic process for comparing benefits and costs of a project/program to determine if it is a sound investment (justification/feasibility) and to see how it compares (ranking/priority assignment). An immediate outcome of the cost-benefit analysis is clear understanding of the benefits that can be obtained by value drivers of AI-enablement, both tangible monetary and intangible, and costs that will be incurred to achieve the benefits over a longer time horizon.

[1] https://sloanreview.mit.edu/article/companies-are-making-serious-money-with-ai/

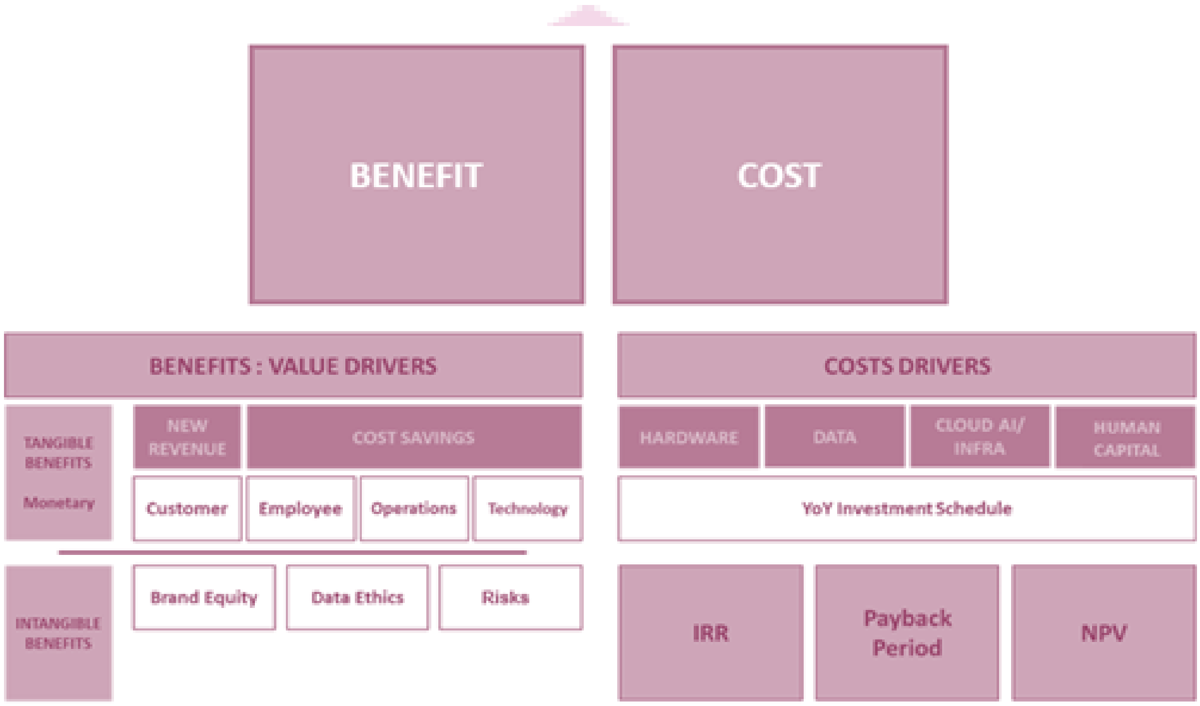


Figure 12. Cost-benefit analysis for AI-BD technology projects[2].

COSTS IDENTIFICATION

The costs of implementing an AI&BD technology include:

Explicit costs: These are accounting costs with explicit monetary value

- Implementation costs:
  - Human (in-house / outsourced)
  - Data (collection / treatment)
  - Software (cloud AI)
  - Hardware (computers / machinery)
  - Training (informed and aware workforce)
- Ongoing costs:
  - Enhancement and upgrades
  - Service and support
  - Replacement equipment
  - Training on new features and new associates

Intangible costs: These are qualitative items

- Lost productivity (downtime cost)
- Reduced customer satisfaction

Implicit costs

- Investment in the project (not available for other projects)
- Employees availability (dedication from other projects)

Costs of potential risks

- Delays
- New data adquisition
- Changes in schedule, re-planning
- Compliance with the firm objectives/policy

[2] https://www.linkedin.com/pulse/value-engineering-costbenefit-analysis-ai-enabled-digital-nath-1c

BENEFITS IDENTIFICATION

As with costs, benefits should be categorized:

Direct: This is the accounting profit from the decision

- Cost savings (through efficiency and quality assessment)
- Increased revenue from a new product (sales)
- Increased revenue from a new service (clients)
- Less staff needed for the task covered by the AI and BD technology
- Eliminates costs of old systems (if replaced)

Indirect: These are tangential benefits

- From new technology implementation
- Customers incentivized

Intangible

- Improved customers satisfaction
- Improved employee satisfaction
- Improved safety
- Improved brand consciousness/image

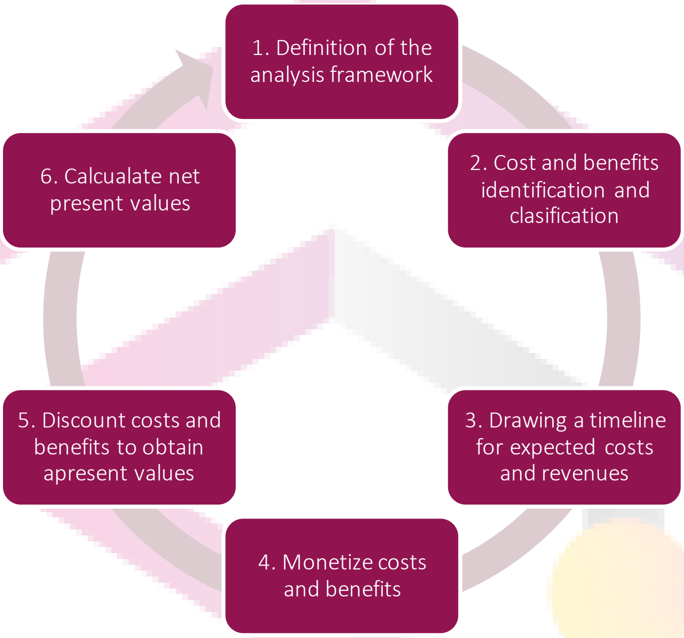
Competitive: These are benefits of gaining a competitive edge in its industry and factor in

- Increased market share
- Competitive advantage

Specific benefits of AI and BD solutions:

- Time savings through efficiency or process automation
- Relying on automated tools to perform mundane tasks instead of hiring people to do them
- Making faster, more accurate decisions so you can adapt to evolving markets
- Reducing costly human errors
- Acquiring more customers
- Targeting customers so they spend more money on your products and services
- Analyzing data to create more effective marketing campaigns
- Better collaboration within teams
- Empowering employees to take control of their job tasks
- Reduced onboarding and training time
- Supporting remote work, which became essential during the pandemic
- Cross-training employees to improve customer experiences

To carry out a cost-benefit analysis before implementing an AI and BD technology in your organization follow the following steps. Identify the costs and benefits relevant to your specific project and quantify all that you can. You can also make a qualitative assessment of those costs and benefits non-monetary or difficult to quantify.


1. Definition of the analysis framework
2. Cost and benefits identification and clasification
3. Drawing a timeline for expected costs and revenues
4. Monetize costs and benefits
5. Discount costs and benefits to obtain apresent values
6. Calcualate net present values

TOMORROW

AI-CUBE developed 4 future scenarios based on different assumptions representing diverse possible future development paths of several key factors or driving forces. Hence, the scenarios represent a selection of the significant trends that influence the implementation of AI&BD technologies and a subset of the technological, organizational, financial and human-related impacts that respond to these trends. After literature research and internal discussion, the trends are combined into four preliminary scenarios. These preliminary scenarios are not prescriptive; rather, they provide a starting ground for discussion.

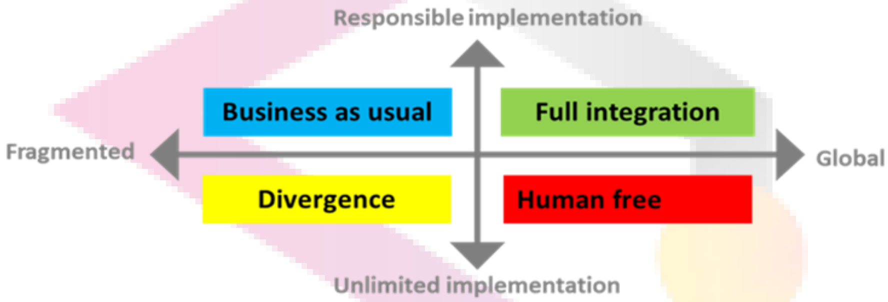


Figure 13.AI-CUBE future scenarios.

The project considered two pivotal uncertainties. The first is the "degree of implementation" in the organization and sector. If the technologies are implemented in all the processes and activities of the organization (scenarios FULL INTEGRATION and HUMAN FREE) or if the implementation is fragmented in the organization or the sector (BUSINESS AS USUAL and DIVERGENCE). The second uncertainty is related to the type of implementation. The implementation of AI&BD technologies was considered responsible, considering the implication for the whole organization or sector (BUSINESS AS USUAL and FULL INTEGRATION), or unlimited, without any qualm in the impact on the operations, business or workforce for the organization or sector (DIVERGENCE and HUMAN FREE). The scenarios identified in AI-CUBE in relation to the uncertainties mentioned above are shown below:

Full integration	In this scenario, AI & BD has evolved, and it's integrated into all the departments and processes of the industry. AI & BD helps the operators with dangerous and repetitive work, improving efficiency and optimizing processes, so humans can focus on core activities and be more productive. AI and BD help with sales and other services as well as at the strategic level, helping with decision-making, customer satisfaction and new product design. AI&BD technologies allow the optimization of resource management along the supply chain.
Business as usual	AI & BD technology has been slightly introduced in the industry and contributed in a limited way to the organization's objectives and the optimization of production, processes and maintenance. Humans are the main resource in the organization. Natural evolution of the industry with time.
Divergence	Low investment in AI&BD technologies leads to a low implementation level in many companies, with only big firms investing in these technologies and displacing small companies from the market, making differences between small and big companies even bigger in terms of competitiveness (potentially leading to "irresponsible" use of AI & BD because of unfair competition, abuse of power by large firms and reduced customer welfare).
Human free	AI has been extensively used in the industry with no control or protective strategy, replacing many workers in the industry. Organizations trim headcount as a result of AI technologies eliminating humans from organizations. Society segregation (pro AI or against AI). Humans are jealous of the attention AI gets.

TIMELINE – FUTURE PERSPECTIVE OF AI&BD IN THE INDUSTRY

The scenario DIVERGENCE is expected to become a reality within the next 5-10 years since big companies are already investing in AI&BD technologies while small companies are not, especially in the water sector. In the medium term, within 20 years from now approximately, however, the sector expects a FULL INTEGRATION scenario where AI & BD applications are completely integrated into all the organizations of the sector at all levels due to the inclusion of small companies in the big ones or their disappearance from the market.

AI&BD providers pointed out that there is hope for small companies since AI&BD applications will become a commodity, present in all industries, like chips, little devices and software applications, which could enable the use of AI&BD technology at all levels.

In conclusion, the integration of AI&BD integration in the short term (by 2025) looks pretty complicated, as pictured in the scenario FULL INTEGRATION. There are significant challenges in data centralization, integration, and verification in industrial plants before integrating mathematical models required by AI and BD. In line with the "garbage in, garbage out" principle, if the wrong data is integrated, the model will be wrong. The industry experts seem optimistic, though, that within approximately 10 years, these barriers would be overcome, and the process industry would benefit from AI & BD, similar to the benefits other high-tech industries are currently enjoying.

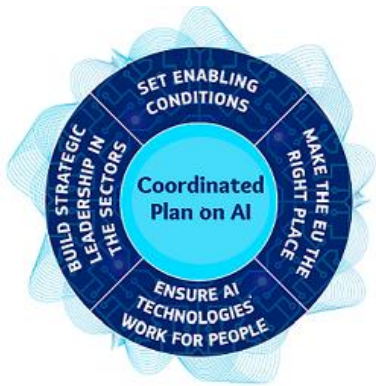
AI AND BD ROADMAPS AND EU-FUNDED PROJECTS

AI-CUBE guidelines are aligned with the European strategy and policies to fostering excellence in Artificial Intelligence as a way to strengthen Europe's potential to compete globally. The European approach to artificial intelligence centers on excellence and trust, aiming to boost research and industrial capacity while ensuring safety and fundamental rights.

Click **here** to know more.

The **2021 Coordinated Plan on Artificial Intelligence** builds on the collaboration established between the Commission and Member States during the 2018 Coordinated Plan. It sets out the strategy to:

- accelerate investments in AI technologies to drive resilient economic and social recovery aided by the uptake of new digital solutions;
- act on AI strategies and programmes by fully and timely implementing them to ensure that the EU fully benefits from first-mover adopter advantages;
- align AI policy to remove fragmentation and address global challenges.



It will do so by:

- setting enabling conditions for AI development and uptake in the EU;
- making the EU the place where excellence thrives from the lab to market;

- ensuring that AI works for people and is a force for good in society;
- building strategic leadership in high-impact sectors.

Click **here** to read more about the **national strategies** for artificial intelligence in European countries.

For strategic insights and contextual intelligence from the **world economic forum**, go here.

To explore and monitor the issues and forces driving transformational change across economies, industries, and global issues, check out these links:

Chemical | Oil and gas | Mining and metals | Supply chains

The **AI Watch** from the European commission takes a holistic view of what is happening in AI, working with key partners from industry, academia, governments and inter-governmental organisations to provide detailed analysis and reliable data.

AI Watch includes an **interactive map** of Europe showing the countrys' AI strategy reports, ai landscape, and investment dashboards.

Some key cross-cutting areas monitored by the AI Watch are:

AI Landscape | Evolution of AI technology

LINK TO OTHER INICIATIVES – EU-FUNDED PROJECTS

COGNITWIN - Cognitive plants through proactive self-learning hybrid digital twins

INEVITABLE - Optimization and performance improving in metal industry by digital technologies

HyperCOG - Hyperconnected Architecture for High Cognitive Production Plants

FACTLOG - Energy-aware Factory Analytics for Process Industries

CAPRI - Cognitive Automation Platform for European PRocess Industry digital transformation

COGNIPLANT - Cognitive platform to enhance 360º performance and sustainability of the European process industry

AI-CUBE BUSINESS MODELS

AI-DRIVEN INNOVATIVE BUSINESS MODELS - GENERAL

AI technology as the catalyst of business model innovation[3].

Business model denotes an activity system or a set of interdependent activities spanning firm boundaries, and business model innovation is defined as a significant change in the company's operations and value creation, typically resulting in an improvement in firm performance. AI has been fostering business model innovation across industries including technology/media, consumer products, financial services, health care, industrial, energy, public sector, and so on. Interviews with more than 3,000 business executives revealed that 84 percent think AI will enable their companies to obtain or sustain a competitive advantage, and 75 percent state that AI will allow them to move into new businesses and ventures[4]. In this context, what should we consider to develop or innovate our business model with AI?

The five steps outlined in Andrew Ng's AI playbook[5] to transform companies with AI by drawing insights from his experiences leading Google Brain and Baidu AI are identified in the following figure.

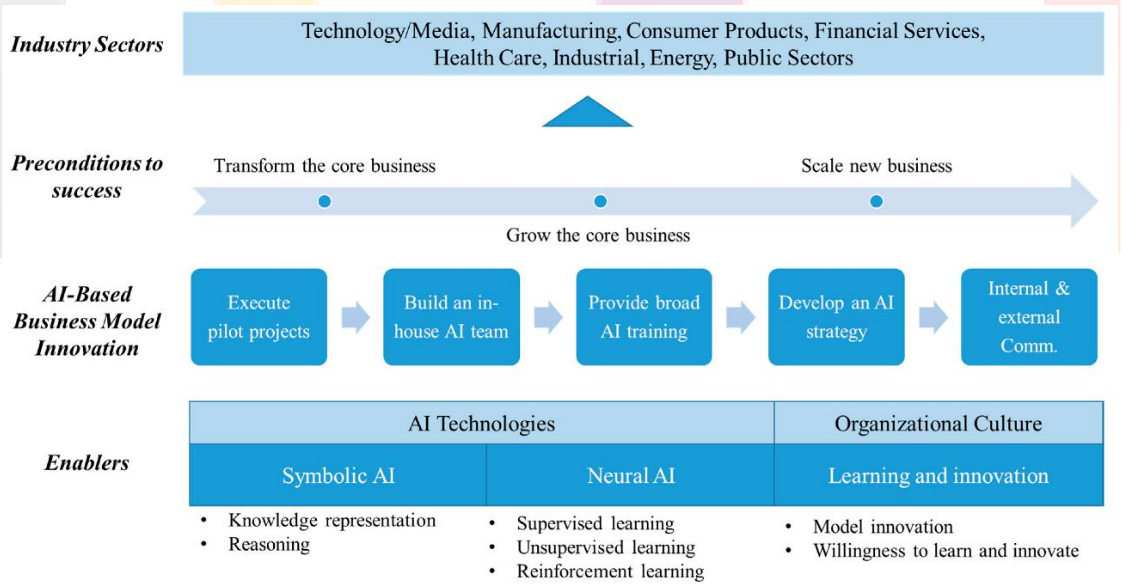


Figure 14.Developing an Artificial intelligence (AI)-Based Business Model.

Execute Pilot Projects to Gain Momentum. Early in the use of AI, a company needs to have pilot projects that succeed in order to build momentum toward business model innovations. Successful small-scale pilot projects allow employees to become familiar with AI technology, recognize that it does not mean the loss of their jobs, and generate enthusiasm for the use of AI. Commonly, many companies are so soaked in

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[3] Emerging Technology and Business Model Innovation: The Case of Artificial Intelligence. Jaehun Lee, Taewon Suh, Daniel Roy and Melissa Baucus. Journal of Open Innovation: Technology, Market, and Complexity 2019.

[4] How Artificial Intelligence is Revolutionizing Business in 2017. Available online: https://www.forbes.com/sites/louiscolumbus/2017/09/10/how-artificial-intelligence-is-revolutionizing-business-in-2017/#11ba98b15463 (accessed on 3 May 2019).

[5] Ng, Y. AI Transformation Playbook. 2018. Available online: https://landing.ai/ai-transformation-playbook/ (accessed on 3 May 2019).

the AI syndrome that they fail to achieve their technical goals. Companies should instead focus on technically feasible smaller projects that are readily achievable. The adoption of AI represents and should be managed as a major organizational change effort, including making information that explains the why and how of the pilot projects available to all employees in understandable language. Furthermore, in designing a team for the projects, AI experts should be mingled with domain-experts such as human resource managers, marketing or social media experts, or employees well-versed in operations. It is obvious that the knowledge from domain experts is so essential for symbolic AI and helpful for neural AI and these experts can offer diverse perspectives on the problem being tackled.

Build an in-House AI Team. Andrew Ng recommended building an in-house AI team to execute projects efficiently. This is natural if companies want to build a more unique competitive advantage or have tremendous confidential data such as a customer usage log. Small and medium sized companies or new startups often cannot afford to hire a significant number of AI researchers and data scientists so they will need to consider alternative strategies. They may need to out-source AI to another company or form a joint venture with an AI company to get the necessary expertise. This reliance on "outside" experts will have to be managed carefully so competitors do not gain access to the company's activities.

Provide Broad AI Training. Most companies do not have enough AI researchers and experts, and companies find it difficult to hire them due to a shortage in the AI field. Thus, Andrew Ng suggested educating employees—all the way from training business executives down to AI researchers by utilizing digital content such as MOOCs. Digital content is relatively affordable and allows a more personalized experience so it could be applied in small and medium sized companies. Companies may want to help develop additional content for AI education since it not only solves the current issue—the insufficiency of AI researchers—but it also fuels lasting AI business model innovation.

Develop an AI Strategy. For instance, Google has tremendous data, so it can build an accurate search engine as a product (A). This product enables Google to acquire more users (B), who then create more data on Google (C). The key factor in AI is to have good quality and sufficient quantity of data. Companies too often attempt to drive AI without appropriate data like building a palace on quicksand. Data acquisition and data infrastructure are vital to transforming the business model. Approaches such as the lean startup method encourage companies to develop minimum viable products that they get customers to use, gathering data in order to test which designs and features are most viable: this virtuous cycle is essential for building an innovative business model and is used in a variety of contexts including new venture startups. Companies using the virtuous cycle will recognize that building a good platform (or new business model) becomes an open-ended challenge.

Develop Internal and External Communications. The company's stakeholders need to be informed about how AI is transforming the business model and the consequences this has for them. Protecting the privacy of customers' and employees' data has become a major issue for companies, as well as ensuring that their actions and decisions comply with laws, regulations and ethical standards, and use of AI to process data and make decisions will create bigger challenges in these areas. Business model innovations developed through the use of AI will increase the company's value to stockholders and provide opportunities to enhance value for customers. Innovations often arise from communications with a company's customers who suggest ideas and highlight what they do not like about current offerings and processes [52] so two-way communication may lead to greater business model innovations. Since AI is not well understood and AI technologies are changing very rapidly, companies will need to inform and educate all of their stakeholders as to how they use AI, the benefits of its use and potential drawbacks or limitations of AI.

SUSTAINABLE BUSINESS MODEL

The first step in the transaction to a sustainable business model is the introduction of some sustainability practices within the production process. In parallel, any sustainability practice should be evaluated with environmental, economic and social sustainability assessment tools, to assess its feasibility. Some sustainability practices could lead to a reduction of environmental impacts but at the same time, they may not be economically feasible. In a manufacturing context, the assessment of sustainability is facilitated by industry 4.0 paradigms, which have enabled companies to increase production efficiency and monitor their production process. The successful implementation of sustainability practices, in addition to an operational process change, also requires strategic evolution. This evolution occurs through innovation in the business model, namely a change in the value proposition of a company. A sustainable business model must represent the sustainability practices that a company has decided to implement. At the same time, the new model must also represent how the sustainable practices introduced impacts on the company's customers and all stakeholders involved in the value creation process.

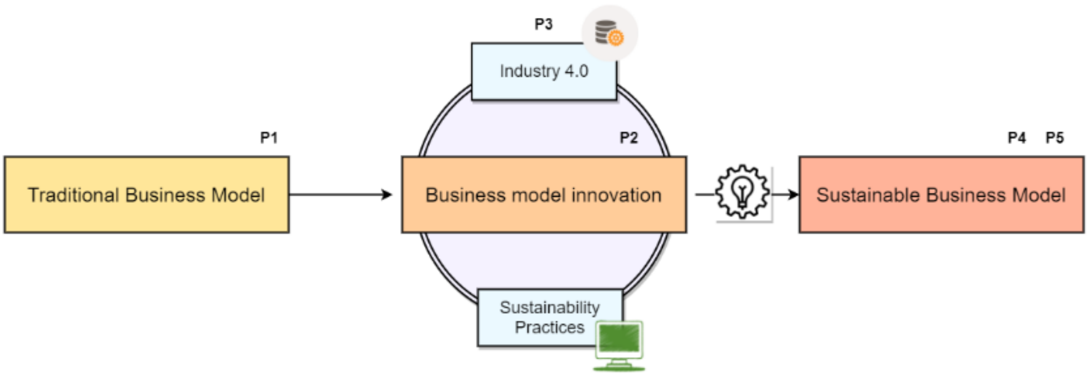


Figure 15.Sustainable business model innovation.

The perspective of a traditional business model canvas does not allow the reader to intuitively perceive the path of sustainability that a company is undertaking. Specifically, the environmental and social pillars of sustainability assume a secondary role, being concealed by an analysis that remains merely economic. The partial analysis of sustainability and a lack of harmonization of the three pillars enables to exploit only part of the benefits resulting from a sustainable transition. In order to extend the analysis to all the three pillars of sustainability, an instrument adopting a triple bottom line perspective is needed. In this regard, the TLBMC created by Joyce and Paquin [6] [10] is a comprehensive choice to better represent also the environmental and social point of view. This model consists of three separate business model canvas, one for each pillar of sustainability. The economic pillar is represented by the traditional canvas while the other two are organized on different items. The following paragraphs, therefore, deal with the environmental and social layer of the TLBMC, entering the specifics of each item.

[6] Joyce, A.; Paquin, R. The triple layered business model canvas: A tool to design more sustainable businessmodels. J. Clean. Prod. 2016, 135, 1474–1486.
(1) (PDF) Sustainability Transition in Industry 4.0 and Smart Manufacturing with the Triple-Layered Business Model Canvas. Available from: https://www.researchgate.net/publication/340028961_Sustainability_Transition_in_Industry_40_and_Smart_Manufacturing_with_the_Triple-Layered_Business_Model_Canvas [accessed Oct 16 2022].

The environmental layer of the TLBMC is based on a view of the entire life cycle from a life cycle assessment perspective. The fundamental purpose of this model is to understand the environmental benefits deriving from the company's sustainability path and the major environmental impacts deriving from the product's life cycle. The advantage of this model is the possibility to understand the most critical environmental issues of the company and the most important practices of circularity and sustainability that the company is undertaking.

The social layer of the TLBMC represents the social pillar of sustainability and it investigates the relationship between stakeholders and the organization. The objective of the model is to understand the major social impacts arising from relations with key stakeholders to exploit only part of the benefits resulting from a sustainable transition. In order to extend the analysis to all the three pillars of sustainability, an instrument adopting a triple bottom line perspective is needed.

LINEAR BUSINESS MODEL

KEY PARTNERSHIPS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Raw material suppliers	Ceramic tile designs	Provide collections of porcelain stoneware tiles totally made in Italy and with the best value for money.	Extensive sales network	Residential customers
Suppliers of glazes and inks	Manufacturing of ceramic tiles		1to1 interaction with distributors	Commercial buildings
Plant and machinery suppliers	Marketing and sales		Offer of ancillary services to the product	Public buildings
Suppliers of electricity	Facilities operations & maintenance			Business customer
Suppliers of methane	Sourcing			
Packaging suppliers	Logistics planning			
Suppliers of chemical additives	Management Accounting & Control			
IT Solution Providers				
Financial services providers				
	KEY RESOURCES		**DISTRIBUTION CHANNELS**	
	Three manufacturing units		Large-scale retails	
	Five logistics warehouses		Independent distributors	
	IT Infrastructure		Specialized stores	
	Human capital			
	Operational know-how			
	Financial assets			

COSTS STRUCTURE	REVENUE STREAM
Manufacturing costs	Volume of sales
Commercial costs	
Research & development costs	
General and administrative costs	
Financing cost	

SOCIAL BUSINESS MODEL CANVAS

LOCAL COMMUNITIES	GOVERNANCE	SOCIAL VALUE	SOCIETAL CULTURE	END-USER
Private business	Privately-owned group	Develop long term value for customers, offering a quality product produced and designed by local labour force	Culture of cooperation deriving from the district context	High quality product
Staff and employees	Functional specialization			Italian style and design
Local Public Institutions	Transparency in communication			Traceability
Trade channel operators				Eco-friendly products
Suppliers				Quality-price rate
Trade unions		Production in compliance with regional, national and European regulations on sustainable development		
Partners				
Public and private organizations				
Final Product Consumers				
Media	**EMPLOYEES**		**SCALE OF OUTREACH**	
Competitors				
Environment	Local workforce		Global sales network	
	High recruitment rate		Long term relationships with local suppliers	
	High level of gender equality		Strong link with local trade associations	
	Low level of turnover			

SOCIAL IMPACTS	SOCIAL BENEFITS
Damage from industrial activity	Job creation
	Transparency of financial information
	Regulatory compliance
	Fair management of suppliers
	Respect for human rights

ENVIRONMENTAL BUSINESS MODEL CANVAS

SUPPLIES AND OUTSOURCING	PRODUCTION	FUNCTIONAL VALUE	END-OF-LIFE	USE PHASE
Electricity	Ceramic body milling	One square metre of tile, multiplied by the total production over the period of one year	Removal of flooring	Installation phase
Methane	Spray-dring process		Product disposal	Detergents
Water	Tile pressing and drying			Water for cleaning
Inks	Glazing and decoration			
Milling pebbles	Glazed tiles firing			
Laboratory consumables	Tiles cutting and shaping			
Laboratory equipment	Size and flatness control			
	Sorting and packing			
	MATERIALS		**DISTRIBUTION**	
	EU Clay		Truck transport	
	Local Clay		Ship transport	
	Local feldspar		Train transport	
	Local feldspar sand		Logistic centres	
	Extra EU clay			
	Extra EU feldspar			
	Raw materials for glazes			

ENVIRONMENTAL IMPACTS	ENVIRONMENTAL BENEFITS
Air polluting emissions	Efficient consumption of raw materials
Production waste	High-percentage of local raw materials
Virgin resources consumption	Heavy metal-free glazes
	Electricity from coogeneration
	Water reuse

Figure 16.Linear, social and environmental business models CANVAS.

Example: Sustainable business model in the ceramic industry

In order to evaluate the transition from a traditional to a sustainable model, it has been decided to consider one of the largest producers of tiles in the Sassuolo ceramic district as a case study to test the conceptual model [7]

Looking at the results obtained, in the model concerning the environmental pillar, important details of the ceramic production process are highlighted, including the raw materials used, the distribution channels and the process phases throughout the entire life cycle. In addition, the main environmental impacts created by the production activity and the greatest benefits in environmental terms, deriving from sustainability practices undertaken by the company analyzed, are considered. The simultaneous reading of the traditional and environmental business model allows the reader to have a much more detailed picture of the company's activity. In particular, it reveals how the company has individually engaged in a path of sustainability that not all other companies in the sector may have chosen to pursue. This choice can be exploited by the company to create value for its finished product, no longer based solely on price or quality. The business model represented in this way is already an intuitive tool that can be communicated externally in this respect. In the model concerning the social pillar, instead, the functional structure of the company, the company's governance and the main stakeholders involved are specified, with a focus on employees and the end-user. Furthermore, the main social impacts and benefits deriving from business activity are also analyzed. In this situation, the social model added to the other two further increases the information provided to the reader. In particular, the model provides details of the social benefits that the company generates, which could be important information to share with the company's main stakeholders. In addition, the social model provides guidance for a possible social audit by the company's authorities or clients or for the preparation of a sustainability report that also includes

[7] García-Muiña, Fernando & Medina-Salgado, Maria-Sonia & Ferrari, Anna & Cucchi, Marco. (2020). Sustainability Transition in Industry 4.0 and Smart Manufacturing with the Triple-Layered Business Model Canvas. Sustainability. 12. 2364. 10.3390/su12062364.

the company's social commitment. In summary, the results show the company's value proposition in a revised and significantly more detailed form than the previous traditional business model.

From the results of the paper, the sustainability path undertaken emerges and the reader perceives the awareness that the company has of its production process and the environmental impact it creates. In parallel, the considerations on the social sustainability dimension are also relevant. The environmental damage produced by industrial activity inevitably has social repercussions, particularly in the territory in which the company operates. At the same time, however, no less important are the social benefits that the company generates, especially in creating several jobs in the area and in communicating transparently and ethically with suppliers and customers. The absence of the transition to a sustainable business model tool such as the triple-layered business model canvas, which highlights the creation of social value, does not allow the company to become aware of the social benefits it generates and, by consequence, these benefits are also not communicated to customers and stakeholders.

CIRCULAR BUSINESS MODEL

The circular economy (CE) has the potential to capitalise upon emerging digital technologies, such as big data, artificial intelligence (AI), blockchain and the Internet of things (IoT), amongst others. The results of research works[8] reveal that IoT and AI play a key role in the transition towards the CE. A multitude of studies focus on barriers to digitalisation-led CE transition and highlight policy-related issues, the lack of predictability, psychological issues and information vulnerability as some important barriers. The capabilities driven by digitalization technologies for the CE, including AI and BD, are shown below.

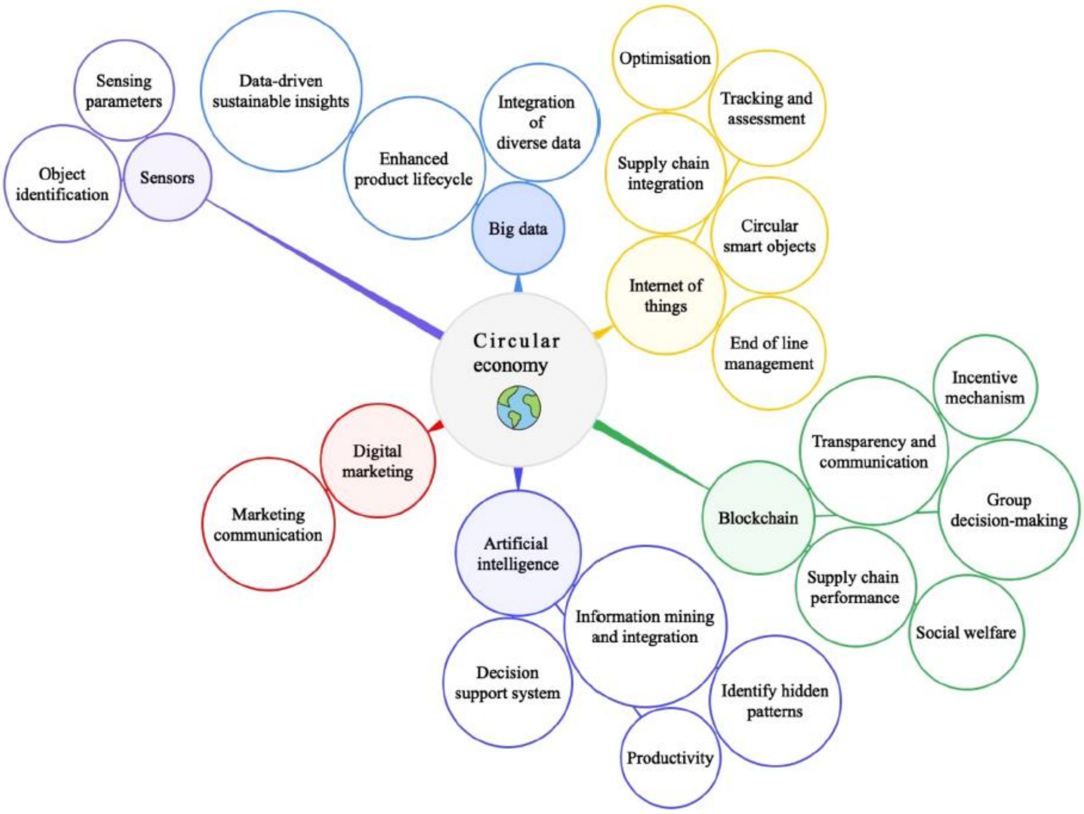


Figure 17.Capabilities driven by digitalization technologies for the CE.

The benefits emerged in supporting the implementation of circulat management strategies with AI is reported below[9].

[8] Chauhan, Chetna & Parida, Vinit & Dhir, Amandeep. (2022). Linking circular economy and digitalisation technologies: A systematic literature review of past achievements and future promises. Technological Forecasting and Social Change. 177. 121508. 10.1016/j.techfore.2022.121508.
[9] Federica Acerbi, Dai Andrew Forterre, Marco Taisch. Role of Artificial Intelligence in Circular Manufacturing: A Systematic Literature Review. IFAC-PapersOnLine, Volume 54, Issue 1, 2021. Pages 367-372, ISSN 2405-8963, https://doi.org/10.1016/j.ifacol.2021.08.040.

Scale	*Entity impacted*	*CM strategy*	*AI benefits*
Micro	Product	Circular Design	Tracking the material starting from the acquisition phase. Prototyping the new product without wasting resources during the test phase Keeping high product modularity exploiting AI to prototype products Gathering data from smart products to improve next generation products on the basis of end-users behaviours
		Servitization	Tracking and monitor the product usage to improve the service provided
		Disassembly	Defining the best and most efficient disassembly path relaying on AI in collaborative robots
		Reuse	Tracking the product to monitor the conditions and evaluate whether the product reuse is possible
		Recycle	Tracking the product to monitor the conditions and evaluate whether and how the product components and materials can be recycled
	Process	Waste Management	Tracking the type of material present in the waste to evaluate its recyclability or disposal
		Resource Efficiency	Tracking energy, water, and other resources usage during the production process
		Cleaner Production	Tracking energy, water, and other resources usage during the production process to evaluate possible improvements
Meso	Network of firms	Closed-loop Supply Chain	Creating collaboration by mapping the most convenient circular path Forecasting return products quality, quantity, and time Tracking products in real-time to estimate the residual value Tracking vehicles to manage the loading of waste and recyclable resources
		Circular Design	Designing the product considering the actors involved in the value chain
		Remanufacture	Tracking the turned back product to monitor the conditions and evaluate whether the product can be remanufactured Exploiting product data, once returned, so to define the best remanufacturing path
Macro	Nations, Regions, Cities	Waste Management	Keeping track of circular performance to forecast it in nations, regions and cities Monitoring municipal waste type and quantity

The literature analysis performed by Garcia-Muiña 2018[10] provided us a theoretical model shown below which aims to provide a conceptual background to respond to the main research question in the case of a circular business model and to support the application to this specific case study. The different blocks of the model are correlated with each other by the propositions enunciated in the theoretical framework and built on the basis of the analysis of the literature. The strategic objective of the model takes up the challenge arising from the research question: "How to increase the competitiveness of a company in an industrial district through the adoption of practices of environmental, economic and social sustainability?". On the one hand, the territory offers a favorable competitive context for achieving the goal of sustainable enterprise, thanks to the opportunities offered by the socio-economic structure of the industrial district (mesoeconomic space) and by the relations that exist between individual enterprises (microeconomic space) along the same supply chain. On the other hand, the Industry 4.0 paradigm and IoT technologies provide the technical platform to collect process data and build powerful databases to conduct economic and social environmental impact assessments, using LCA, LCC and S-LCA tools respectively.

[10] García-Muiña, Fernando & González-Sánchez, Rocío & Ferrari, Anna & Settembre Blundo, Davide. (2018). The Paradigms of Industry 4.0 and Circular Economy as Enabling Drivers for the Competitiveness of Businesses and Territories: The Case of an Italian Ceramic Tiles Manufacturing Company. Social Sciences. 7. 255. 10.3390/socsci7120255.

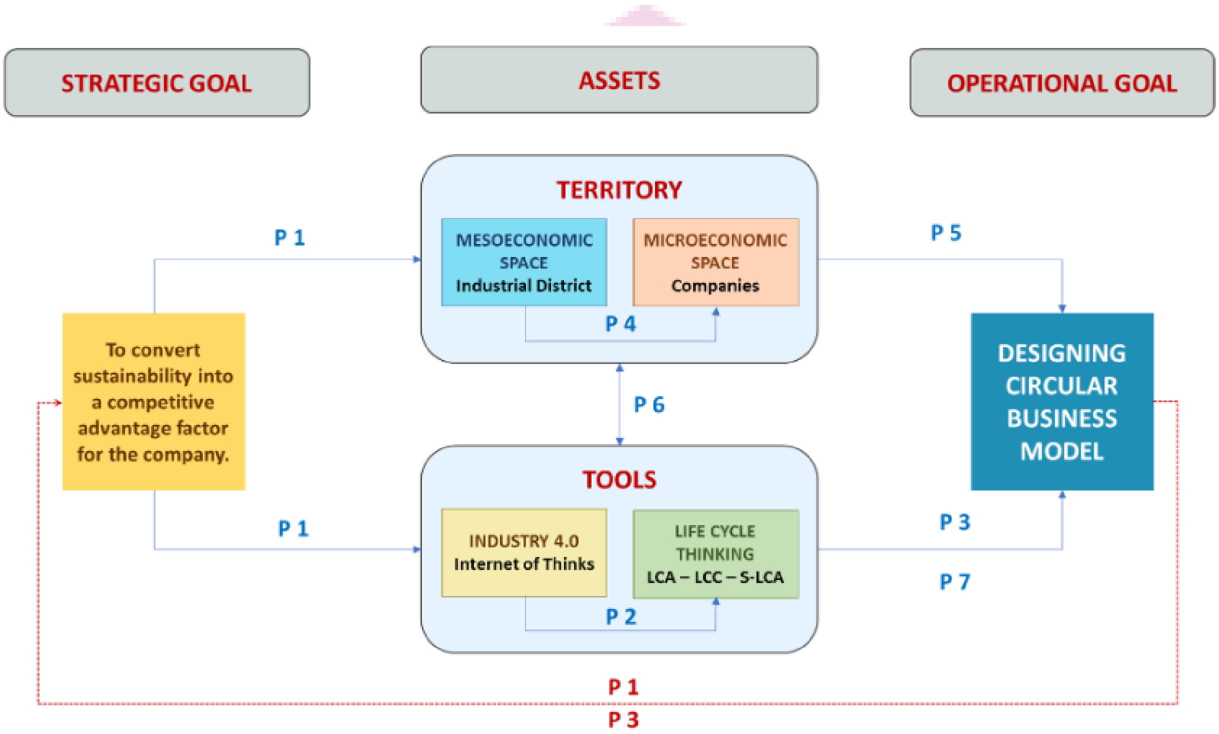


Figure 18.Conceptual model for the integration of sustainability into the BM of an industrial company.

The integration of all these assets, both socio-economic and technological, provides the information needed to design a new circular business model that represents the operational goal to integrate sustainability into the business of the enterprise. The proposed conceptual model already introduces an element of circularity: The operational findings from the implementation of the Circular Business Model within the company offer useful indications to support the strategic planning of top management to pursue an improvement in competitiveness through the principles of sustainability.

Example: Ceramics sector

The transition to a circular economy aimed at integrating sustainability into the company's business, has required a structural change in the traditional manufacturing model. This change was carried out through the digital transformation of the production system in one year of activity, implementing in the ceramic production process the main enabling technologies of Industry

The evolution towards industry 4.0 consists of integrating new production technologies, to improve working conditions and increase productivity and quality. These production technologies create collaboration between the elements characterizing the production, i.e., exchange of information between machinery and plants, in the broadest sense, so not only machines in the production department but also automatic warehouses for feeding the production lines or storage of finished products and any other device that is part of the workflow of value creation. The digital innovation in our case study was based on the Enterprise Resource Planning (ERP) already implemented by the company. The ERP already integrated and governed all business processes, so we intervened on the change of forms of information exchange. The assumption for the change was that from the moment a plant is able to receive and transmit information, it will be relatively easy to use it to equip processes already managed by the information system, even if previously through other forms of data collection. Therefore, the design of the Industry 4.0 environment has focused on the dialogue systems between plants in the different phases of the process to communicate with each other and with the information system, receiving orders, executing them, communicating their progress and communicating data on resource consumption and emissions, as well as useful information to plan production and arrange for appropriate maintenance.

The roadmap for the digitization of the ceramic production process provided for the installation of a network of meters (sensors for the acquisition of factory data capable of measuring consumption and emissions of machines) for each phase of the process (Figure 4). These sensors are intelligent and interconnected, able to collect some process data and communicate with each other without, however, giving significant information on production trends. In order to generate usable knowledge from the collected data, it is necessary to have a series of MES (Manufacturing Execution System) which are software capable of exploiting the data (thanks to inter-functional algorithms) and providing managers with useful information to make the right decisions at the right time. The MES systems translate the data collected and give it meaning, allowing a precise knowledge of what is happening in the factory in real time.

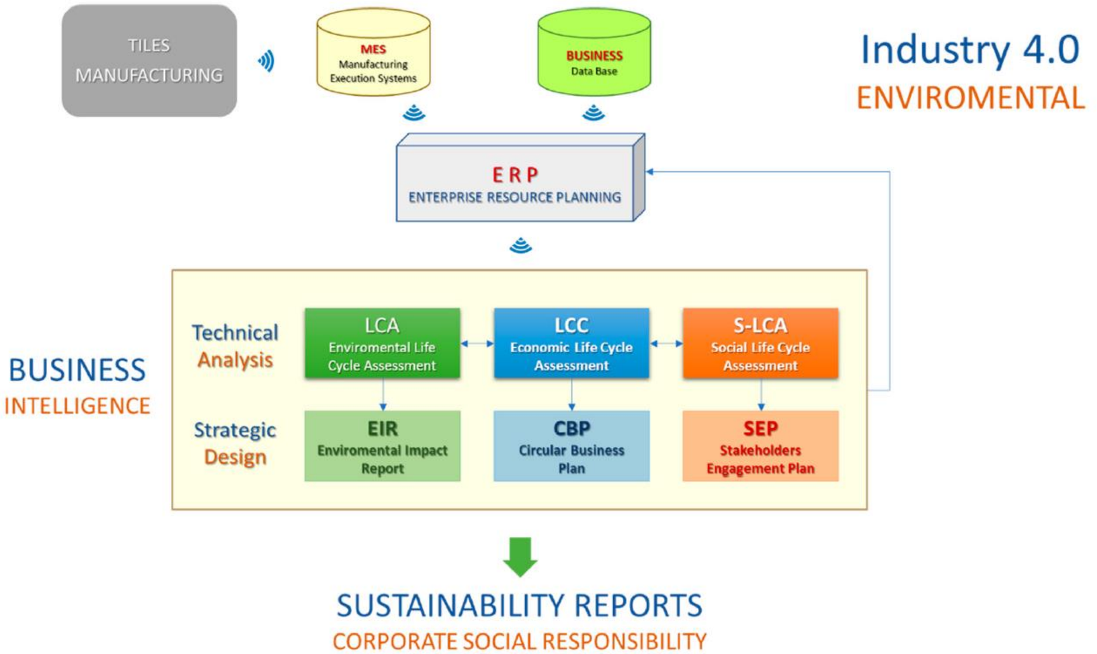


Figure 19.Assessing ceramic manufacturing data in an Industry 4.0 environment.

A sustainability analysis allows to collect all the elements needed for strategic planning aimed at innovating the business model, moving from the traditional linear to the circular scheme. In this case, the innovative element, compared to the current model (linear), is the implementation of elements related to environmental, economic and social sustainability. To describe and illustrate the business model of the company under study, a Business Model Canvas (BMC) tool is used.

The scheme of the current Business Model of the ceramic company involved in this example is shown below. It is obviously a linear model (take-make-dispose), which through the nine basic elements of the CANVAS provides the set of organizational and strategic solutions that allow the company to create, distribute and acquire value.

Moving from a linear to a circular business model may seem easy in theory, but it proves complex in practical application, and many different paths can be taken. To manage the transition between the two models, the focus is on the stakeholders to broaden the ways of creating value by also taking into account the environmental, economic and social benefits. Accenture (Lacy and Rutqvist 2016)[11] proposed five types of CBM: (i) Circular Supply-Chain (search for innovative renewable, recyclable resources that can be used in consecutive life cycles); (ii) Recovery and Recycling (recovery of waste and by-products from a production process); (iii) Product Life-Extension (maintenance, updating and repair of the products); (iv) Sharing Platform (renting, sharing and exchanging non-utilized goods); (v) Product as a Service (combining a physical product with a service component).

In managerial practice, it is difficult to adopt only one of the types of BM described above, it is more realistic to combine aspects of each of them. The integration of the company in an industrial district, and thanks to the virtuous collaborative network with suppliers has led us to focus on the innovation of the BM, shifting the focus of the company from the corebusiness (manufacture tiles) to the inclusion of complex collaborative networks for the recovery of materials and resources within the supply chain. In particular, the focus was on the use of renewable and recyclable resources (raw materials and energy sources); the recovery of waste from internal processes and from other players in the ceramic industry; and finally, the extension of the service component associated with the ceramic product. The result of the new circular business model is shown below where innovative components compared to the linear model are indicated in orange ink. In line with the strategic choices described above, the new CBM has introduced the main stakeholders mapped and prioritized with the S-LCA analysis and, among these, it should be noted that the environment also appears. Key resources have been integrated with more efficient manufacturing systems both in terms of resource use and energy sources. The Value Proposition has been extended by introducing the principle of eco-design and the commitment to adopt technological solutions to manufacture ceramic products with respect for people and the environment. The service attributes of the ceramic product have been extended to include the possibility of creating customized products based on customer needs, and also used for this purpose are digital distribution channels to meet the demand of the new “green” segment of customers. In the cost structure, both externalities and social costs have been introduced, while on the revenue side advantages are expected generated using recycled materials.

[11] Lacy, Peter, and Jakob Rutqvist. 2016. Waste to Wealth: The Circular Economy Advantage. Berlin: Springer.

CIRCULAR BUSINESS MODEL				
KEY PARTNERSHIPS	**KEY ACTIVITIES**	**VALUE PROPOSITION**	**CUSTOMER RELATIONSHIPS**	**CUSTOMER SEGMENTS**
Raw material suppliers	Ceramic tile designs	Provide collections of porcelain stoneware tiles totally made in Italy and with the best value for money.	Extensive sales network	Residential customers
Suppliers of glazes and inks	Manufacturing of ceramic tiles		1to1 interaction with distributors	Commercial buildings
Plant and machinery suppliers	Marketing and sales		Offer of ancillary services to the product	Public buildings
Suppliers of electricity	Facilities operations & maintenance		On-demand product development	Business customer
Suppliers of methane	Sourcing	Apply eco-design techniques to the development of new products, using ecofriendly and resource saving raw materials.		Green consumers
Packaging suppliers	Logistics planning			
Suppliers of chemical additives	Management Accounting & Control			
IT Solution Providers				
Financial services providers		Develop innovative solutions for our manufacturing processes for sustainable growth while respecting people and the environment around us.		
KEY STAKEHOLDERS	**KEY RESOURCES**		**DISTRIBUTION CHANNELS**	
Private business				
Trade channel operators				
Suppliers	Three manufacturing units		Large-scale retails	
Staff person	Five logistics warehouses		Independent distributors	
Final consumers	IT Infrastructure		Specialized stores	
Competitors	Human capital		Cloud based interactive multi-channel	
Public Institutions	Operational know-how			
Environment	Financial assets			
Partners	Energy-efficient manufacturing system			
Trade unions	Resource-efficient manufacturing system			
Public and private organizations				
Media				

COSTS STRUCTURE	**REVENUE STREAM**
Manufacturing costs	Volume of sales
Commercial costs	Value recovered from the use of recyclable materials
Research & development costs	
General and administrative costs	
Financing cost	
Environmental costs (externalities)	
Social costs	

Figure 20.Representation of the innovative circular business model (CANVAS).

COLLABORATIVE SYMBIOSIS BUSINESS MODEL[12]

"Collaboration" is a crucial challenge for the 4th industrial revolution, and thus the "Collaborative Networks" area, among others, needs to be taken as a core enabler for this transformation.

In the literature, Industry 4.0 is often discussed in reference to 4 main dimensions, i.e.: (1) "vertical integration/networking", (2) "horizontal integration/networking", (3) "through-engineering", and (4) "acceleration of manufacturing". Some publications also refer two additional dimensions: (5) "digitalization of products and services", and (6) "new business models and customer involvement". These dimensions can be described briefly as:

1. "**Vertical integration**" relates to integrating systems and processes vertically across the whole organization, i.e., networking all its units, from the shop floor layer (e.g., "smart production systems", "smart products", "smart logistics"), up to the engineering and business layers (e.g., engineering and development, product and production management, quality assurance, marketing, etc.) [1,10,16]. This interconnection through information and communication technology (ICT) is expected to allow easy data access and transparency, facilitating decision-making and agility. As sub-systems progressively become smarter, more than integration the direction is towards seeing the organization as a network of smart (and partially autonomous) units.
2. "**Horizontal integration**" refers to "networking along the whole value chain, from suppliers and business partners to customers", bringing them into a "close working relationship with each other", i.e., "in order to achieve seamless and secure cooperation between enterprises" and towards the market. Horizontal integration should be based on a reliable and secure infrastructure supporting the collaboration between manufacturing organizations and their partners in the supply chain. Through such support all actors and units involved can communicate changes and share information in real-time. This infrastructure also allows collaboration with technology and machine providers, and software developers, by offering them a standardized framework for interaction.
3. "**Through-engineering**" dimension, also known as "end-to-end engineering", integrates all engineering-related activities involved in the entire product lifecycle, from design/manufacturing to disposal/recycling. Digitalization enables new functions for collaboration at the various phases of the lifecycle where different actors are involved, supported by the exchange of large volumes of data on products and processes. It also allows better interaction with the customer. New meanings to "design" can be given, going far beyond the product per se but linking the product to specific needs of the market, e.g., design for environment, design for maintenance, customized product configuration.
4. "**Acceleration of manufacturing**" focuses on optimizing the entire value chain, resorting to the integration of the "exponential technologies" (i.e., technologies that have an exponential growth), and "accelerating and making industrial processes more flexible". In fact, some of these technologies have been around for many years, e.g., robotics, artificial intelligence (AI), neuro-technologies, but a significant development boost only recently became evident. Often more than one of these technologies enter the manufacturing arena simultaneously, which in some cases leads to disruptive transformations. These combined effects also lead to the notion of "acceleration of manufacturing".
5. "**Digitalization of products and services**" not only relates to creating digital models of products but also to moving toward "smart products", through the addition of sensing, computing, and communication capabilities to these products. This also comprises (1) availability of product data along the product's lifecycle (facilitating tracking and tracing), (2) introduction of new "digital products", and (3) adding "business services" to the physical products. The idea of "service-enhanced products" or "product-service-systems" is now well-known in the market, where even several products are living a new commercial life thanks to integrated and

[12] Camarinha-Matos, Luis & Fornasiero, Rosanna & Ramezani, Javaneh & Ferrada, Filipa. (2019). Collaborative Networks: A Pillar of Digital Transformation. Applied Sciences. 9. 5431. 10.3390/app9245431.

embedded services. In some sectors, the value offered to the customer is not any more focused on the physical product but rather on the associated business services that provide value to the customer (servitization trend).

6. "**New business models and customer involvement**", focusing on innovative business models that take advantage of the digitalization process, networking along the value chain, and data-rich contexts. These models explore new possibilities offered by technology and foster closer "digital relationships" with more demanding and empowered customers. Furthermore, they "accelerate globalization but with distinct local/regional flavors". For instance, the platform-based economy, big data-driven value chain, sharing economy, software as a service, etc., are some of the models under discussion both at scientific and industrial level to fully exploit the potential of digitalization.

	Dimension	Some Relevant Topics/Key Challenges	Examples of Core Enabling Technologies
1	Vertical integration of smart production systems	▪ Interoperability ▪ Decentralization and Modularization ▪ Service orientation ▪ Needs-oriented and individualized ▪ Fast decision-making processes ▪ Agility and reconfigurability ▪ Sustainability ▪ Optimization models	▪ Extensive cyber physical systems (CPS) and Internet of Things (IoT) ▪ Sensing and real-time availability of data ▪ Artificial intelligence ▪ Virtualization of processes, digital twins ▪ Data analytics ▪ Augmented reality ▪ Cybersecurity and Distributed ledger
2	Horizontal integration through global value chain networks	▪ Collaboration and Transparency ▪ Interoperability ▪ Decentralization ▪ Business ecosystems ▪ Global optimization and flexibility ▪ Resilience ▪ Regulatory framework ▪ Data sharing, tracking and tracing	▪ Cloud computing ▪ Collaboration platforms ▪ Mobile computing and IoT ▪ Safety and security ▪ Distributed business processes orchestration ▪ Cybersecurity and Distributed ledger
3	Through-engineering across the entire value chain	▪ Co-engineering, co-design ▪ "End-to-end integration" ▪ Circular economy ▪ Connection of and customers involvement ▪ Tracking and tracing ▪ Data privacy on personal data ▪ Intellectual property management	▪ Product life-cycle management systems ▪ Cloud computing ▪ Open innovation platforms ▪ Data management along product and process lifecycles ▪ Cybersecurity ▪ Simulation and virtual reality
4	Acceleration of manufacturing	▪ Integration of new players ▪ Advanced human–machine interfaces ▪ Ergonomics ▪ Hybrid collaborative systems ▪ Increased transparency along shop floor ▪ Interoperability among machines ▪ Decentralization of decision-making ▪ Flexibility and reconfigurability ▪ Distributed intelligence ▪ Cognitive systems	▪ Collaborative machines, robotics and drones ▪ Cloud, big data and analytics ▪ CPS, IoT, Mobile computing ▪ Artificial intelligence, machine learning ▪ Additive manufacturing ▪ Sensing technologies ▪ Neuro-technologies, Nanotechnologies ▪ Cybersecurity ▪ Wearable devices and smart fabric
5	Digitalization of products and services	▪ Self-identification ▪ Product history, tracing and tracking ▪ Data availability ▪ "Service-enhanced products", Product-service ecosystems ▪ Monitoring, self-diagnosis, assistance, self-configuration	▪ Cloud computing and IoT ▪ Augmented reality and simulation ▪ Real-time product monitoring systems ▪ Service design, Service integration and evolution ▪ Smart products ▪ Digital twins
6	New business models and customer involvement	▪ Customer experience and intimacy ▪ Dynamic value chains ▪ Hybrid value systems ▪ Sustainability, social responsibility ▪ New challenges in intellectual property ▪ Glocal enterprise	▪ Business model design & innovation tools ▪ Co-design/co-creation platforms ▪ Sharing platforms ▪ Cloud computing, mobile computing ▪ Cybersecurity ▪ Link to smart infrastructures

Figure 21. Examples of characteristics and technologies in Industry 4.0.

Nowadays, CNs are being applied to a great variety of domains, moving from academic research to manufacturing and other industrial applications. These implementations are supported by a variety of collaboration forms, which range from "supply chains" to emerging dynamic structures in industry, science, and services. The multiple CN manifestations can be organized in a taxonomy, which has been evolving with the advances of ICT tools in the last two or three decades.

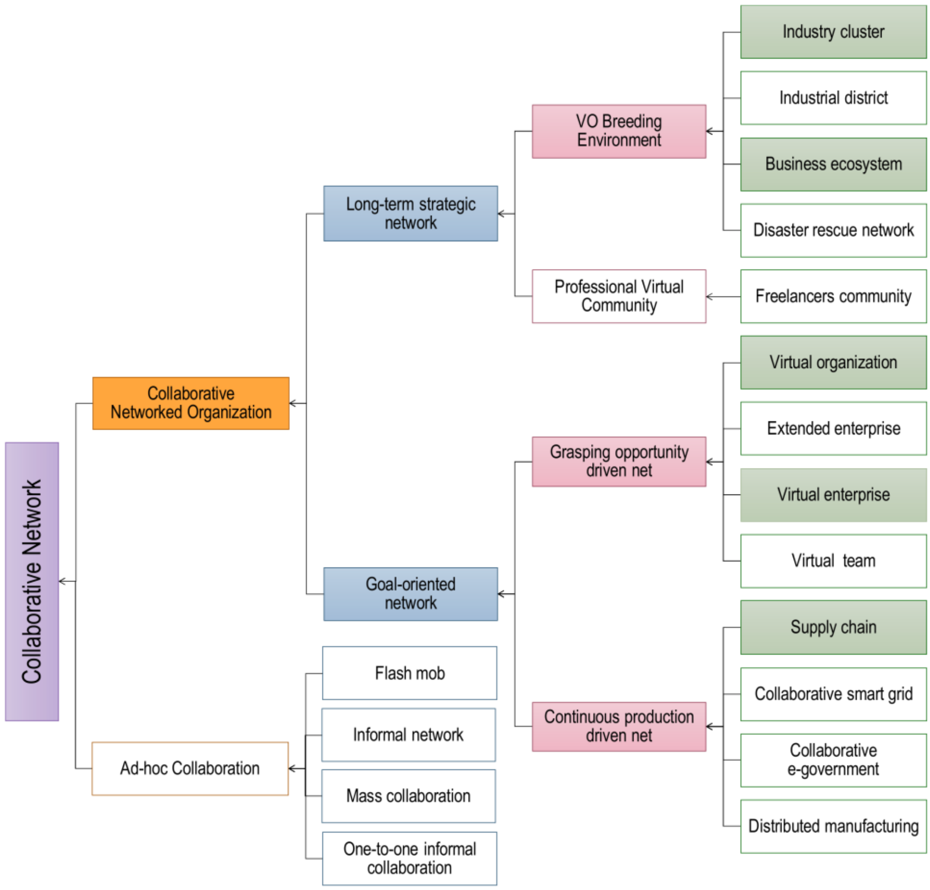


Figure 22. A partial taxonomy of collaborative networks (CNs).

The first level of the CN taxonomy distinguishes between "collaborative networked organization (CNO)" and "ad-hoc collaboration". A CNO characterizes a network, typically business-oriented, with solid organizational aspects in terms of structure, roles definition, and governance rules, while an ad hoc collaboration characterizes a spontaneous and not structured network which might emerge for instance, in a crisis. There are two main classes of CNOs: (i) the goal-oriented networks and (ii) the long-term strategic networks.

Goal-oriented networks are networks characterized by intense interaction among its participants aiming at reaching a common goal. They include the (a) continuous production-driven networks, which are networks that remain stable for a long period of time with well-defined roles for their participants. Supply chains or collaborative smart grids are examples of such networks; and the (b) grasping opportunity-driven networks, i.e., networks that are dynamically created to pursue some business opportunity within a limited time window. Virtual organizations (VO)/virtual enterprises (VE) and virtual teams (VT) are examples of such networks, which are composed of groups of independent organizations or individuals sharing skills and resources in response to business opportunities.

In turn, long-term strategic networks are characterized as strategic alliances created to act as source or breeding environments for "goal-oriented networks", i.e., aimed at providing proper conditions and support environment for dynamic creation of goal-oriented networks whenever a business opportunity arises. This class includes the (a) professional virtual communities (PVC), which are networks composed of individual professionals that get together in a long term basis to be prepared to rapidly react in response to business opportunities through the dynamic creation of temporary VTs, and the (b) VO breeding environment (VBE) that represents "an association of organizations and a number of supporting institutions committed to a long term cooperation agreement, complying with common operation principles and infrastructures, with the main goal of increasing their preparedness towards rapid configuration of temporary alliances for collaboration in potential VOs". Examples of such classes are industry clusters or business ecosystems.

To enable and support this wide variety of CNs, a substantial portfolio of models, mechanisms, tools, and platforms/infrastructures, has been developed and refined in the last years, as briefly illustrated in the following figure.

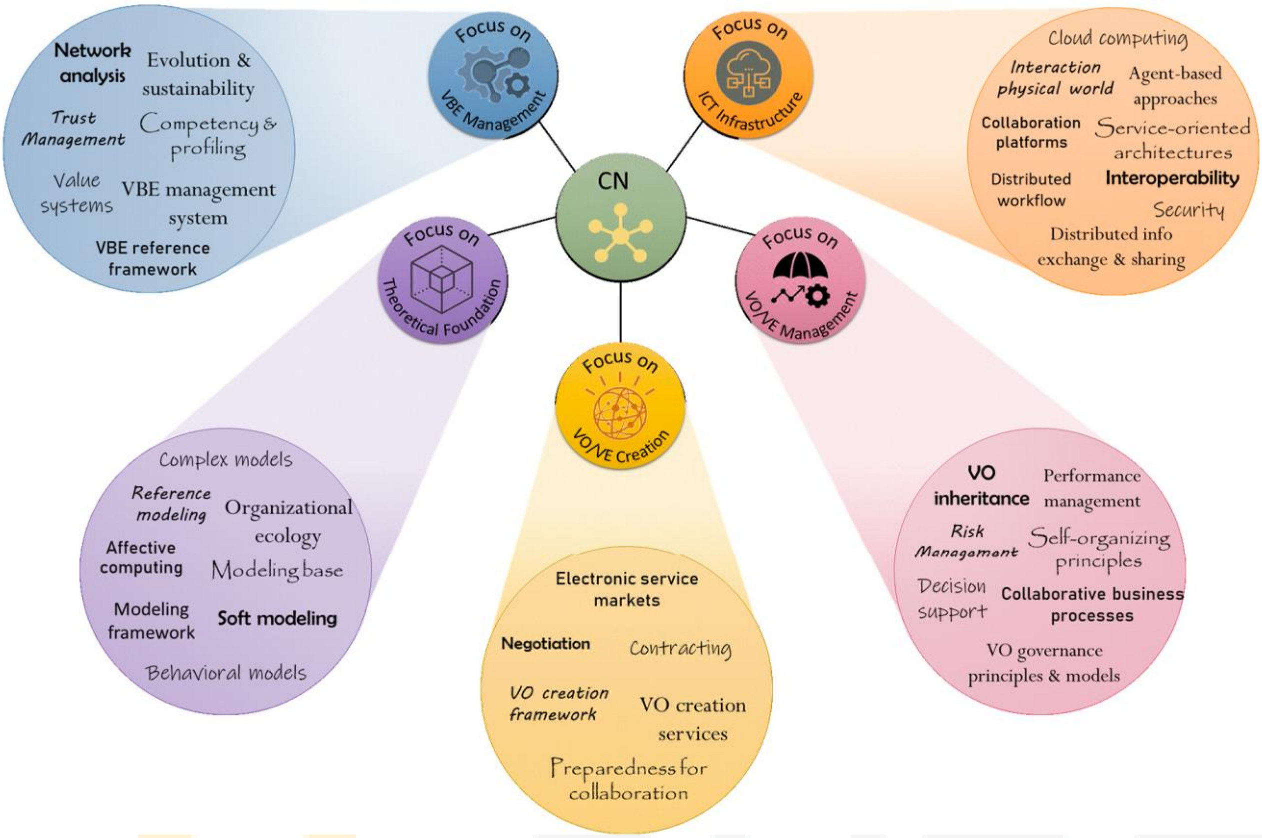


Figure 23. Collaborative networks supporting developments according to focus areas. VO: Virtual organization, VBE: VO breeding environment.

The possibilities offered by AI and BD technologies, allowing for high levels of interconnection among people, organizations, and systems, naturally inspire the emergence of new business opportunities supported by new business models. In a way, the horizontal integration dimension is extended by exploring the potential of collaboration along the value chain. This dimension corresponds to a very dynamic area where innovative solutions are likely to emerge at a fast pace. The following examples clearly illustrate the need for collaborative approaches in this area.

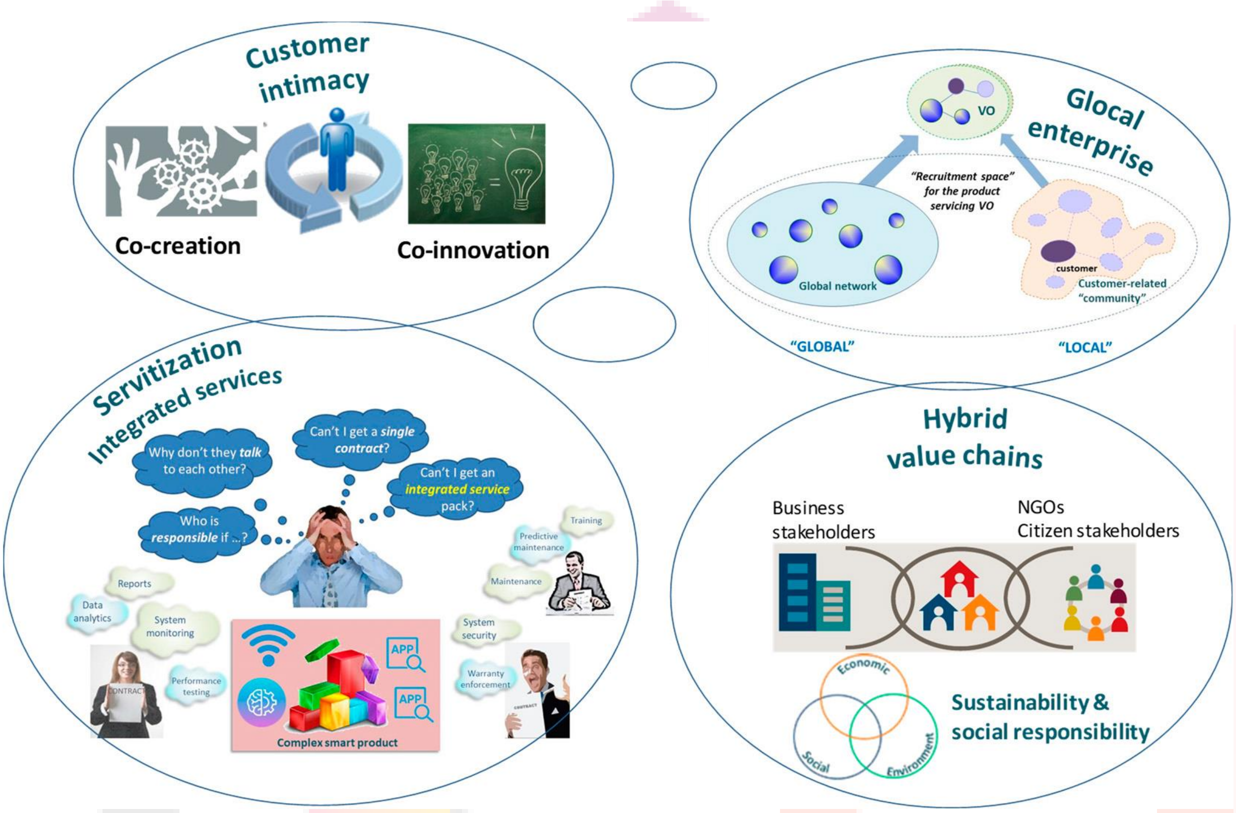


Figure 24. Examples of collaboration in new business models.

Collaborative engagement of customers, namely in the process of co-design/co-creation of products and services, is becoming very relevant. The term "customer intimacy" is often used to reflect this trend. This collaboration is not necessarily restricted to the one-to-one model, but rather extending to a community context. To improve customers' experience, especially in the context of global markets, it is also necessary to pursue close collaboration among all stakeholders in the value chain.

Investing in global markets while considering the local specificities, as reflected in the neologism "glocal enterprise", while also satisfying higher demands for transparency and compliance, can only be effectively achieved if resorting to collaboration among global manufacturers/producers and local suppliers/service providers as well as other organizations (e.g., regulators) operating near the customer.

Progressing towards "servitization/product-service systems" demands tight collaboration between manufacturers and service providers.

Coping with concerns of sustainability, transparency, and increasing social responsibility, that more and more challenge the business world, require strong collaboration ties between industrial companies and other societal entities. Hybrid value chains, which combine for-profit with not-for-profit entities, are a significant example."

Various examples illustrate the importance of CNs contribution to new business models:

- A large variety of goal-oriented networks have been established in a wide variety of industry sectors, providing a good experimental basis for new developments.

- The engagement of customers in (networked) co-creation processes has been pursued in multiple areas, e.g., consumer goods sector, solar energy, etc. Collaboration in co-innovation and open innovation networks is also an active research topic.

- Collaborative networks have been suggested as an effective way for the materialization of the “glocal enterprise” concept.

- The contribution of CNs to the development of product-service systems/servitization has been thoroughly discussed in the literature and various demonstrative experiments have been

developed.

- New collaboration models have been proposed for non-hierarchical and dynamic value chains.

- The potential contributions of CNs to sustainability can be found in various works, e.g.

- The concepts of green virtual enterprise and green enterprise breeding environment have been proposed and characterized.

- CNs in the implementation of the circular economy."

HUMAN FIRST BUSINESS MODEL

Human-centered AI refers to artificial intelligence that learns from human collaborations and is based on systems that are nurtured and constantly improved thanks to human input, therefore allowing better communication between robots and humans. This type of AI has the goal of bridging the gap between humans and machines: the understanding of emotions, behaviors, and languages. It leverages qualitative data to identify patterns and get a better understanding of drivers, deep needs, and aspirations that rule human decisions. It supports the idea that algorithms used by AI solutions must be designed keeping in mind that they are part of a larger system consisting of humans. Instead of removing real humans from the process, human-centered AI works with us to help us reach goals. We cover each other's weaknesses symbiotically, in a way. Machines are capable of massive data analyses that would take humans a lifetime to properly process, while humans are able to guide, manage, and utilize AI to properly conform to human necessities. [13]

Whether it's your employees, your customers, or your external stakeholders, the intention of this tool is to invite you to reflect on your AI transformation from the point of view of the people who will be impacted first. Use it as a compass to guide you on this journey, by revealing the ripple effects of your transformation in the broader context of your organization and provoking conversations about the implications of designing a self-preserving, resilient and well-balanced AI system.

AI is bringing structural change to the way companies operate that expands far beyond technological considerations. Developing a design mindset with this canvas should help you anticipate how digitalization powered by AI will impact the constructing parts of your organization. Hopefully this canvas will also facilitate approaching AI as an interdisciplinary field, by creating a common language and serving as a starting point for discussion that expands beyond computer science and engineering disciplines.

With cultural and behavioral challenges being at the top of the list of the most significant barriers to digital effectiveness, inclusivity, transparency, and openness are indispensable requirements when designing new digital models. Companies have the responsibilities to educate and engage their employees to avoid any forms of ignorance that could raise uncertainty or misunderstanding about the value of AI, which I hope this tool will facilitate.

For example, most of today's AI cannot learn by itself, it relies on intensive human feedback. Probably 90% of machine learning applications today are powered by supervised machine larning.[14]

This canvas is composed of 10 building blocks[15]. Start by defining who will be the audience you are trying to solve a problem for ("Designed for"). It might be your customer or a specific department within your organization. Once you have picked the people whose perspective you will be doing this exercise for, you will be able to work your way through the canvas from the top-right to the left, ending with the three boxes at the bottom.

[13] https://www.itexico.com/blog/human-centered-ai-for-your-business

[14] https://books.google.es/books?hl=es&lr=&id=bNo2EAAAQBAJ&oi=fnd&pg=PA1&dq=Business+model+human+centered+AI&ots=qxLAo4RYKM&sig=CUGQa3Qm7D-l9wWficj03x1wOoQ#v=onepage&q=Business%20model%20human%20centered%20AI&f=false

[15] https://medium.com/@albmllt/introducing-the-human-centered-ai-canvas-a4c9d2fc127e

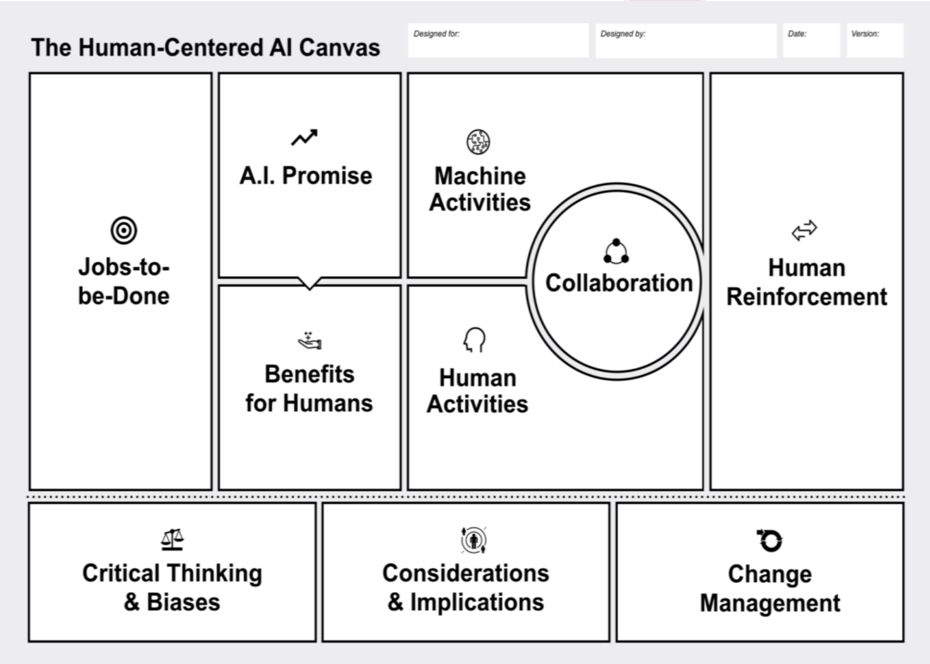


Figure 25.Human-centered AI CANVAS

Example

Here is a concrete example with a start-up I have been involved with, Mr Young. The company's product is a conversational agent, powered by AI, to help its users cope with anxiety. Its objective is threefold: demystifying anxiety and mental health, providing a medium to evaluate and track anxiety, and helping get access to quick and personalized resources to get in control. Through conversational platforms, Mr Young provides screening tests, suggests videos and articles to CBT-based exercises, or connects directly with a mental health professional.

The tool is aimed at human resources departments, with the promise of allowing members of their organization a quick access to multiple valid solutions in order to look after themselves.

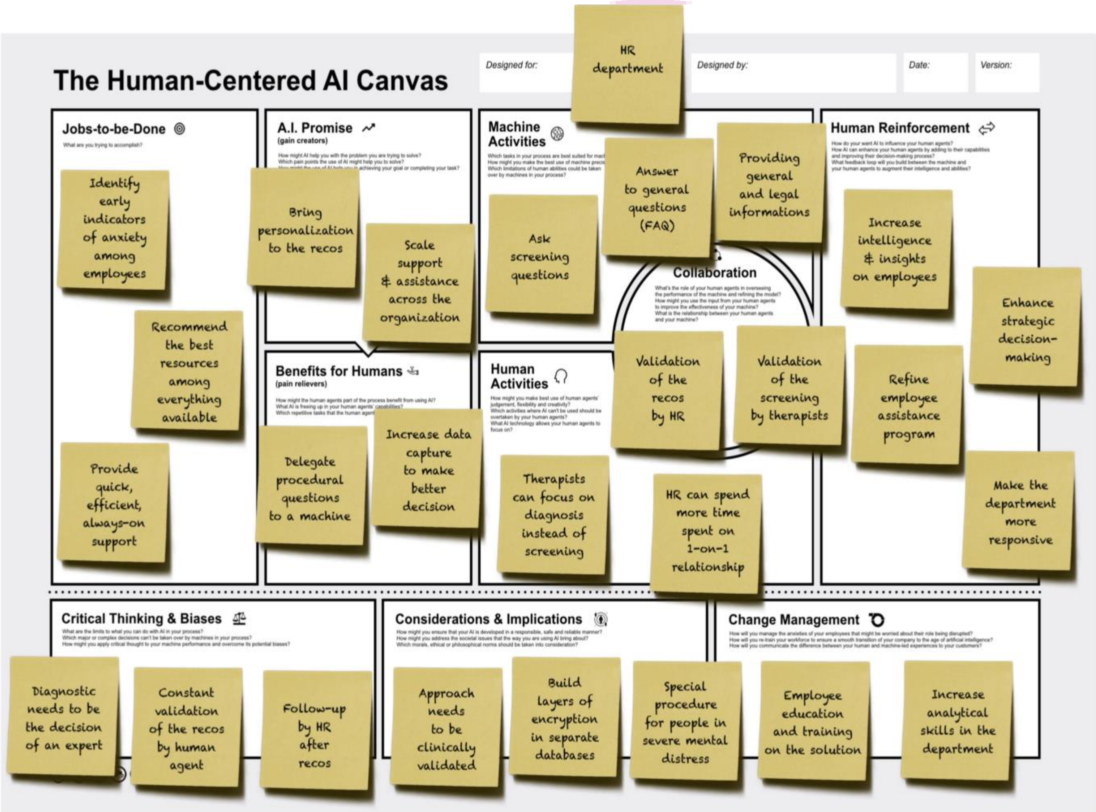


Figure 26. The human-centered AI CANVAS.

In this case, the audience for the canvas is the HR department, who is considering implementing an AI-assistant to create a work environment with stable well-being.

CUSTOMER-DRIVEN & CUSTOMIZATION

The way a company adapts its business model and its organization to demands for customization can make the difference between performance that leads a sector and performance that lags industry peers[16]. Indeed, companies that more effectively balance the value that customization brings to their customers with the complexity costs it can impose generate organic sales growth and profit margins significantly higher than their industry average, according to a Booz Allen Hamilton study of product and service companies in North America and Europe. The study, which benchmarked business units with sales from $1 billion to more than $20 billion at 50 companies, found striking differences between companies that adapted and aligned their customer strategies and fulfillment operations, and those that constructed more ad hoc responses to customer demands. The research encompassed such industries as consumer goods, chemicals, telecommunications, media, and financial services. The study revealed a two-to-one performance gap between “smart customizers” and “simple customizers.”

16 https://www.strategy-business.com/article/04104

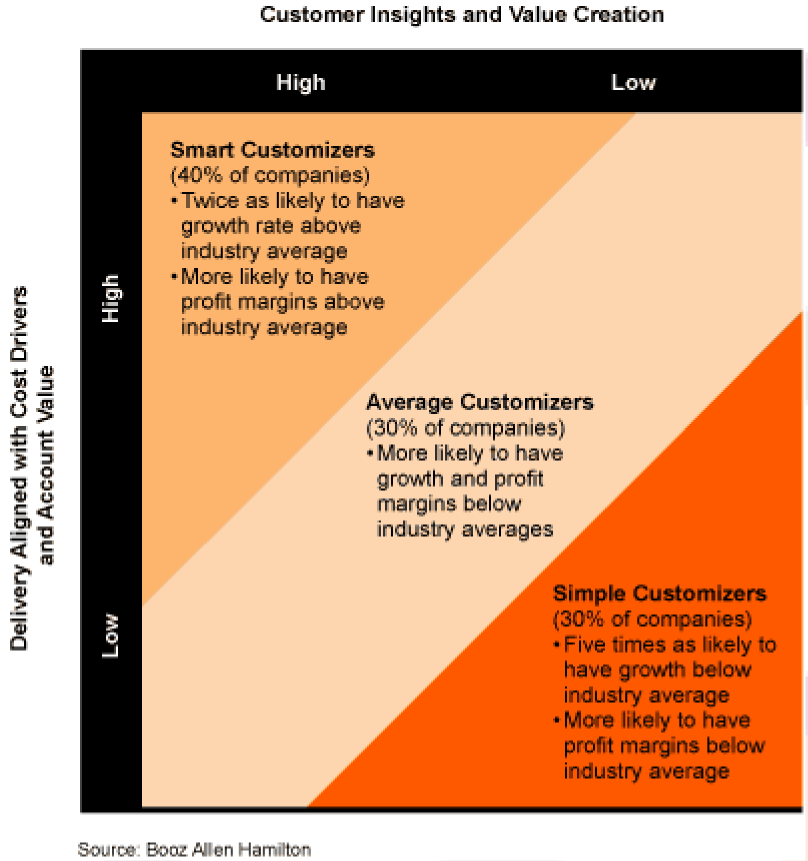


Figure 27.Smart customizers vs simple customizers.

To fully capture the benefits of smart customization, companies must focus on three sources of improved performance:

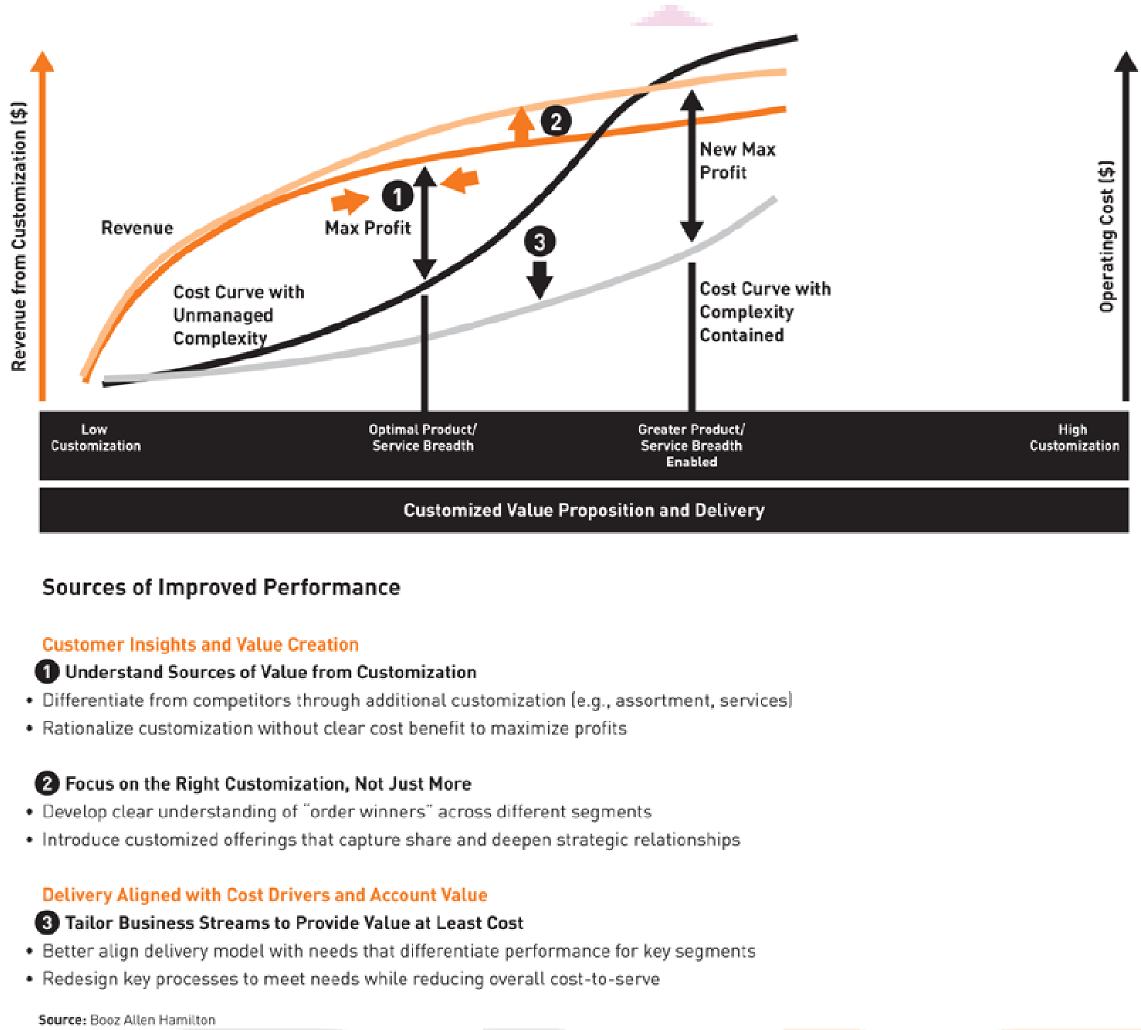


Figure 28.The smart customization performance curve

Understand the sources of value from customization. Companies often attempt to generate additional value through more differentiation and more complicated segmentation. They add assortment, insert new specifications to products, create brand extensions, and design value-added services. Over time, competitors also add more variety, segmenting the market more narrowly, to differentiate themselves and to stimulate additional demand. Typically, the focus is on capturing the next share point without fundamentally changing the production and delivery system. Costs remain under reasonable control, and profits increase.

Problems arise, though, when companies "overshoot" the optimum level of complexity; further customization efforts start to cut into margins. Soon, they reach a tipping point at which the additional complexity drives costs up faster than the incremental revenues from differentiation.

What's more, when a company is engaged in a customization competition with industry rivals, it's hard for it to keep an eye on growth and costs simultaneously. Most companies end up driving customization efforts with one foot on the gas and one foot on the brake; they get nowhere fast and wear out their performance engine. Simply striking an appropriate balance between more and less variety can certainly boost growth, but it isn't enough to generate superior earnings or shareholder returns. What companies really need is a calculation of value that reflects both the opportunities in the segments they choose to serve and the potential for effective delivery.

Evolve toward "virtuous variety." To generate a step-change in performance and positively shift the customization revenue curve (see Exhibit 3, arrow 2), companies must gain a deeper understanding of different segments' needs, and distinguish the unique requirements of some segments from the needs common to all. This can be accomplished by separating "order qualifiers" from "order winners."

Order qualifiers are products and services that are required if companies want to stay in the battle with competitors. They're generally not drivers of growth, though, because they are part of an arms race in which minimum product and service requirements continually escalate, regardless of whether they produce sustainable gains. A company must match the arms race at least possible cost by standardizing as many components of order qualifiers as possible.

Order winners are products and services that meet a customer's most critical needs. Order winners can vary across segments, although many threshold needs are shared across segments. By developing a clear understanding of what customers' order winners are, a company can create customized offerings that capture market share and deepen strategic relationships, and still preserve economies of scale and scope.

Tailor business streams to provide value at least cost. Smart customizers match their segmentation strategies with delivery mechanisms designed specifically to serve each segment profitably. In our parlance, they "tailor the business streams" to provide the highest value at the lowest cost.

Tailoring business streams (TBS) is a powerful approach for optimizing the complexity that is a natural by-product of an increasingly competitive, transparent, and interdependent economy. Businesses can create and align multiple flows to serve multiple needs, delivering differentiated services and products. The simplest and most predictable products/services flow through the most efficient streams of people, asset management control systems, and processes. Harder, less predictable undertakings flow through a more robust infrastructure. The streams can be kept distinct to prevent costs from rising; easy operations don't require expensive management and operational infrastructure that more complicated activities need.

At its core, TBS involves segmenting flows to satisfy different customer requirements regarding cost, value, speed, quality, and predictability of demand. These flows aren't immune to the forces that typically corrupt business models, so it's also necessary to develop policies and control limits that enable each stream to continually create value for company and customer together. The streams also include guidelines for tuning them as market conditions and costs change over time.

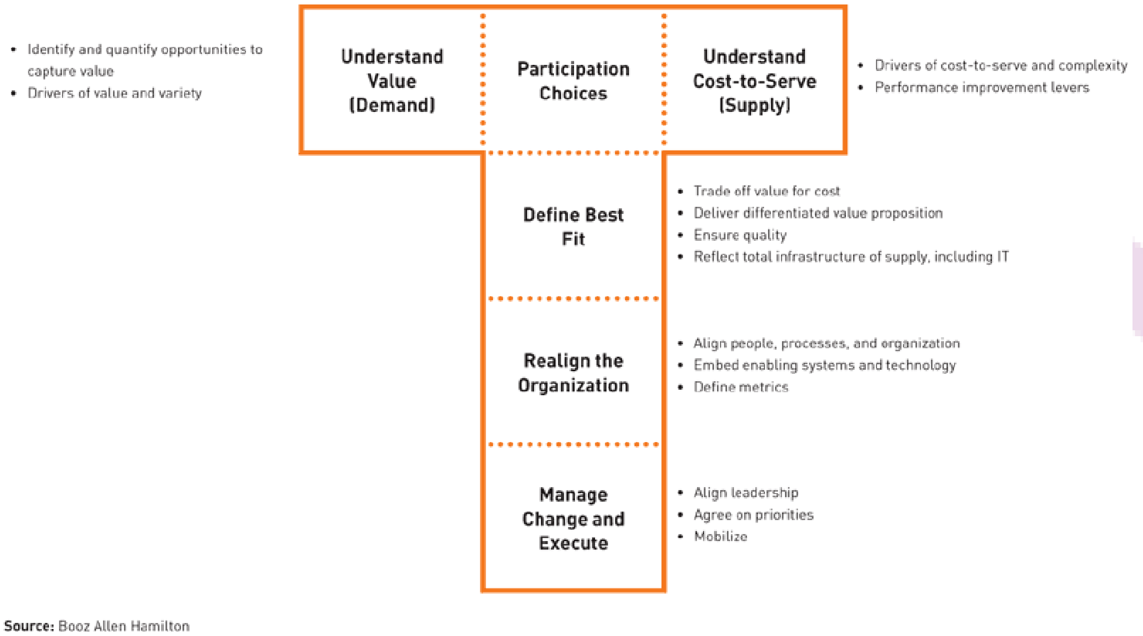


Figure 29.Tailoring the company's business streams.

Think of these tailored business streams as separate, mini-operating models. They include product development, demand generation, production and scheduling, the supply chain, customer care — the many flows that take value from a company to its customers. Each stream may contain people, processes, and technologies required to deliver parts of the product/service offering. Each stream caters to different expectations for cost, quality, speed, and innovation. Each has the appropriate management tools and processes in place to deliver at the lowest cost with the greatest return. But these streams flow together into a consciously integrated whole that isolates the highly complex and expensive parts of the business from the standardized portions. TBS allows a company to create a high degree of differentiation without constraining scale. In addition, a company gains the ability to continually align its business streams with changes in customer value, providing solutions where merited and more "transactional" approaches where customer needs and economics require them.

Differentiation does not have to compromise scale. By tailoring their business streams and aligning sales, marketing, and operations strategies with customer value, today's leading companies are able to provide some customers bespoke solutions that truly drive organic growth. Such smart customization is an imperative in current business conditions, not an option. The distance between smart customizers and simple customizers will be measured by accelerating differences in performance. Companies that want to build smart customization need analytical insight to understand the sources of value and drivers of cost, experience in identifying trade-offs and designing solutions, and the change management skills to follow through.

Customization business model CANVAS

Applying the business model canvas, the parts of a business model affected by mass customization capabilities and how they are impacted is identified17. A comparison of standardized, mass customized, and fully customized service business models and analyze the effects of service characteristics such as

[17] Sievänen, M & Heiskala, Mikko & Tiihonen, Juha & Paloheimo, Kaija-Stiina & Siirilä, T. (2010). Analyzing service mass customization business models.

intangibility, heterogeneity, inseparability, and perishability. Mass customization affects how all parts of the business model should be set out. There are differences in which parts of the business model the key mass customization capabilities are most important. When comparing standard customization, mass customization, and customization business models, the main difference appears to be in key resources. Mass customization requires a more skilled and knowledgeable workforce than standard services. Compared to a fully customized service, the robust process design becomes more significant in service mass customization.

Figure 30.Business Model Canvas for Mass Customization Business Model.

Table 1. Value proposition

Standard	Mass customized	Customized
Acceptable - good enough	Close to customer's requirements, useful	Fulfills customer's requirements
Take it or leave it	Parametric/modular	Unique, result of negotiations
Easy to buy	Easy to buy, specification required, Buying experience	High customer sacrifice when buying
	Co-configuration	Co-design
Readily available	Medium availability	Limited availability

Table 2. Channels

Standard	Mass customized	Customized
What & where	Information in systematized form	Information in free-form
No personal contact required when purchasing	No personal contact required when purchasing	Personal contact required (also in virtual)
Many channel types		Skilled channels
Catalog	Configurator	Personal assistance

Table 3. Customer relationship

Standard	Mass customized	Customized
Self-service?	Can be (partly) automated	Personal interaction necessary
Transaction		Long relationship
Limited potential for re-applying customer information	Re-applying customer information necessary	Potential for re-applying customer information
Customer intimacy low		Customer intimacy high

Table 4. Key activities

Standard	Mass customized	Customized
Limited – strictly defined	Limited – pre-defined	Everything possible within resource limits
Robust	Robust	Creative
Runners	Runners, Repeaters	Strangers
Back-office		Front-office
Production, execution		Design, problem-solving
Limited customer inputs		Significant customer inputs

Table 5. *Key resources*

Standard	Mass customized	Customized
Efficiency	Multi-skilled	Multi-skilled, creative
Fault-free		Know-how, expertise
Able to perform routine tasks	Able to combine routine tasks	Able to apply tacit knowledge to create new tasks
	Flexible IT-systems	Adaptable IT-systems
Easily replaceable		Scarce

PROACTIVE AND PREDICTIVE BUSINESS MODEL

Ever since asset failures have caused downtimes and extra costs, accidents or inefficiencies, businesses have supplied material and human resources to minimize their impact and avoid their re-occurrence. Current approaches try to preserve function and operability, optimize performance and increase asset lifespan with optimal investments. The current technical development in industry regarding information handling and digitalization leads to new ways of producing goods. The industry demands flexible, safe, environmental friendly and available production processes.

Proactive monitoring and maintenance (PMM) in the industrial sector is key to improve competitiveness, productivity, reduction of downtime machine, interventions for remote machines and travels among others. Proactive maintenance solutions are common in processing industries like Oil and Gas, Wind, Utilities, and aerospace. Across the new PMM paradigm, industrial companies and technological providers can offer new services associated with smart products. With aims to establish proactive monitoring and maintenance, companies should address a new strategy based on servitization and service business model adding new technology and services related to industrial internet of thing.

The new PMM strategy should be analysed through 9 blocks related to the well-known BM CANVAS as well as economic evaluations in order to project the future benefits of the business model. Thus, the value proposition with the introduction of integrated IT solution to monitor industrial assets with some different characteristics depending on the sector. Customer segments, relationships and channels are the business models blocks are the most relevants to reinforce and relate the companies activities with the end-user for sharing asset data and new revenue streams. Key activities, resources and partners blocks help the development of the principal IT-OT system with predictive advanced algorithms, sensors, cloud system, middleware or research, allowing future competitive advantages. Finally, cost structure and revenue streams blocks to recognise the traditional and new type of payment as software ad-hoc or as a service or for asset availability, among other features.

Throughout the execution of the MANTIS project[18], current and future PMM Business Models Canvases were analysed by industrial partners in production asset maintenance, vehicle management, energy production and health equipment maintenance. In addition, economic evaluations and projections have also been analysed.

Example[19]

In the transition from traditional to PMM business models, a financial tool is applied in MANTIS project. The principal items to take into account on behalf of the financial tool are revenue streams, costs and cost savings. Each item impacts on a segment of the company's strategy, referring, for example, revenue streams to more competitive product sales, maintenance contract sales, consultancy or new maintenance software services. On the other hand, the financial tool should reflect the costs and investments, such as specialized manpower, new technologies, new infrastructure, new marketing strategies, even amortizations, travel expenses and logistics. All the maintenance changes on the business model should translate to a reduction of operational costs and incremental revenues.

Economic evaluation and projection was developed in the MANTIS project, resulting in economic data from last year and 5 year projections comparing current and future PMM Business Models for industrial

[18] https://cordis.europa.eu/project/id/662189
[19] https://www.riverpublishers.com/pdf/ebook/chapter/RP_9788793609846C8.pdf

business cases. For technological providers, new business model with advanced maintenance software as value proposition and 5 years projections were analysed.

The railway use-case for traditional to PMM business model here presented aims at reducing the cost of maintenance manpower by means of improvements such as implementing tools as data acquisition, data processing and maintenance strategy optimization. As it was seen, maintenance cost is the most important one, with an impact of around 50%, followed by maintenance services and spare parts with 14% and 13% respectively. With the incorporation of new PMM strategy, in the 5-year projection the railway use-case would have a reduction of 25% costs in manpower. Other use-cases analyzed within the MANTIS project, achieved an impact between 15% to 25% on machine downtime, warranty repairs, intervention costs, manpower, among others. Once the reduction of maintenance costs is achieved, in case of revenue streams, the objective would be to offer advanced services such as industrial asset monitoring to know in real-time the status of them and to perform possible corrections before downtime assets. The railway use-case, during the 5 year projection, would include 70 assets to monitor with a profit of more than 600.000 by the end of year 5. Due to techniques such as the servization of maintenance, the railway use-case, as well as others analyzed in MANTIS project, would imply an increase of income between 10% to 20 %.

ASSET MANUFACTURER			
Value Proposition	Key Activities	Customer Relationships	Revenue Streams
Asset design & production • Increase equipment lifespan • Increase operational efficiency • Improve quality • Improve product lifecycle Improve and optimization of product design *Innovation* • New product introduction • R&D process optimization *Supply chain & logistics* • Delivery time optimization *Customer experience* • Improvement of accuracy of warranty modelling • Production output customization	*Asset design & production* • Asset reliability analysis • Advanced HMI *Innovation* • Analyse remote product performance *Supply chain & logistics* • Stock management *Accounting* • Maintenance & warranty limits	*Asset design & production* • Tap into customer base • Machine virtualisation *Innovation* • Customer connected products • Integrate real-time customer feedback *Supply chain & logistics* • Increased customer satisfaction *Customer experience* • Production/CRM integration • Downtimes reduction • Improved customization *Accounting* • Tap into customer base • New payment models which transform capex into opex for asset end-users • Financial services • Retain customer • Gain new customers	*Asset design & production* • Idle time reduction • Start-up time reduction *Innovation* • Accelerate time to market *Supply chain & logistics* • Workpiece traceability *Accounting* • Service business models • Perpetuation of revenue streams instead of one-off asset sale for suppliers • Customer's financial challenges overcome

Figure 31.PMM business model CANVAS

In conclusion, PMM is key to improve maintenance processes applied in industrial companies, which can be either production asset maintenance, vehicle management, energy production or health equipment companies. New service business models should carry out monitoring industrial asset with sensors and predictive technology. As a consequence, new smart products with advanced services could be offered to achieve the impact to reduce around 25% in maintenance costs and increase 20% of revenue streams.

DATA USE / CONTROL & QUALITY FOR SC BUSINESS MODEL

Supply chain digital transformation is one of those megatrends, affecting small and medium-sized companies as well as big enterprises. For big enterprises, digitization is already a way of life and now it is time for small and medium size businesses to jump on board and start using digital technologies in order to get benefits in the supply chain and catch up with these big enterprises to outperform the competition.

There are many technologies impacting the supply chain area from core systems, such as Enterprise Resource Planning (ERP), Transportation Management Systems (TMS) to decision and interaction tools to drive analytics, collaboration and visualization. Along with the Internet of Things (IoT), robotics (RPA) and Artificial Intelligence (AI), this offers opportunities to facilitate growth by lowering the cost of current (or future) services.

These tools can help companies optimize supply chains, meet customer demand, successfully expand to emerging markets, and get an edge over the competition. An optimized supply chain provides new opportunities to small and medium-sized companies, including a greater range of products and service offerings that target different customer segments as a result of greater delivery accuracy and a more strategic location.

There are core solutions like SAP ERP and Oracle ERP that have been used for many years now. These solutions helped streamline processes and created a huge amount of data, which was not fully used until now. Nowadays, in the age of new technologies, it is highly important to find the right tools to improve decision making. Figure 1 indicates some of the examples that we have seen at our clients. Using the right tools in combination with understanding the demand will lead to real value.

The traditional supply chain network positioned their manufacturing and shipping centers in the most cost-efficient areas to gain a competitive advantage. Today, the shift towards customer centricity encourages companies to optimize their supply chains by creating regional ecosystems, and a key factor will be the establishment of end-to-end supply chain integration.

Rather than investing in a single large facility, companies need to create a localized network of smaller outsourced partners. Supply chain network partnerships, especially third-party network providers, help companies leverage necessary resources and manage logistics more effectively. This model provides an optimal service level that promises next-day delivery with a guarantee that every delivery will be supplied on time and in full.

Achieving expedited delivery requires a wide range of tools that can prepare data, visualize different angles on existing data and provide new insights into customer behavior. Leveraging these capabilities allows companies to speed up the process of optimization and receive the benefits. The figure below illustrates the benefits of differentiated approach to supply chain network design. [20]

[20] https://www.compact.nl/en/articles/supply-chains-go-digital/

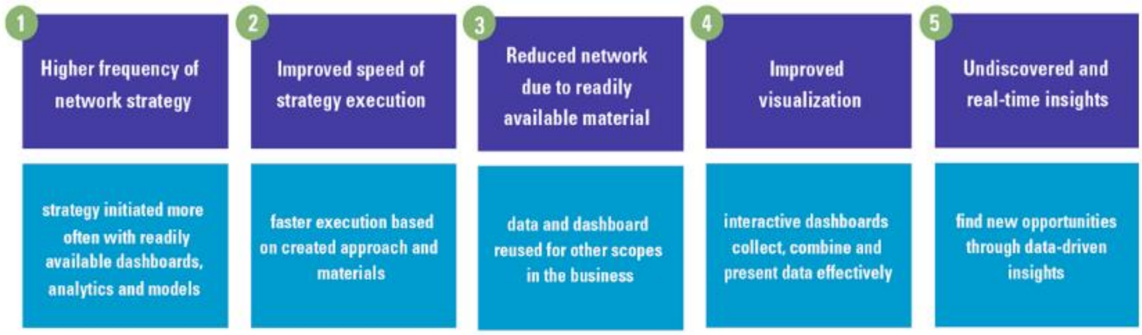


Figure 32.The benefits of differentiated approach to supply chain network design.

Companies that realize these benefits can offer lower prices to customers, operate at lower costs and potentially gain a leading position in the market.

Next figure indicates, supply chain transformation starts with a solid plan that requires you to go through a structured process to visualize the future state, before getting into the detailed design. Digital tools also allow companies to perform these assessments on a more frequent basis, ensuring the organization remains nimble in an ever-evolving market.

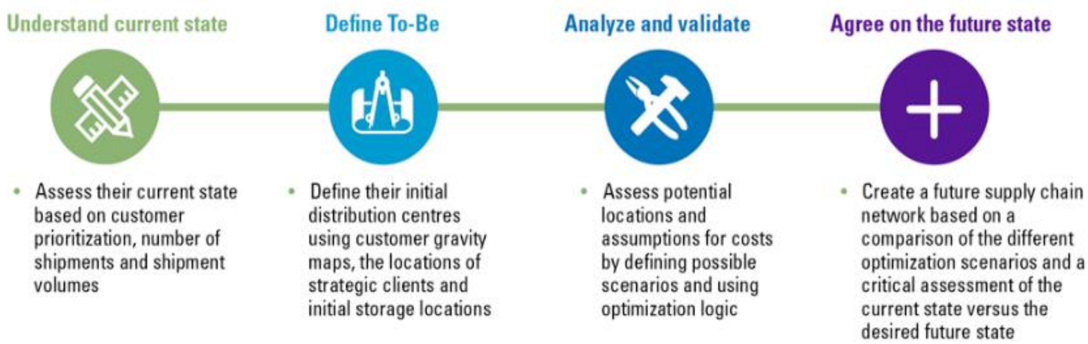


Figure 33.Plan to follow when optimizing a supply chain network.

The goal of the digital supply chain is ambitious: to build an altogether new kind of supply network that's both resilient and responsive. The digital supply chain, as envisioned by PwC[21], consists of eight key elements: integrated planning and execution, logistics visibility, Procurement 4.0, smart warehousing, efficient spare parts management, autonomous and B2C logistics, prescriptive supply chain analytics, and digital supply chain enablers. Companies that can put together these pieces into a coherent and fully transparent whole will gain huge advantages in customer service, flexibility, efficiency, and cost reduction; those that delay will be left further and further behind.

Driving the transformation to the smart supply chain are two tightly intertwined trends. On one hand, new technologies like big data analytics, the cloud, and the Internet of Things are pushing into the market.

[21] https://www.strategyand.pwc.com/gx/en/insights/2016/industry-4-digitization/industry40.pdf

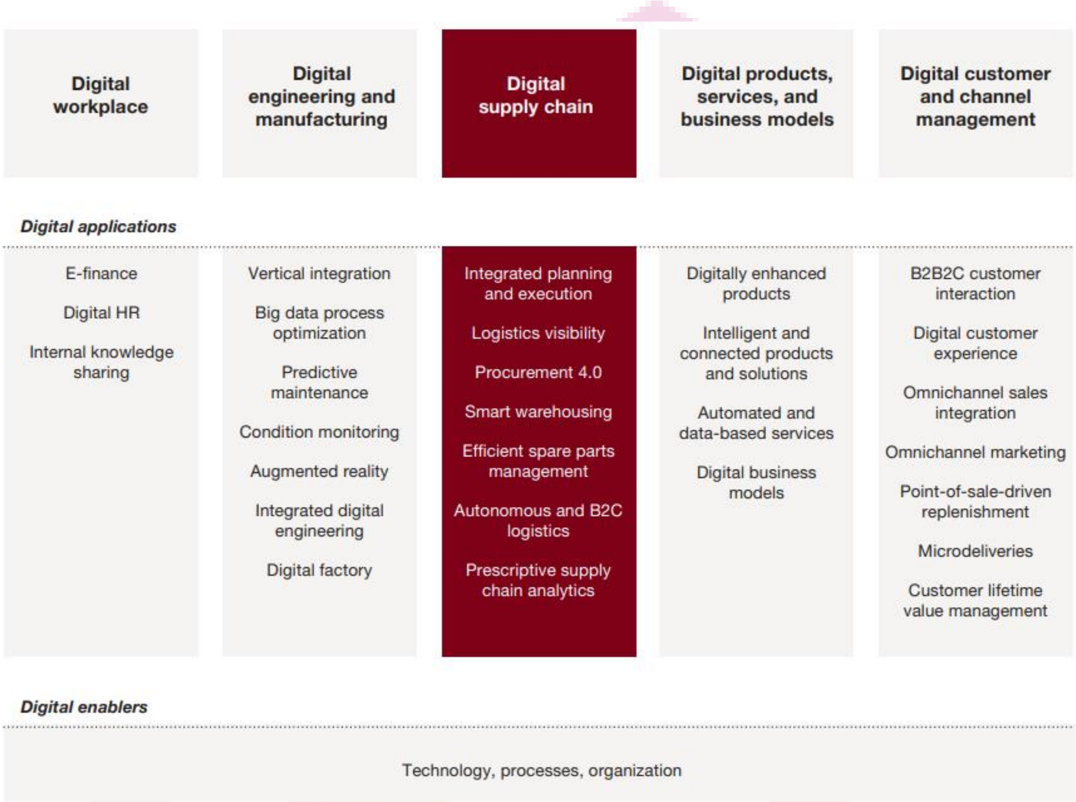
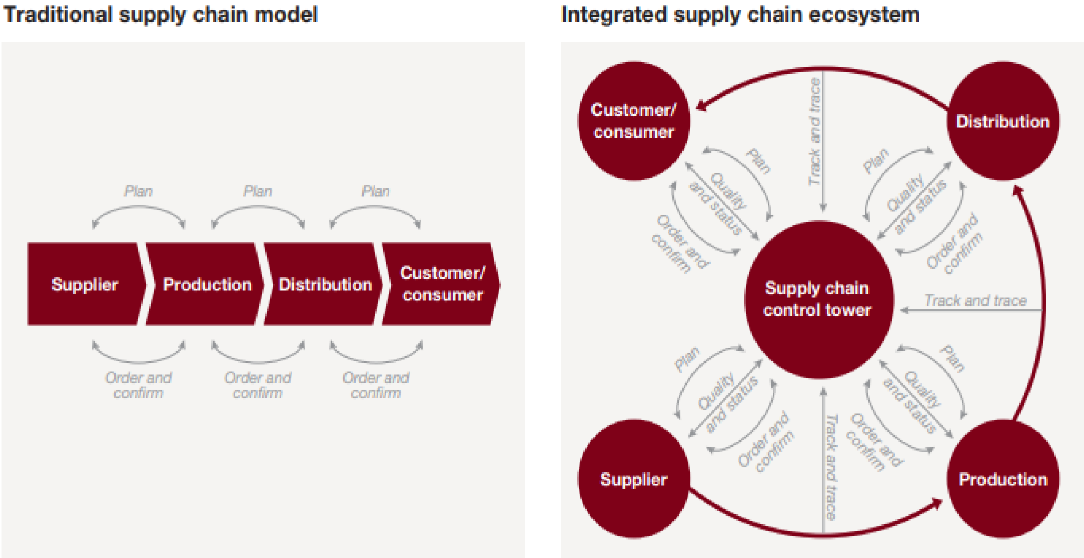


Figure 34.The supply chain at the center of the digital enterprise.

This ecosystem will be based on full implementation of a wide range of digital technologies — the cloud, big data, the Internet of Things, 3D printing, augmented reality, and others. Together, they are enabling new business models, the digitization of products and services, and the digitization and integration of every link in a company's value chain: the digital workplace, product development and innovation, engineering and manufacturing, distribution, and digital sales channels and customer relationship management.

At the heart of all this activity sits the digital supply chain, and it is key to the operations of every company that manufactures or distributes anything. Indeed, for many companies the supply chain is the business. It extends the vertical integration of all corporate functions to the horizontal dimension, knitting together relevant players — the suppliers of raw materials and parts, the production process itself, warehousers and distributors of finished products, and finally the customer — through a network of sensors and social technologies, overseen via a central control hub, and managed through an overarching data analytics engine.



Transparency	Limited view of supply chain	Complete view of supply chain
Communication	Information delayed as it moves through each organization	Information available to all supply chain members simultaneously
Collaboration	Limited visibility to the entire chain, hindering meaningful collaboration	Natural development of collaboration depth to capture intrinsic supply chain value
Flexibility	End customer demand distorted as information flows along the material path	End customer demand changes are rapidly assessed
Responsiveness	Different planning cycles resulting in delays and unsynchronized responses across multiple tiers	Real-time response on planning and execution level (across all tiers to demand changes)

Source: Strategy& analysis

Figure 35.The digitally enabled supply ecosystem vs. traditional linear supply chain

Companies across industries are already investing heavily to develop their own versions of the DSC. According to a recent PwC study on the rise of Industry 4.0, a third of the more than 2,000 respondents say their companies have started to digitize their supply chains, and fully 72 percent expect to have done so five years from now. The reasons behind the investment rush are easy to see. Supply chain professionals expect digitization to bring significant economic benefits to both top and bottom lines: Companies with highly digitized supply chains and operations can expect efficiency gains of 4.1 percent annually, while boosting revenue by 2.9 percent a year.

Some industries are further along the digital supply chain continuum than others. Electronics manufacturers, for example, have learned a great deal about building and managing DSCs through their longstanding efforts to create outsourced manufacturing networks. Not so far advanced are consumer-facing companies, like retail and fastmoving consumer goods, which are still vulnerable to serious disruptions in their supply and distribution networks. Yet, these industries are already working to transform their chains, as are even more asset-intensive industries like chemicals.

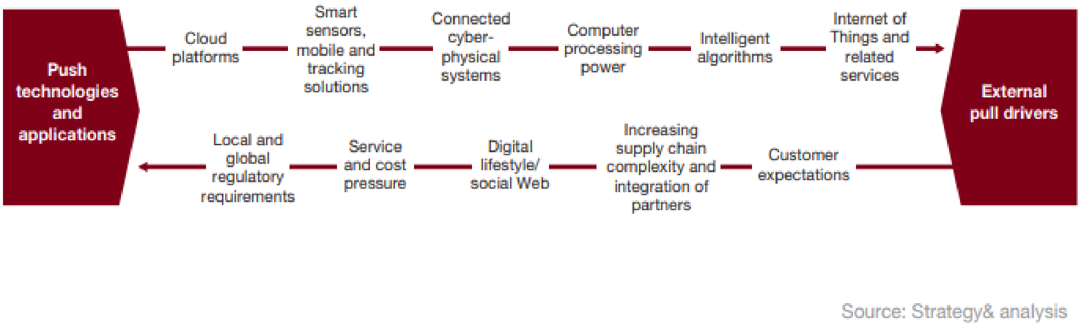


Figure 36.Effect of push technologies and pull demand on the digital supply chain.

Supply chains operate along the traditional SCOR[22] processes — plan, source, make, deliver, return, and enable. Every one of these elements is rapidly being revitalized through technological innovation. We divide up the technologies into eight key areas: integrated planning and execution, logistics visibility, Procurement 4.0, smart warehousing, efficient spare parts management, autonomous and B2C logistics, prescriptive supply chain analytics, and smart supply chain enablers.

The business goal of the digital supply chain is to deliver the right product into the customer's hands as quickly as possible — but also to do so responsively and reliably, while increasing efficiency and cutting costs through automation. This goal cannot be achieved unless the supply chain is fully integrated, seamlessly connecting suppliers, manufacturing, logistics, warehousing, and customers, and driven through a central cloud-based command center

[22] The Supply Chain Operations Reference model (SCOR) is the world's leading supply chain framework, linking business processes, performance metrics, practices, and people skills into a unified structure. It was developed in the 1990s by a number of industrial companies and by the management consulting firm PRTM, now part of the PwC network.

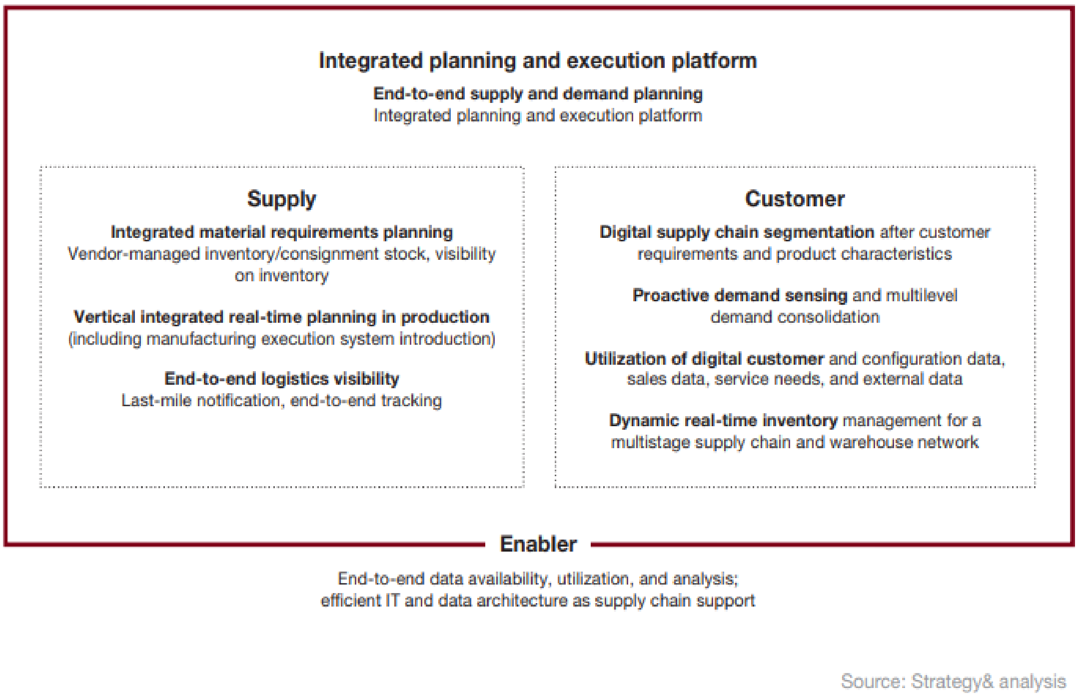


Figure 37.The integrated planning and execution platform in the supply chain.

Next figure illustrates the different elements of the logistics visibility framework:

• Data from internal and external sources, such as transport tracking devices and social listening, is brought into a single platform.

• The data is consolidated and enriched with cross-referenced information, such as supply chain events impacting supply shipments. Relevant information is scoured from weather, traffic, and news feeds. Even social media networks are monitored — companies that paid attention to Twitter activity, for example, could have anticipated the recent workers' strike in the port of Los Angeles as early as four weeks before it happened.

• This enriched information is then linked within the platform and put through additional analytics and simulation runs, allowing various levels of strategic optimization such as route network improvements and carrier performance reviews. If all this information is to be really useful, it must feed into a control center that monitors and manages logistics activities and applies advanced analytics and prescriptive algorithms to the equation.

• The resulting "single source of truth" lets companies optimize their choices under different conditions, using the information to alert factories, warehouses, and customers to endangered arrival times and engage in mitigation actions. Visibility into both transport status and expected external impacts on lead time, and the ability to change plans accordingly, will be instrumental for companies looking to use their supply chains to competitive advantage, and to manage more carefully the many risks associated with supply chain activities.

Eventually, machine-learning algorithms will become smart enough to automate even this kind of human intervention, allowing managers and other stakeholders to make smarter decisions daily. These algorithms will offer mitigation advice and proven routine solutions from the past, when available. Benefits will include workload reductions and even greater increases in supply chain efficiency.

Chain visibility depends on the creation of an effective "track and trace" (T&T) system that allows players to determine the status of any given shipment of goods at any point in its travels, by any transport mode. Transport data and status information will be captured from enterprise resource planning systems as well as from carriers, either through direct connections or via third-party portals. GPS technology will enable companies to check exact shipment locations, while field sensors monitor environmental conditions such as temperature and humidity, and even provide remote theft protection. But because data is arriving from many different sources — suppliers, transporters, warehouses, distributors — quality and interoperability of the data is critical, and still a significant technological barrier that a wide range of companies are working on.

The command center for these remote-sensing activities is the control room or logistics visibility platform, akin to a traffic control tower. The great virtue of the control room is that it can provide executives and senior managers with a fully transparent view of the company's supply chain, and thus support the many decisions that have to be made to keep the flow of parts and products going.

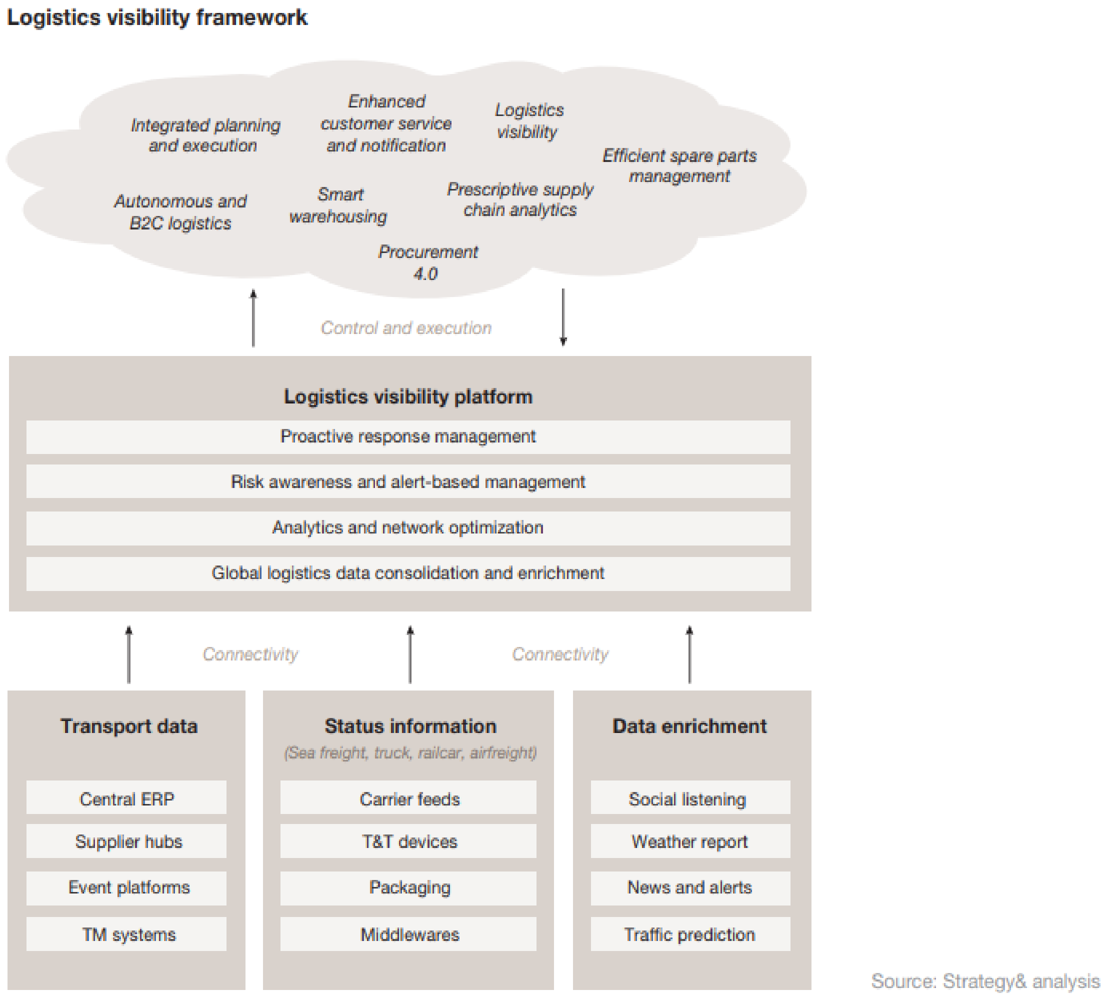


Figure 38.A single platform drives the logistics visibility framework.

Smart supply chain enablers — success factors

Companies setting out to build the smart supply chain face a difficult task, one that will likely prove impossible unless they develop a clear strategy that is fully responsive to the opportunities on offer in a fully digital environment. It must be based not just on the company's current operations and business model but also on new business models available once digitization has been implemented, such as creating direct sales channels and leapfrogging levels in the value chain.

Once the strategy is determined, companies must put into place several key capabilities needed to carry it out, in addition to the supply chain applications discussed above. These key capabilities include the following:

• Processes. Establish the new end-to-end processes connecting suppliers and customers that digitization makes possible, such as how to collaborate on cloud-based platforms.

• Organization and skills. Generate an end-to-end understanding of the mechanics of the value chain. That means switching from a firefighter mentality, solving each problem as it pops up, to becoming a supply chain "orchestrator" — seeing, managing, and optimizing the entire chain. Achieving this will also require a shift to an open, fast-learning digital culture that promotes communication across different media, programs, and user groups. Develop the talent and expertise needed to build the technology and carry out the new supply chain operations.

• Performance management. Develop a set of straightforward business rules covering the management of the supply chain, and the key performance indicators needed to measure outcomes.

• Partnering. Focus on boosting your ability to partner with other companies, as the fully integrated supply chain cannot be built without collaborating with a wide variety of suppliers, distributors, and technology providers.

• Technology. Devise a road map for the many technologies, old and new, that will underpin the digital supply chain, including the information integration layer, database and analytics capabilities, and the cloud.

Supply chain maturity

Few companies have reached anything close to complete maturity in their efforts to put together the fully digital supply chain. To develop a supply chain strategy and organize their ensuing efforts in a coherent fashion, it is critical that companies understand their starting position. The process leads through four stages of maturity:

1. Digital novice. These companies have yet to embark on the journey. Their supply chain processes remain discrete, carried out by individual departments and business units.
2. Vertical integrator. Companies at this stage have managed to integrate their supply chain processes internally, across departments and functions.
3. Horizontal collaborator. Here, companies have learned to work with their supply chain partners to set business goals, define and carry out common processes, and achieve a fair degree of transparency into the chain.
4. Digital champion. These companies have achieved the highest level of collaboration with partners and transparency into operations, while developing mutually beneficial processes and analytical techniques for optimizing the entire supply chain.

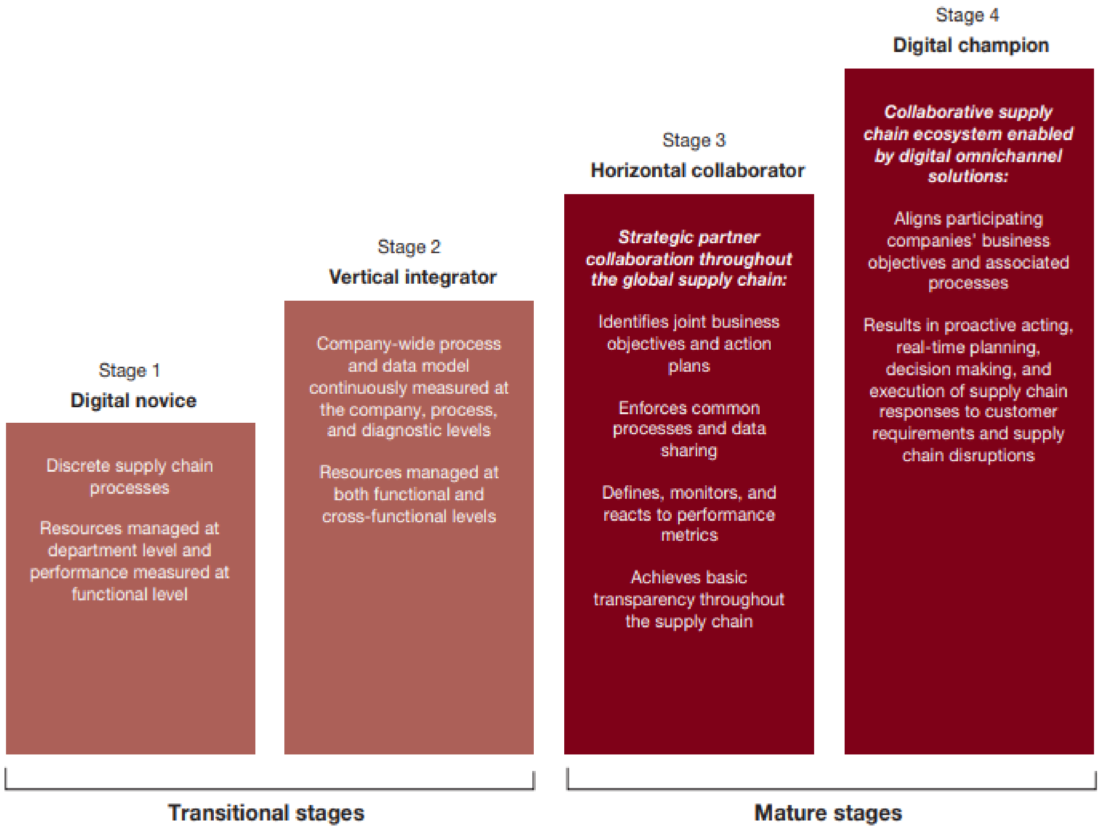
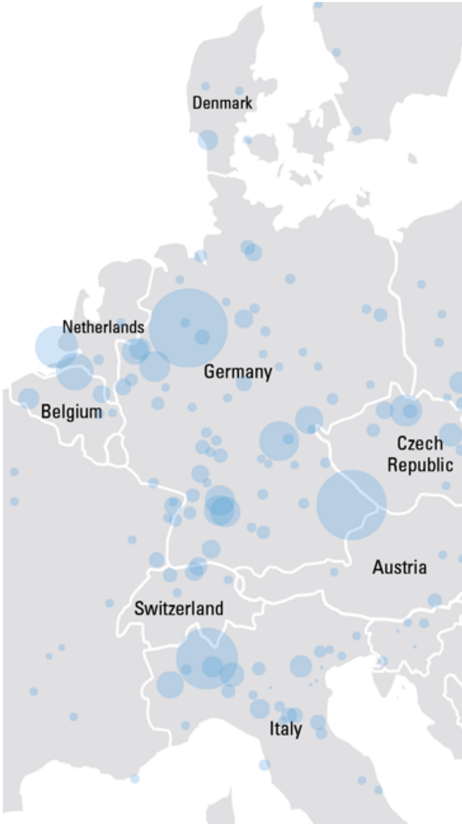


Figure 39.The four stages of supply chain maturity

Example – Chemical sector

Case study – Global chemical product manufacturer



A data-driven approach in Supply Chain network optimization to provide insights utilizing digital Supply Chain tools

Challenge

A global producer of chemical products asked KPMG to conduct a strategic study to design a Supply Chain network to better serve customers based on data analysis.

Significant growth is expected in the market in the coming years. This needs a rapid approach and quick decision making.

In recent years, the market trend has been to be closer to the customer, enabling optimal delivery. This trend is followed by key competitors, who operate stock points across Europe near key customer demand areas.

Customers increasingly prefer other suppliers over our client, as the delivery promise cannot be matched compared to key competitors.

Expected driver shortage in the (near) future in mainland Europe demands more efficient movements.
This also contributes to internal strategic objectives to debottleneck key production facilities.

Solution

Using digital Supply Chain tools, the KPMG team surprised the client with new insights and uncovered opportunities.

By conducting a customer gravity analysis in Tableau (1), we identified potential stock point locations. We also optimized the To-Be network by developing a constraint network model in AIMMS (2). After the prioritization of stock points, we assessed the impact of each stock point on the current network.

Digital tooling can enable the customer service level optimization process in various ways. A wide range of tools is available to visualize different angles of existing data or provide insights that are new to customers by combining and reshaping pools of data.

Leveraging the capabilities of these tools not only provides useful insights, it also speeds up the process of analysis, which helps gain a key advantage over competitors.

Key benefits

- Higher frequency of network strategy
- Improved speed of strategy execution
- Reduced rework due to readily available material
- Improved visualization
- Undiscovered and real-time insights

AI-AS-A-SERVICE BUSINESS MODEL

Technologies such as big data, IoT, additive manufacturing and blockchain can optimise value creation by increasing efficiency and improving performance. For example, introducing a 3-D manufacturing facility enhances the creation of robust products and services for customers and delivers value creation benefits for CIRCULAR BMs. In essence, as traditional manufacturing firms adopt digitalisation and CE, they tend to move towards servitization, that is transformation towards service portfolio development, such as extended service contractions, performance contacts, etc. IoT and big data create unique opportunities for firms to improve and broaden their services portfolios and deliver value to their customers. IoT helps firms to monitor operational flows and performance in real-time, improving managerial decisions aimed at servitization value creation. Information and knowledge systems create value for a new set of consumers because such consumers seek detailed information regarding the environmental impacts of the advanced services offered to them. [23]

In its simplest terms, servitization refers to industries using their products to sell “outcome as a service” rather than a one-off sale. Netflix and Spotify are probably the most well-known example of this, delivering media as a service, rather than customers buying the CDs, DVDs et cetera that produce those outcomes. Although very different to media streaming businesses, manufacturing can also benefit from servitization. Manufacturing businesses can offer additional services to supplement their traditional products such as maintenance, keeping a fleet of vehicles on the road as a service. Servitization is usually a subscription model and can be applied to most industries in one way or another; be that £xx/month for music, £xx/month to keep a fleet of vehicles on the road, or even £xx/month for the fleet – all in!

This developed out of the necessity for businesses to remain profitable and competitive in an age where the financial aspects of design and manufacturing are becoming increasingly challenged by emerging markets and the life-cycle of manufactured products increases and the technology which develops them improves products are tending to need replacing less frequently. The need to include additional services including consultancy, all aim to improve the performance and profitability of a company.

There are three levels of servitization within manufacturing[24];

- Product Provision You’re already doing this and have been for years! This is the basics of manufacturing business – build and sell. Once it leaves the factory, the product ceases to be a concern to the manufacturer, but it also ceases to be a revenue stream.
- Aftersales Servicing, repairs and condition monitoring. The maintenance of a product provides an ongoing source of revenue for manufacturers.
- Advanced Services Taking aftersales to the next level, advanced services are more relationship focused and customer-centric than just selling and maintaining a product. In many cases, advanced services are delivered on a subscription model in which the consumer pays for the outcome – whether that be hours of jet propulsion or pages printed.

[23] Chauhan, Chetna & Parida, Vinit & Dhir, Amandeep. (2022). Linking circular economy and digitalisation technologies: A systematic literature review of past achievements and future promises. Technological Forecasting and Social Change. 177. 121508. 10.1016/j.techfore.2022.121508.
[24] https://www.k3syspro.com/advice-centre/jargon-buster/servitization/

Next to a business model innovation process, servitization is also a transformation journey. Companies need to develop the required capabilities to deliver services and solutions that can supplement their traditional product offering. In this work[25] the focus is on the 'Design' and 'Validate' phase of the journey. The adoption of a servitization strategy brings with it significant cultural and corporate challenges. As they servitize, companies are confronted with a new set of dynamics in their relationship with their customers. Research by several universities reveals that, in order to be successful, an organization must not only adapt its proposition from product-centric to a product-service system, it also needs to redesign its organization. They attribute this to organizational misalignment with their commercial business models. There are huge differences between a traditional manufacturing firm that develops, sell, manufactures and (reactively) supports its installed base products and a firm that operates their equipment and sells performance. The latter has to develop new customer facing processes, has a different customer relation, needs a different (more customer centric) culture, needs to understand that maintenance no longer is a source of income but a cost that needs to be limited, uses more and different information generated by the systems in the field, and so on. Such a process can be visualized in the stages of a typical product development funnel.

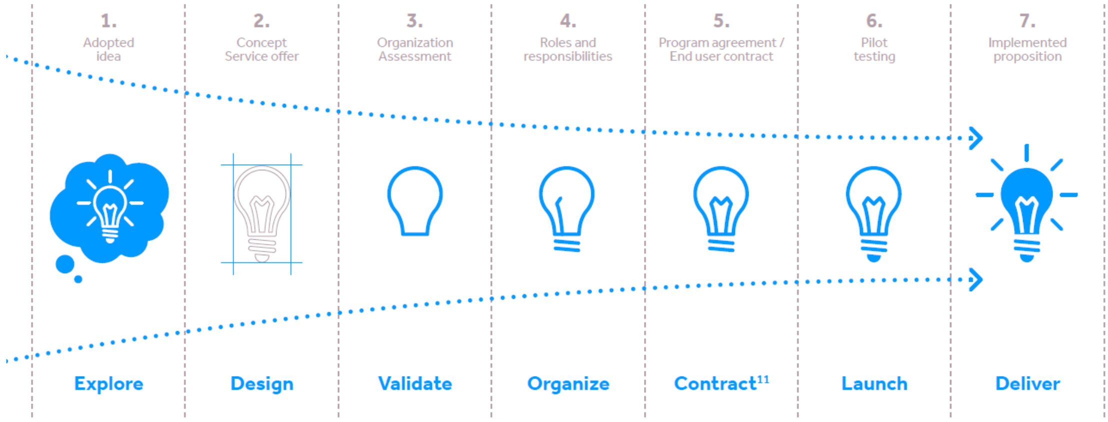


Figure 40.The product development process.

An integrated servitization maturity model, which integrates business model and organizational elements, would be of significant value to practitioners that want to successfully implement new servitized propositions.

[25] https://www.dllgroup.com/en/-/media/Project/Dll/Global/Documents/Servitization/DLLServitizedbusinessmodels.pdf

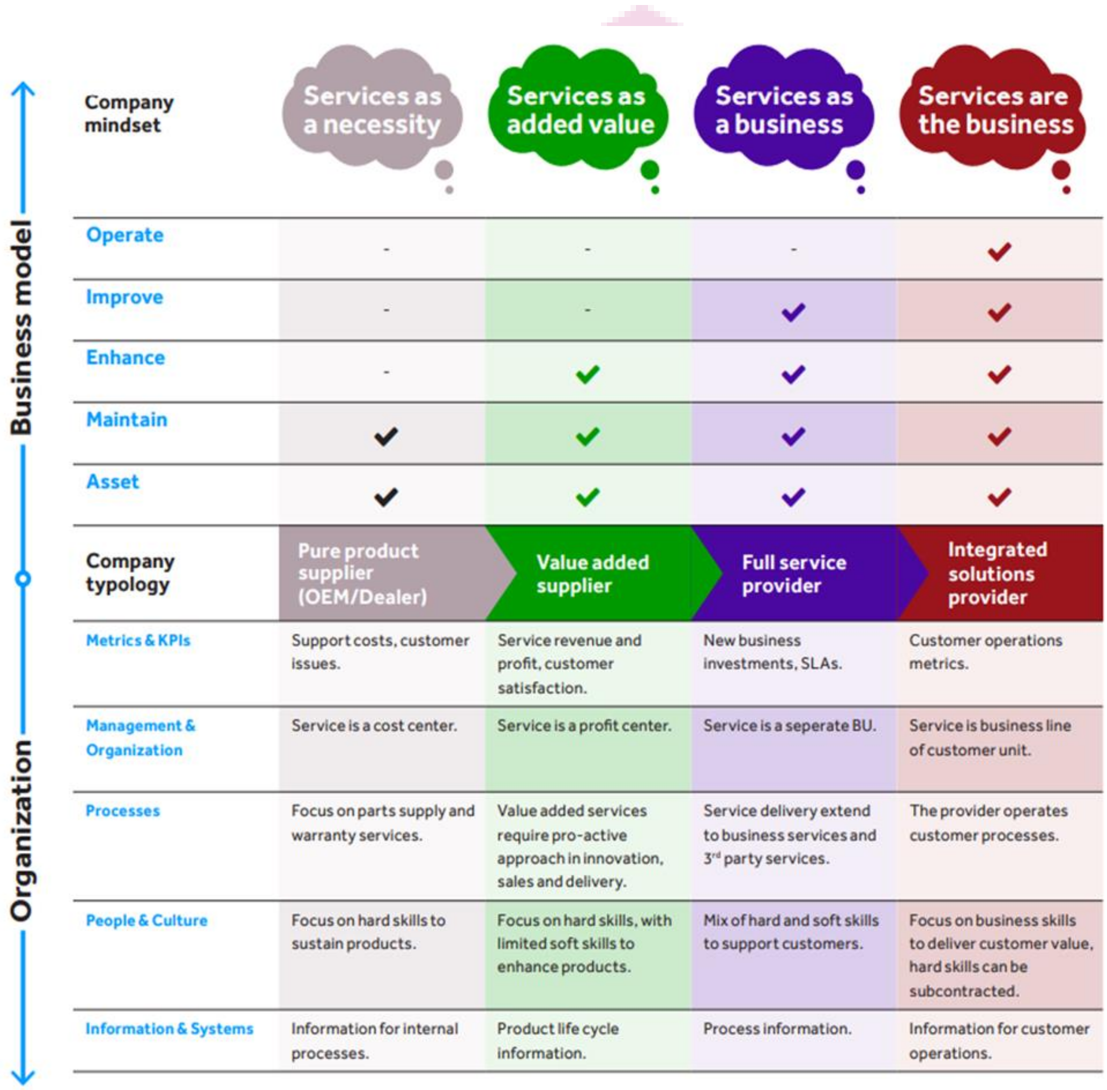


Figure 41.The Praetimus Servitization Maturity Model.

Example: manufacturing industry

Based on hundreds of executive interviews, company consultancy work, studying the action research method applied in companies, company observations and numerous servitization workshops during the last eight years, this work[26] has compiled a comprehensive understanding of manufacturers that have servitized their businesses. Four distinct business models for manufacturers have been identified: 1) the product business model, 2) the service-agreement business model, 3) the process-oriented business model, and 4) the performance-oriented business model. The first two business models focus on products, while the two latter models focus on the customer's process development. In the product and service-agreement business models, the customer owns the process or product, while in the process-oriented and performance-oriented business models the supplier owns the process or product on the customer's behalf.

[26] Huikkola, Tuomas & Kohtamäki, Marko. (2018). Business Models in Servitization. 10.1007/978-3-319-76517-4_4.

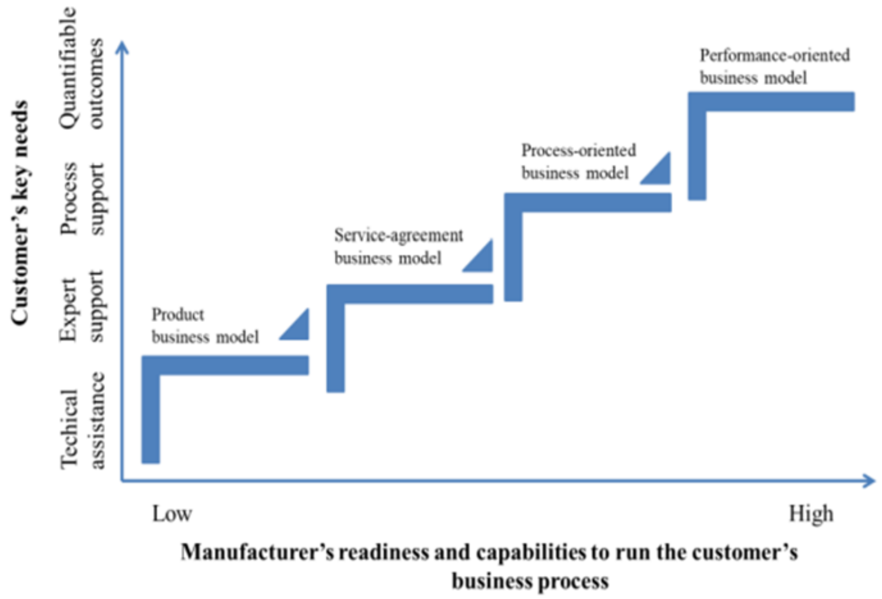


Figure 42.Ideal types of servitization business models.

The next table summarizes the above mentioned business models, the rationale behind each business model, examples of the service-products provided by the business model, key targeted customer segments, the supplier's focus areas, process/product ownership (customer *vs.* supplier), key customer value propositions, profit formulas, key resources and processes that are developed in the business models, examples of the materialization of the business models, and suggestive time frames for business deals.

	Simple--Complex			
	Product Business Model	**Service-agreement Business Model**	**Process-oriented Business Model**	**Performance-oriented Business Model**
Process ownership	Customer owns the process		Supplier owns the process	
Product vs. Process	Supplier's focus is on the product		Supplier's focus is on the customer's process	
Customer segments	Technologist	Fleet manager	Outsourcer	Business partner
Examples of services provided to the clients	-R&D services -Documentation -Product training -Instruction services -Product maintenance -Repair services and spare parts for own products -Warranty -Technical support/backup -Financial services	-Maintenance and spare parts for competitors' equipment or 3rd party products -Predictive maintenance -Service contracts -Extended warranties -Customer training -Modernization services -Remote services -Product upgrades	-Outsourcing services -Operations services -Comprehensive upkeep of the equipment -Remote diagnostics -Customer projects -Equipment rental/leasing	-Operations and maintenance services (O&M) -Consulting services -Turn-key solutions -Integrated solutions -Data analytics services
Customer value proposition	-Technical features -Product superiority -Fill rates -Short repayment periods	-Shorter response times -Better availability -Increased returns on investment (ROIs)	-Increased utilization rate of production -Increased productivity of the process -Decreased transaction costs -Decreased and verified cost savings	-Risk outsourcing (risk evaluation is transferred to the supplier) -Increased overall business performance -Making outcome-related costs planned and predictable
Profit formula	-Low margins (few units sold) -Overall profits are based on exceeding fixed costs -High inventory turnover -Infrequent payments	-High service margins (services are sold frequently) -Overall profits are based on exceeding the variable costs -Low inventory turnover -Frequent payments (e.g., monthly or biannually)	-Profits are based on project success -Usage-based pricing	-Profits are based on customer's business performance -Value-based pricing -Pay-per-outcome
Key resources and processes	-Distribution channel (dealers) -Production plants -R&D -Installed base of products	-Installed base of products and service contracts -Service-aware salespeople -Field personnel (technicians) -Service depots & spare part centers -Fleet management development	-Existing customer relationships -References (reputation) -Project teams -Direct sales force (senior managers) -Risk management -Project management	-Solution sales workforce (includes also executives) -System suppliers -Contract management -IT infrastructure and IoT development -Customer value identification, quantification, communication, and verification processes -Risk management -Network management
Rationale behind the business model	-Easy for everyone to understand -Relatively big deals	-Predictability -Income stability -Customer lock-in	-Customer lock-in -Project-based business logic	-Win/win situation -Partnership -The most difficult BM to copy
Examples of associated products, services, and solutions	-Truck tire and add-on services (remolding services) -Elevators and escalators -Engines and spare parts -Services to support product purchase & delivery	-Tire and wheel contracts -Service agreements for elevator, escalator, and automatic doors (service level depends on contract type) -Engine maintenance contracts -Product life-cycle services	-More extensive tire and wheel contracts -People flow solutions (large projects) and people flow analyses -Engine leasing -Operating services	-Michelin's fleet solutions (kilometers charged) -People flow optimization solutions -Power-by-the-hour solutions -Total solutions
Typical time frame for deals	<1 year	0-4 years	-2-5 years	-5-30 years

Figure 43.Four service business models for a manufacturer.

Example: Light As a Service

Dutch electronics firm Philips offer a fantastic example of a servitization. Amsterdam-Schiphol, as part of their ambition to be one of the most sustainable airports in the world, is now receiving LED lighting-as-a-service from Philips. LED lamps are incredibly efficient however expensive to buy. Under this business model, Schiphol will benefit from a 50% reduction in electricity consumption, but without the upfront cost of buying the lamps. Philips retain ownership of the equipment and instead sell light as the product rather than the units. Add to this the “internet of things” connectivity and Philips are able to monitor each lamp and replace any faulty units often before the fault occurs, providing the complete servitization package.

Example: Servitization for Circular Economy

Product-service system (PSS) has been acknowledged as an important business model innovation for achieving the digitalisation enabled CE.[27]

Product-service systems Business model innovation can reduce the impact on the natural environment, promote the development of sustainable products and drive the redesign of supply chains. Digitalisation not only enables CANVAS BMs but also acts as a trigger for novel business models that promote CE. PSS is seen as a novel business model, which focuses on cost, convenience, the CE and the environment and has ability to improve value creation through improvements in circularity. The vast majority of literature on business models in the context of digitalisation and the CE focuses specifically on the PSS. In a PSS business model, products are either offered entirely as a service, or services, such as customisable maintenance contracts, are provided in addition to the product; this combination of products and services enhances the value creation aspect of the business model. The support services also enhance the product life cycle and improve reuse, recycling and remanufacturing operations of products. PSS ecosystems consist of intelligent systems that form the infrastructural base to enable interconnectedness and smartness (the technical aspect) along with servitisation, which provides the value proposition to increase revenue. Big data, IoT and cloud computing have emerged as influential enablers of PSS business models. Technologies, particularly IoT, drive PSS business models by improving the tracking of products during and after use. PSS is seen as effective in the modern context, given the rise in smart products and digitalisation technologies. PSS-based waste management platforms can provide detailed information on waste streams that were previously limited by the lack of data. Nevertheless, developing, assessing and verifying the feasibility of the PSS requires understanding consumer behaviour and certain intervening factors. The PSS focuses on service innovation because services are viewed as an avenue of value creation and circularity improvement.

[27] Chauhan, Chetna & Parida, Vinit & Dhir, Amandeep. (2022). Linking circular economy and digitalisation technologies: A systematic literature review of past achievements and future promises. Technological Forecasting and Social Change. 177. 121508. 10.1016/j.techfore.2022.121508.

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