The Transition to Industry 4.0 in the Catalan Chemical Industry. Baseline 2020.

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La transición a la Industria 4.0 en la industria química catalana. Línia de base 2020.

La transició a la indústria 4.0 a la indústria química catalana. Base 2020.

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ABSTRACT

The baseline for the state of implementation of Industry 4.0 technologies in the Catalan chemical industry in 2020 is established using the model proposed by the Industry 4.0 Commission of the Institution of Engineers of Catalonia. Two panels are convened, one comprising AIQS experts and the other industry executives. The responses from both panels exhibit similar trends. Among the levers used by the model, Inventory Control emerges as the most successfully implemented in the industry, followed by Cybersecurity, Production Planning, Monitoring and Control, and Environmental Efficiency. However, certain deficiencies are noted in the implementation of advanced maintenance practices. Industry executives generally express satisfaction with the current level of Industry 4.0 technology implementation. However, they exhibit lower satisfaction levels with levers such as Relationships with Suppliers, Data Collection, and Process Modelling. Anticipated impacts of Industry 4.0 technology implementation are expected to be highly favourable and desirable, particularly in the realm of manufacturing processes. Additionally, a projection of Industry 4.0 technology implementation with a horizon extending to 2025 is conducted, which will require comparison with future studies.

Keywords: Industry 4.0, Survey, Chemical Industry, Catalonia, 2020 Background, 2025 Horizon

RESUMEN

La línea de base para la implantación de tecnologías de Industria 4.0 en la industria química catalana en 2020 se establece a partir del modelo propuesto por la Comisión de Industria 4.0 de la Institución de Ingenieros de Cataluña. Se convocan dos paneles, uno compuesto por expertos de AIQS y el otro por directivos de la industria. Las respuestas de ambos paneles muestran tendencias similares. Entre las palancas utilizadas por el modelo, el Control de Inventarios emerge como la más implementada con éxito en la industria, seguida de la Ciberseguridad, la Planificación, Monitoreo y Control de la Producción y la Eficiencia Ambiental. Sin embargo, se notan ciertas deficiencias en la implementación de prácticas de mantenimiento avanzadas. Los gerentes de la industria generalmente expresan satisfacción con el nivel actual de implementación de la tecnología Industria 4.0, aunque exhiben niveles de satisfacción más bajos con palancas como la relación con proveedores, la recopilación de datos y el modelado de procesos. Se espera que los impactos previstos de la implementación de la tecnología Industria 4.0 sean muy favorables y deseables, particularmente en el ámbito de los procesos de fabricación. Además, se realiza una proyección de la implementación de la tecnología Industria 4.0 con un horizonte que se extiende hasta el año 2025, lo que requerirá comparación con estudios futuros.

Palabras clave*:* Industria 4.0, Encuesta, Industria Química, Cataluña, Antecedentes 2020, Horizonte 2025

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RESUM

La línia de base per a la implantació de les tecnologies de la indústria 4.0 a la indústria química catalana l'any 2020 s'estableix a partir del model proposat per la Comissió d'Indústria 4.0 de la Institució d'Enginyers de Catalunya. Es convoquen dues comissions, una formada per experts de l'AIQS i l'altra per responsables del sector. Les respostes dels dos panells mostren tendències similars. Entre les palanques utilitzades pel model, el Control d'Inventari emergeix com el que més s'ha implementat en el sector, seguit de Ciberseguretat, Planificació de la Producció, Monitorització i Control i Eficiència Ambiental. Tanmateix, s'observen certes deficiències en la implementació de pràctiques de manteniment avançades. Els directors del sector generalment expressen satisfacció amb el nivell actual d'implementació de la tecnologia Indústria 4.0, tot i que mostren nivells de satisfacció més baixos amb palanques com la relació amb els proveïdors, la recollida de dades i la modelització de processos. S'espera que els impactes previstos de la implementació de la tecnologia Indústria 4.0 siguin molt favorables i desitjables, especialment en l'àmbit dels processos de fabricació. A més, es realitza una projecció de la implantació de la tecnologia Indústria 4.0 amb un horitzó que s'estén fins al 2025, que requerirà comparació amb estudis futurs.

Paraules clau*:* Indústria 4.0, Enquesta, Indústria Química, Catalunya, Antecedents 2020, Horitzó 2025

INTRODUCTION

Currently, Industry 4.0 has emerged as a transformative paradigm in the industrial sphere, generating a significant impact across various economic sectors. This article focuses on the application and evaluation of Industry 4.0 in the chemical sector of Catalonia, with a particular emphasis on the study started by IQS in 2019. We analyse the level of adoption, its potential benefits, associated risks, and future outlook, providing a detailed perspective on the evolution of the chemical industry in the era of digital connectivity. This work establishes a baseline that will serve as a reference for subsequent studies.

To fully understand the relevance of Industry 4.0, it is essential to contextualize it within the framework of previous industrial revolutions. It all began with the so-called 1st Industrial Revolution in the second half of the 18th century in Great Britain, with the invention of the steam engine by James Watt (1769), which meant the substitution of the human labour force by the machine. Between 1870 and 1914 these technological-industrial advances spread to other countries like Germany, the United States of America and Japan, and other advances also arose: mass production (assembly line), steel production, the use of new materials (steel and oil), the appearance of new energy sources (gas and electricity), and new transport systems (airplanes and automobiles), the development of chemistry and the invention of the telephone and the radio. This period is known as the 2nd Industrial Revolution. Later, around 1969, the so-called 3rd industrial revolution emerged with the irruption of information technologies, followed by communication technologies, the development of the Internet at the end of the 20th century, digitalization, and the so-called renewable energies. And now we are in a new stage of the industrial and technological evolution of society, the so-called 4th industrial revolution, named Industry 4.0 by Klaus Schwab in 2016[1].

Industry 4.0 involves the interconnection of sensors, machines, and information technology systems, encompassing all entities in the supply chain (suppliers, manufacturers, distributors, and retailers). These interconnected systems can interact using standard internet protocols and, by analysing the data they collect, provide benefits to companies by adapting more swiftly, flexibly, and efficiently to changes.

The prevailing trends today, such as customization, automation, globalization, digitization, and sustainability, outline the trajectory of Industry 4.0. These elements manifest with greater emphasis in the chemical industry, where resource optimization and improved sustainability have become imperatives. The implementation of the technologies associated with Industry 4.0 has turned into a tangible reality in several industries including the chemical industry, and its impact is reflected in operational efficiency and the reduction of environmental footprints.

In this context, this paper specifically addresses the implementation of Industry 4.0 in the Catalan chemical sector. Key aspects will be explored, including the satisfaction level of companies regarding the implementation of the technologies associated with Industry 4.0, emerging trends, and the overall impact in terms of digitization. The model proposed by the Industry 4.0 Commission of the Institution of Engineers of Catalonia[1] in 2018[2] serves as a reference for this analysis (the currently available version is referenced). This analysis aims to establish the groundwork for a deeper understanding of the ongoing industrial breakthrough and to anticipate its potential implications for the Catalan chemical sector.

THEORY

The utilized model comprises four dimensions encompassing 46 levers and 11 technologies (Figure 1). To streamline the questionnaire administration process, the number of levers was reduced to 34 (***Table 1***), excluding items typically unrelated to chemicals, such as 'personalization' or 'interoperability'. The model also includes 'Blockchain' as an independent technology, but in the present study, it has been encompassed within 'Cybersecurity'. The level of operation for each lever serves to establish the degree of implementation of Industry 4.0 within a company. The 4 dimensions are as follows:

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- **Strategy and Business Model**. In a fiercely competitive market where we are nowadays, characterized by volatility, uncertainty, complexity, and ambiguity (VUCA), companies can (and, in fact, should) leverage Industry 4.0 technologies to enhance their competitive position. Leading companies must determine how to utilize these technologies to compete in the market, not only by improving existing business models but also by identifying new business models based on these technologies.

- **Products and Services**. These technologies assist companies in the customization of the products and services they offer to customers, thereby enhancing their value proposition in the market.

- **Manufacturing Processes.** The utilization of these technologies aids in improving responsiveness (lead time) to unexpected changes in demand, enhancing product quality, and increasing production flexibility and efficiency.

- **Human Capital & Organization**. It is often stated in management that staff is the most valuable asset of any organization. It becomes evident, then, that for the efficient and effective use of these technologies, the company's personnel must be trained to successfully implement them. This, in turn, presents a challenge for companies to organize and manage the training, development and capacitation of their personnel effectively.

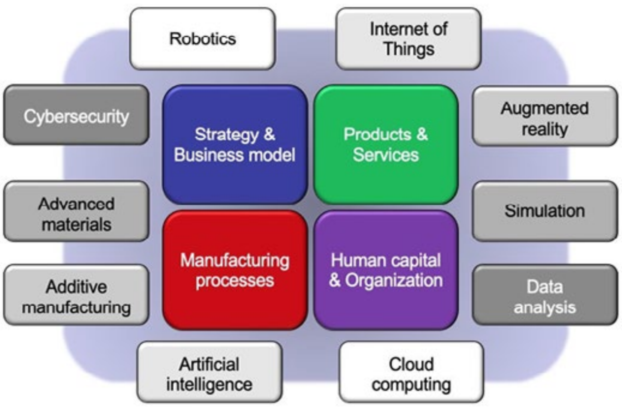

Figure 1. *Model proposed by the Industry 4.0 Commission of the Institution of Engineers of Catalonia in 2018.*

The 10 considered technologies are Robotics[3,4], Cibersecurity[5,6], Advanced Materials[7,8], Additive manufacturing (3D Printing)[8–10], Artificial Intelligence[11,12], Cloud Computing[13,14], Data Analysis (Big Data)[15,16], Simulation (Digital Twins)[17,18], Augmented Reality[19,20], and (IoT) Internet of Things[21,22].

The questionnaire comprises one question per lever. Responses are categorized into four levels. The first, Level 1, indicates that the lever is not being utilized. Level 2 corresponds to the use of technologies or traditional techniques predating Industry 4.0. Level 3 implies a significant level of digitization but lacks the advantages of interconnected technologies and their autonomy, which are present at Level 4. Additional questions about the estimated relevance of the lever for the chemical industry, the satisfaction with the implementation of each one, and a forecast with a horizon of 5 years are included.

Table 1. *List of the 34 levers proposed by the model.*

DIMENSION	LEVER	
Strategy and Business Model	1A	Strategy 4.0
	1B	Internalization of Industry
	1C	Relationship with suppliers
	1D	Sourcing strategies
	1E	Product design
	1F	Relationship with customers
	1G	Demand Forecast
Products and Services	2A	Products
	2B	Services
	2C	Maintenance of products
Manufacturing Processes	3A	Equipment
	3B	Flexible Manufacturing
	3C	Production Planning (I)
	3D	Production Planning (II)
	3E	Inventory Control
	3F	Inbound Logistics
	3G	Cold Chain Logistics at controlled temperature
	3H	Outbound Logistics
	3I	Picking
	3J	Monitoring and control
	3K	Standard Operating Procedures (SOP)
	3L	Maintenance (I)
	3M	Maintenance (II)
	3N	Data Collection
	3O	Process Modelling
	3P	Process Analysis
	3Q	Energy Efficiency
	3R	Environmental Efficiency
Human Capital and Organization	4A	Information Systems
	4B	Data Management
	4C	Human Capital
	4D	Staff Monitoring
	4E	Cybersecurity
	4F	Teamworking

METHODOLOGY

To prepare the questionnaire administration, interviews were conducted with seven experts in different technologies belonging to the Industry 4.0 Commission of the Institution of Engineers of Catalonia. The objective was to ensure the clarity of each of the posed questions. Such experts were the heads or relevant members of the working parties on Robotics, Intralogistics, Additive Manufacturing, Software and Integration, Artificial Intelligence, and Embedded Systems & IoT. This panel of experts also gave its opinion on Augmented Reality, Simulation and Digital Twins, Data Science, and Cybersecurity.

The classification of the commercial activity of the various chemical industries to be interviewed was carried out according to the classic Kline matrix[23,24] into True Commodities, Branded Commodities, Fine Chemicals, and Specialty Chemicals.

Secondly, to establish a framework of reference, 36 experts from the chemical sector of AIQS, the alumni association of IQS, were interviewed; 6 belonged to the True Commodities segment, 3 from the Branded Commodities segment, 6 from the Fine Chemicals segment, and 21 from the Specialty Chemicals segment. They were asked to rank the relevance of each lever in the questionnaire and its expected level of implementation in the industry.

Finally, online, and in-person surveys were conducted with senior executives from 26 chemical companies with production in Catalonia. It should be noted that some of the companies have commercial activity in more than 2 market segments, so they appear duplicated in the following list: 7 companies in the True Commodities segment, 5 in the Branded Commodities segment, 6 in the Fine Chemicals segment, and 14 in the Specialty Chemicals segment.

RESULTS AND DISCUSSION

In response to the question of whether a dimension or a lever is relevant or not to the chemical industry (Figure 2), industry executives are far more radical than experts from AIQS. Nevertheless, when considering that a 75% affirmative response rate marks the threshold for a lever to be significant, both expert groups concur that Dimension 2 and Lever 3G are not relevant to most of the chemical industry.

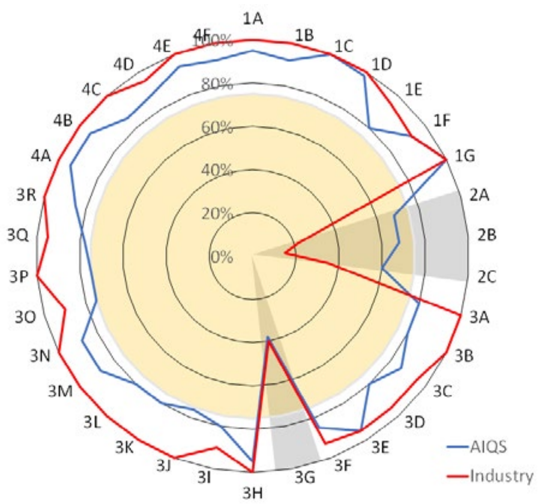

Figure 2. Relevance of model's levers for the chemical industry.

For Dimension 2, Products and Services, the questions contained in the questionnaire for Lever 2A pertain to the connectivity of products. It seems evident that, at present, chemical products do not have or require this capability. Lever 2B queries whether post-sales services are digitized or if new business opportunities arise due to digitization. In this sense, it is known that few companies in the chemical sector are indeed capitalizing on this possibility. Perhaps, companies supplying industrial gases are an exception. Therefore, it is logical that most of the chemical industry does not consider this aspect important because chemicals do not include digital devices. The same holds for Lever 2C, which refers to product maintenance. In the chemical industry, it is not customary to employ Cold Chain Logistics at controlled temperatures (Lever 3G) for distributing industrial products; if a particular substance requires it, it is utilized, but such practices are not the norm. Consequently, and setting aside the aforementioned levers, it is acknowledged that the questionnaire aligns well with the chemical industry.

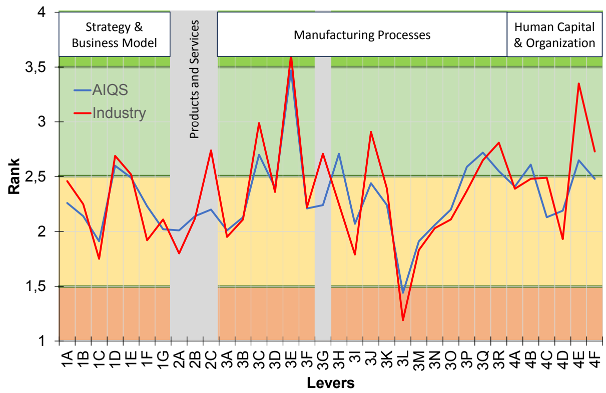

Figure 3. Mean of the responses considering the degree of implementation for each lever.

Figure 3 depicts the mean of the responses on a scale of 1 to 4 considering the degree of implementation for each lever. Some differences can be detected between the opinions of senior executives from the industry and experts from AIQS. However, the trends are essentially the same.

Regarding Dimension 1 (Strategy and Business Model), all results are above 2 on a scale of 1 to 4, except for lever 1C (Relationship with suppliers). It could be said that this dimension is weakly implemented in the chemical industry. The highest value corresponds to lever 1D (Sourcing strategies).

Dimension 2 (Products & Services) has been previously noted as not significant both for the executives and the experts.

In dimension 3 (Manufacturing Processes), all values are above 2, except for levers 3L (Maintenance (I)) and 3M (Maintenance (II)). The highest value is attributed to lever 3E (Inventory Control) which, according to the panel from the industry, is followed by lever 3C (Production Planning), 3J (Monitoring and Control) and 3R (Environmental Efficiency).

In dimension 4 (Human Capital and Organization), all levers have a score above 2, with the highest scores being for levers 4E (Cybersecurity) and 4F (Teamworking). Experts from AIQS include 4B (Data Management) as potentially relevant.

Figure 4 illustrates the breakdown for each market segment to which the survey participants belong.

According to AIQS experts (Figure 4A), in the True Commodities segment (red columns), Dimension 3 (Manufacturing Processes) is the most important, followed by Dimension 1 (Strategy and Business), and Dimension 4 (Human Capital and Organization). For the Branded Commodities (yellow columns) and Fine Chemicals (green columns) segments, Dimensions 3 and 4 are the most crucial. As for the Speciality Chemicals segment (blue line), all three dimensions (Strategy and Business Model, Manufacturing Processes, and Human Capital and Organization) are equally important. It is emphasized once again that Dimension 2 (Products and Services) is not significant for any segment.

Figure 4B presents the same breakdown of industry executives' responses for each market segment they belong to. For the True Commodities segment, the order of importance of dimensions from highest to lowest is Dimension 3, Dimension 4, and Dimension 1. The other three segments, Branded Commodities, Fine Chemicals, and Speciality Chemicals, all agree that they give the highest importance to Dimension 3, followed by Dimension 4, and lastly Dimension 1.

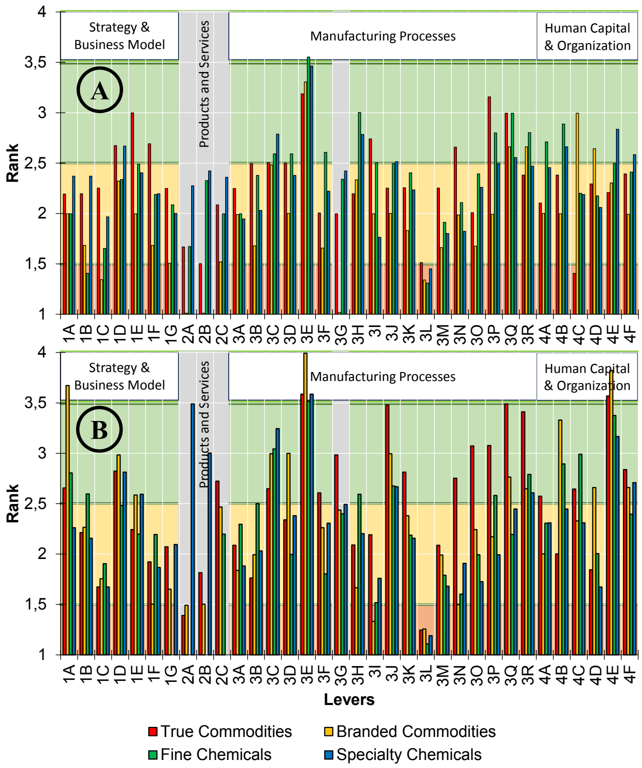

Figure 4. *Breakdown responses from AIQS experts (A) and chemical industry executives (B) concerning the implementation of Industry 4.0 for each market segment.*

The panel of industry executives was asked about satisfaction levels regarding the use of these technologies in the range from 0 to 5; the results are shown in Figure 5. The vast majority of the levers fall within a favourable satisfaction level, ranging between 3.5 and 4.5 out of 5. The levers with a lower satisfaction level among companies are 1F (Relationship with customers), 3N (Data collection), and 3O (Process Modelling).

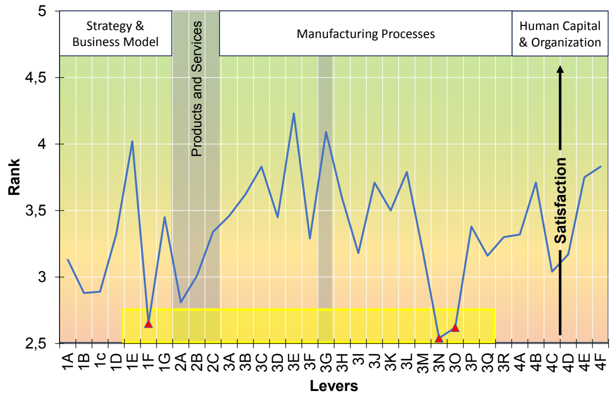

Figure 5. *Satisfaction levels regarding the use of Industry 4.0 technologies.*

Upon detailed analysis of the meaning of the 34 levers and comparing their implementation level, which constituted the first part of the interviews, with the companies' satisfaction level, the results are consistent. We observed that Dimension 1 is not widely adopted in this sector. On the other hand, we believe that these technologies can help improve companies' competitiveness and profitability by better understanding customer needs, even leading to the creation of new business models that expand the strategic offering of products and services.

We also noted that all companies and industry experts emphasized the importance of Dimension 3, but also identified areas for improvement such as maintenance. Now, we see that the satisfaction level regarding levers 3N and 3O is low. We speculate that companies recognize these as areas for improvement in the future, given the technological power of Industry 4.0 technologies. Therefore, enhancing data capture and modelling, coupled with maintenance using these technologies (predictive maintenance and the use of Digital Twins), will likely mark a significant step forward in improving the manufacturing processes of this industry.

Figure 6 depicts the current implementation level and the expected future utilization level of Industry 4.0 technologies as indicated in Figure 1.

As expected, the industry thinks that the trend in the use of these technologies will increase in the future, foreseeing a greater increase in IoT, Big Data, Cloud computing and Artificial Intelligence technologies. We think, however, that the increase in the use of these technologies will be even higher than estimated by the industry executives interviewed.

Industry executives were also asked about the impact that digitization associated with Industry 4.0 will have on companies in the sector in terms of economic and competitive advantage. The response to this question was unanimous, indicating that the impact will be highly favourable and desirable. Lastly, they were questioned about the impact these benefits will have on the four dimensions of our model. Figure 7 captures the responses to this question.

It can be observed that the dimension in which industry managers believe the impact of digitization will be greater is Dimension 3 (Manufacturing Processes). Nevertheless, the impact will be comprehensive across

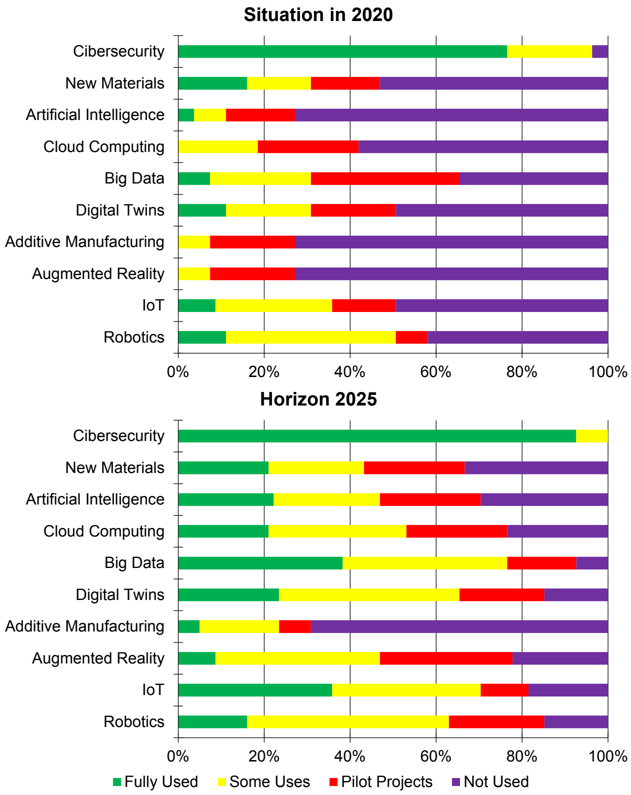

Figure 6. *Current implementation level and the expected future utilization level of Industry 4.0 technologies.*

the entire company, as the executives' estimations for the other dimensions are fairly balanced.

Finally, it is worth highlighting that the implementation of Industry 4.0-associated technologies is not without risks, and to ensure the success of their implementation and practical application, certain aspects should be considered. These include the selection of technology providers, establishing relevant Key Performance Indicators (KPIs) for monitoring implementation, ensuring the knowledge of these technologies among the personnel who will use and implement them, addressing resistance from staff (commonly known as resistance to change that always exists with any procedural or workflow changes), and last but not least, securing the support of the company's top management for the implementation of such a project.

In conclusion of the research conducted, it can be stated that the final goal of utilizing Industry 4.0-associated technologies is not only to provide customers with products that meet their needs and expectations in terms of quality and service with the least investment and cost possible but also to improve the working conditions of employees, reduce the environmental impact of processes, and increase productivity. This, in turn, leads to an enhancement of sustainability and the so-called Triple Bottom Line, which simultaneously manifests as an economic improvement for companies (profitability) and social and environmental benefits for society, as depicted in Figure 8.

CONCLUSIONS

As a result of everything that has been discussed, the conclusions of this work are as follows:

The baseline for the implementation of Industry 4.0 technologies in 2020 in the Catalan chemical industry is established, as the degree of satisfaction of companies in the sector regarding its use, the future trends, and the impact of the benefits for companies of digitization. The responses from the AIQS expert panel and the panel of directors of chemical industries follow similar trends.

According to the employed model, the dimension of Products and Services and the lever of Cold Chain Logistics at controlled temperature are not relevant for the majority of the Catalan chemical industry. The lever of Inventory Control is the most well-implemented in the industry, followed by Cybersecurity, Production Planning, Monitoring and Control, and Environmental Efficiency. Certain deficiencies are observed also in the implementation of advanced maintenance topics.

Industry managers are generally satisfied with the level of implementation of Industry 4.0 technologies, showing lower levels of satisfaction with the levers Relationship with customers, Data Collection, and Process Modelling.

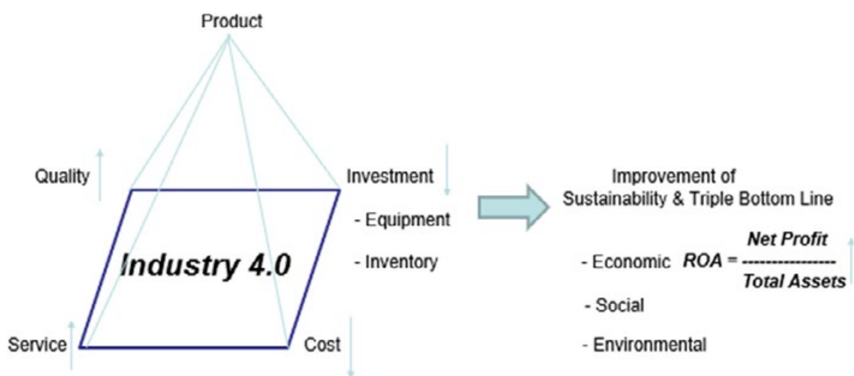

Figure 8. *Economic improvement for companies and social and environmental benefits of Industry 4.0.*

Finally, a projection of the implementation of Industry 4.0 technologies with a horizon of 2025 is carried out, which will need to be compared with future studies.

REFERENCES

1. Schwab, K. *The Fourth Industrial Revolution*; Currency; Illustrated edition, 2017.
2. EIC Comissió Indústria 4.0. *Eina de diagnosi per a la Indústria 4.0*. https://www.eic.cat/promocio/e_marqueting/i40/comissio/2020/Questionari_Eina_diagnosi_v2006.pdf.
3. Javaid, M.; Haleem, A.; Singh, R. P.; Suman, R. Substantial Capabilities of Robotics in Enhancing Industry 4.0 Implementation. *Cognitive Robotics* **2021**, *1*, 58–75. https://doi.org/10.1016/J.COGR.2021.06.001.
4. Lloyd's Register Foundation. *Foresight review of robotics and autonomous systems. Serving a safer world. Lloyd's Register Foundation. Report Series: No. 2016.1.* October 2016. https://www.lrfoundation.org.uk/496934/siteassets/pdfs/lrf_foresight_review_of_robotics_and_autonomous_systems.pdf (accessed 2023-11-23).
5. Aslan, Ö.; Aktuğ, S. S.; Ozkan-Okay, M.; Yilmaz, A. A.; Akin, E. A Comprehensive Review of Cyber Security Vulnerabilities, Threats, Attacks, and Solutions. *Electronics 2023, Vol. 12, Page 1333* **2023**, *12* (6), 1333. https://doi.org/10.3390/ELECTRONICS12061333.
6. Li, Y.; Liu, Q. A Comprehensive Review Study of Cyber-Attacks and Cyber Security; Emerging Trends and Recent Developments. *Energy Reports* **2021**, *7*, 8176–8186. https://doi.org/10.1016/J.EGYR.2021.08.126.
7. Chaikittisilp, W.; Yamauchi, Y.; Ariga, K. Material Evolution with Nanotechnology, Nanoarchitectonics, and Materials Informatics: What Will Be the Next Paradigm Shift in Nanoporous Materials? *Advanced Materials* **2022**, *34* (7), 2107212. https://doi.org/10.1002/ADMA.202107212.
8. Jiang, Y.; Islam, M. N.; He, R.; Huang, X.; Cao, P. F.; Advincula, R. C.; Dahotre, N.; Dong, P.; Wu, H. F.; Choi, W. Recent Advances in 3D Printed Sensors: Materials, Design, and Manufacturing. *Adv Mater Technol* **2023**, *8* (2), 2200492. https://doi.org/10.1002/ADMT.202200492.
9. Savolainen, J.; Collan, M. How Additive Manufacturing Technology Changes Business Models? – Review of Literature. *Addit Manuf* **2020**, *32*, 101070. https://doi.org/10.1016/J.ADDMA.2020.101070.
10. Rasiya, G.; Shukla, A.; Saran, K. Additive Manufacturing-A Review. *Mater Today Proc* **2021**, *47*, 6896–6901. https://doi.org/10.1016/J.MATPR.2021.05.181.
11. Ali, O.; Abdelbaki, W.; Shrestha, A.; Elbasi, E.; Alryalat, M. A. A.; Dwivedi, Y. K. A Systematic Literature Review of Artificial Intelligence in the Healthcare Sector: Benefits, Challenges, Methodologies, and Functionalities. *Journal of Innovation and Knowledge* **2023**, *8* (1). https://doi.org/10.1016/j.jik.2023.100333.
12. MIT Technology Review. *The Great Acceleration: CIO Perspectives on Generative AI*; Cambridge, 2023. https://www.databricks.com/sites/default/files/2023-07/ebook_mit-cio-generative-ai-report.pdf (accessed 2023-11-21).
13. Gourisaria, M. K.; Samanta, A.; Saha, A.; Patra, S. S.; Khilar, P. M. An Extensive Review on Cloud Computing. In *Data Engineering and Communication Technology. Advances in Intelligent Systems and Computing*; Raju, K., Senkerik, R., Lanka, S., Rajagopal, V., Eds.; Springer: Singapore, 2020; Vol. 1079, pp 53–78.
14. Amron, M. T.; Ibrahim, R.; Chuprat, S. A Review on Cloud Computing Acceptance Factors. *Procedia Comput Sci* **2017**, *124*, 639–646. https://doi.org/10.1016/J.PROCS.2017.12.200.
15. Sharifani, K.; Amini, M. Machine Learning and Deep Learning: A Review of Methods and Applications. 2023. https://papers.ssrn.com/abstract=4458723 (accessed 2023-11-29).
16. Radanliev, P.; De Roure, D. New and Emerging Forms of Data and Technologies: Literature and Bibliometric Review. *Multimed Tools Appl* **2023**, *82* (2), 2887–2911. https://doi.org/10.1007/s11042-022-13451-5.
17. Foo, D. C. Y.; Elyas, R. Introduction to Process Simulation. *Chemical Engineering Process Simulation* **2023**, 3–28. https://doi.org/10.1016/B978-0-323-90168-0.00008-1.
18. Llanes, J. M.; Miranda, M.; Mullick, S. Use Modeling to Fine-Tune Cracking Operations. *Hydrocarbon Processing* **2008**.
19. Ko, C.; Lee, H.; Lim, Y.; Lee, W. B. Development of Augmented Virtual Reality-Based Operator Training System for Accident Prevention in a Refinery. *Korean J. Chem. Eng* **2021**, *38* (8), 1566–1577. https://doi.org/10.1007/s11814-021-0804-6.
20. Dargan, S.; Bansal, S.; Kumar, M.; Mittal, A.; Kumar, K. Augmented Reality: A Comprehensive Review. *Archives of Computational Methods in Engineering* **2023**, *30* (2), 1057–1080. https://doi.org/10.1007/S11831-022-09831-7/TABLES/1.
21. Rejeb, A.; Suhaiza, Z.; Rejeb, K.; Seuring, S.; Treiblmaier, H. The Internet of Things and the Circular Economy: A Systematic Literature Review and Research Agenda. *J Clean Prod* **2022**, *350*, 131439. https://doi.org/10.1016/J.JCLEPRO.2022.131439.
22. Rejeb, A.; Simske, S.; Rejeb, K.; Treiblmaier, H.; Zailani, S. Internet of Things Research in Supply Chain Management and Logistics: A Bibliometric Analysis. *Internet of Things* **2020**, *12*, 100318. https://doi.org/10.1016/J.IOT.2020.100318.
23. Kline, C. H. Specialty Chemicals. What Are They? What Do They Do? Where Do They Come from? And Where Are They Going? *American Chemical Society* **1991**, 148–151.
24. Brennan, D. *Process Industry Economics: An International Perspective*, Revised 1990.; IChemE, 1990.

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