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# Industry 4.0 In The Brazilian Automotive Sector: Opportunities And Challenges For Global Competitiveness

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***Abstract:***
*This study aims to investigate the challenges and opportunities faced by automotive companies with manufacturing plants in Brazil within the context of Industry 4.0. The aim is to elucidate how these challenges can be overcome and opportunities leveraged to maintain global competitiveness. Research Methodology: This study is based on a Systematic Mapping (SM) that analyzes academic articles published until 2022, focusing on databases such as SCOPUS, Web of Science, BASE, and Scielo. Thirty articles were classified into eight categories, including the nine technological pillars of Industry 4.0, the size of companies, their position in the supply chain, and the impact (in terms of challenges and opportunities) of Industry 4.0 technologies in the sector. Additionally, bibliometric data of the authors and keywords were analyzed using the VOSViewer software.*
***Main Results:*** *The study identified that Industry 4.0 has significant potential to impact the challenges and opportunities in the Brazilian automotive sector. The main challenges include a lack of subject knowledge, implementation costs, and access to a qualified workforce (both at the managerial and operational levels). The opportunities lie in operational efficiency, data-driven decision-making, and competitiveness in the global market.*
***Originality:*** *This is one of the initial studies to conduct a comprehensive assessment of the impact of Industry 4.0 on the Brazilian automotive sector. It emphasizes the necessity for research focused on smaller enterprises and less advanced links in the technological chain, as well as more detailed comparisons with the state of the art in other countries.*
***Research Limitations:*** *Some limitations of this study include the focus on specific databases and the inability to access all relevant articles, as well as potential biases in article selection due to the multidisciplinary nature of the topic. The research also suggests that future analyses could benefit from a more comprehensive comparison with other developing and developed countries.*
***Main Contributions:*** *This study sheds light on the understanding of the impact of Industry 4.0 on the Brazilian automotive sector. It demonstrates research gaps concerning smaller companies and those in less advanced stages of the supply chain. The existence of critical challenges such as lack of knowledge on the subject, high implementation costs, and the need for skilled labor is highlighted. Simultaneously, opportunities in operational efficiency and data-driven decision-making are pointed out. This work delineates the necessity of industrial policies and business strategies aimed at educating on the subject, workforce training, and financing to overcome these challenges. It serves as a reference for future research and the development of collaborative strategies to boost the sector's competitiveness in the global landscape.*
***Keywords:*** *Fourth Industrial Revolution; automotive production chain; industrial Internet of Things; big data and analytics; public policies and innovation*

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## I. Introduction

The concept of Industry 4.0 was introduced at the 2011 Hannover industrial fair by Kagermann, Dieter, and Wahlster, revealing a high-technology strategic project sponsored by the German Government to maintain the competitiveness of the German industry (Kagermann et al., 2011). Industry 4.0 (I4.0) integrates various technologies that had already been applied in isolation in plants adapted to the reality of the third industrial revolution. From highly roboticized and optimized production cells, a reality of total integration is achieved thanks to the exchange of real-time information throughout the value chain, leading to greater efficiency and transformations in traditional relationships among suppliers, producers, and final consumers (Bianchessi & Mammana, 2018; Rüssman et al., 2015). The nine pillars of Industry 4.0 that qualify it as an Industrial Revolution, according to Rüssman et al. (2015), are: a) automated robots; b) simulation; c) horizontal and vertical integration of systems; d) Industrial Internet of Things (IIoT); e) cyber security; f) cloud computing; g) additive manufacturing; h) augmented reality; and i) Big Data and Analytics. The authors assert that the integrated application of these technologies will enable faster, more flexible, and more efficient processes, leading to increased factory productivity, which in turn will allow for the production of manufactured goods of higher quality at reduced costs. This will cause profound economic changes, influencing competitiveness among companies and regions. In the official report of recommendations for implementation towards the fourth industrial revolution, Kagermann et al. (2013) affirm that in an intelligent and interconnected world, the Internet of Things and Services will play a leading role in distinct areas. The changes affect various sectors, such as energy, smart grids, sustainable mobility (smart mobility and smart logistics), and health (smart health). In the productive sector, there is a trend towards adding intelligence to products and services and meticulous engineering to integrate vertical and horizontal value chains, optimizing network effects. In this context, challenges and opportunities arise for companies in the Brazilian automotive sector, especially those of smaller size and in less advanced links of the production chain, which can leverage their production complexity. There is a need for research focused on Tier III Suppliers and Aftermarket parts, seeking strategies and public policies to promote Industry 4.0 in the Brazilian automotive sector. The implications for global supply chains are profound, with some authors (Abramovitz, 1986; Pitassi, 2014; Sarti & Hiratuka, 2017) predicting a deepening technological gap between leading countries in the race for the adoption of Industry 4.0 technological innovations (such as Germany, China, South Korea, the USA, and Japan) and the emerging economies of the so-called BRICS (Brazil, Russia, India, China, and South Africa) - except for China, which currently ranks as the second country that invests the most in R&D in PPP terms (Purchasing Power Parity), both in absolute values and as a % of GDP (Zhao, Wang, Xiao et al., 2018; OECD, 2019, Menelau et al., 2019). In the context of this race for technological supremacy, there is a growing interest from countries in restructuring their technological infrastructures, adopting public policies, and creating a business environment that promotes investments in Science and Technology (S&T) necessary to maintain the global competitiveness of their companies. Menelau and colleagues (2019) demonstrate that among the measures adopted for this purpose are industrial policies for IT catch-up (Gomes & Strachman, 2005; Ipiranga et al., 2012; Costa, Menezes, & Franzoni, 2016), accumulation of capabilities for innovation (Kagermann et al., 2013), and value appropriation (Brettel, Friederichsen, Keller et al., 2014; Roblek, Mesko, & Krapez, 2016). Some examples of industrial policy programs aimed at I4.0 include the final report of the German National Academy of Science and Engineering, with recommendations for the implementation of the "Industrie 4.0" project (Kagermann et al., 2013), China's "Made-in-China 2025" initiative by the Chinese State Council (SC, 2015), and US initiatives from 2011 onwards (PCAST, 2011 and 2014) and (NIST, 2021). For Chien et al. (2017), a viable strategy for countries in less advanced stages of industrial development, such as Brazil, maybe to seek to maintain reasonable levels of competitiveness through the adoption of a transition scenario that seeks the adoption of certain enabling technologies for existing manufacturing intelligence (currently between the levels of Industry 2.0 and 3.0), reaching an Industry 3.5. The relevance of this study arises from the fact that the automotive sector represents the fourth largest GDP in the Brazilian Manufacturing Industry, according to data from the National Confederation of Industry [CNI] of 2019.

This work aims to identify opportunities and challenges of Industry 4.0 for the global competitiveness of the Brazilian automotive sector through a Systematic Literature Review. The research is justified by the economic relevance of the sector and the need to increase its global competitiveness, especially in smaller companies and less technological segments of the production chain. The research focus is corroborated by investments in Industry 4.0 technologies in Brazil (Santos et al, 2018; Bianchessi and Mammana, 2018) and by the importance of the sector in leading Industry 4.0 countries, such as Germany and China (Lin et al, 2018 ; Kern and Wolff, 2019).

## II. Material And Methods

In this Bachelor's thesis, a qualitative approach was employed to investigate the opportunities and challenges faced by automotive companies in Brazil, of various sizes and across different links of the production chain, in the process of adopting Industry 4.0. Qualitative research is deemed appropriate for this study as it allows for an in-depth exploration of the perceptions, experiences, and processes experienced by companies in the context of Industry 4.0, as well as the identification of emerging patterns and trends (Creswell, 2013; Bryman, 2012).

To materialize this qualitative approach, a Systematic Mapping (SM) was conducted, which entails a comprehensive review of existing primary studies on a specific research topic, aiming to identify and classify the collected evidence (Kitchenham & Charters, 2007). Through SM, the aim is to understand the scope of existing knowledge in the field, identify gaps suggesting the need for future studies, and serve as a guide for new research activities (Kitchenham et al., 2011; Petersen et al., 2008).

The focus of this study is on the manufacturing plants of automotive companies operating in Brazil, examining the challenges they face in remaining competitive in the global market. In this context, the main research question to be addressed by this work is: **"What are the challenges and opportunities faced by Brazilian automotive sector companies in the context of Industry 4.0, and how can they be overcome and leveraged?"** To dissect the issue, the **PICO (Population, Intervention, Comparison, Outcome)** strategy was employed, originally developed for systematic reviews and mappings in the health field (Santos et al., 2007). The acronym PICO represents four fundamental components of a well-structured research question: Population (P), Intervention (I), Comparison (C), and Outcome (O). By structuring research questions using the PICO protocol, researchers can ensure that all relevant information is addressed and that the systematic review or mapping is focused and efficient (Richardson et al., 1995). Although the use of PICO has been associated with clinical studies requiring correlational designs, Nishikawa-Pacher (2022) argues that this protocol can play a fundamental role in promoting methodologies for systematic reviews and mappings in any field of knowledge. For the author, by using this approach, researchers can organize and synthesize information systematically and rigorously, enabling a better understanding of the topics addressed and the identification of gaps in existing knowledge, thus contributing to the advancement of research in their respective areas. Therefore, the research question was divided into four categories, according to the PICO protocol:

**Population:** Automotive sector companies with manufacturing plants in Brazil, of varying sizes and positions in the supply chain, including OEMs, Tier III Suppliers, and Aftermarket parts suppliers.

**Intervention:** Adoption of disruptive technologies of Industry 4.0, focusing on implications for the companies, including challenges and opportunities.

**Comparison:** Manufacturing plants of automotive companies in other countries that adopt Industry 4.0 technologies, aiming to compare with Brazilian automotive sector companies.

**Outcome:** To map the challenges and opportunities faced by Brazilian automotive sector companies in adopting Industry 4.0, including implications for the global competitiveness of Brazilian companies.

Initially, a narrative review with an unstructured search was conducted to gain an initial understanding of the current state of science on the topic. This step was essential to guide the next steps.

Based on the initial analysis and aiming to answer the research question, a metadata search was conducted in the SCOPUS, BASE, and CORE databases, using structured search strings as recommended by Kitchenham and Charters (2007), including the keywords "Industry 4.0", "Automotive Industry", and "Brazil", starting temporally in 2011, the year of the introduction of the concept "Industry 4.0". Some articles were found through related keywords such as "Advanced Manufacturing" and "Automotive Industry". The preliminary search resulted in 539 articles, as shown in Table 1.

**Table 1**. Preliminary search results by database

| String | SCOPUS | Web of Science | BASE | Total (por string) |
|---|---|---|---|---|
| "Industry 4.0" AND "automotive" AND "Brazil" | 18 | 35 | 20 | 73 |
| "Industry 4.0" AND "automotive industry" AND brazil | 8 | 8 | 8 | 24 |
| "Industry 4.0" AND "auto*" AND "Brazil" | 40 | 356 | | 396 |
| "Advanced manufacturing" AND "Automotive" AND "Brazil" | 0 | 30 | 16 | 46 |
| Total (per database) | 66 | 429 | 44 | 539 |

Source: Original research data

To define the articles that would be the subject of the final study, criteria focusing on the P and I components of the PICO framework were employed. Regarding the "Population," it was established that the studied articles should focus on manufacturing plants of automotive sector companies (regardless of their position in the supply chain) in Brazil. Thus, studies that did not include automotive sector companies at least partially, or that solely involved factories outside of Brazil, were excluded from the research.

As inclusion criteria for the "Intervention," articles examining the implications of Industry 4.0 for companies were sought, with a focus on the stage of adoption of Industry 4.0 technologies, the difficulties in this adoption, and, where applicable, the identification of opportunities. Articles not addressing these implications of Industry 4.0 for companies were excluded.

Based on the inclusion criteria, various exclusion criteria were employed in the article search, including temporal (post-2011), geographical limitations (inclusion of companies operating in Brazil), lack of implications of Industry 4.0, articles with incomplete data, removal of duplicates, and unavailability for download. Initially, 539 articles were identified, but after applying the criteria, only 21 met the requirements for inclusion in the final analysis. Another 9 articles were found through non-structured searches, totaling 30 articles used in the research. These criteria were essential to ensure that the selected studies were aligned with the research objectives and with the population and intervention defined by the PICO criteria.

The 30 articles selected for the data extraction phase underwent a thorough reading of their content and were classified according to the criteria displayed in Table 2.

**Table 2**. Classification criteria applied to the chosen articles (continues)

| Classification | Meaning | Codes for Alternatives |
|---|---|---|
| 1 | I4.0 Applications | A – Automated Robots<br>B – Simulation<br>C – Horizontal and vertical integration of systems<br>D – Industrial Internet of Things (IIoT)<br>E – Cybersecurity<br>F – Cloud Computing<br>G – Additive Manufacturing<br>H – Augmented Reality<br>I – Big Data e Analytics |

**Table 2**. Classification criteria applied to the chosen articles (continued)

| Classification | Meaning | Codes for Alternatives |
|---|---|---|
| 2 | Research method | A – Quantitative<br>B – Qualitative<br>C – Conceptual<br>D – Quantitative/qualitative or qualitative/quantitative<br>E – Research<br>F – Case Study |
| 3 | Sector Analyzed | A – Automotive<br>B – More than one industrial sector |
| 4 | Size of Companies Surveyed | The big<br>B – Media<br>C – Small |
| 5 | Supply Chain Link | A – Assembler<br>B – Level I Supplier<br>C – Level II Supplier<br>D – Level III Supplier<br>E – Aftermarket Supplier |
| 6 | Adoption Stage | A – Awareness<br>B – Interest<br>C – Assessment<br>D – Experimentation<br>E – Routine |
| 7 | Challenges highlighted | A – Cost<br>B – Access to technology<br>C – Labor<br>D – Lack of knowledge on the subject<br>E – Lack of Interest<br>F – Macroeconomic Factors<br>G – Cybersecurity<br>H – Interoperability Barriers |
| 8 | Opportunities highlighted | A – Operational efficiency<br>B – Competitiveness in the global market<br>C – Informed decision making<br>D – Compliance with regulations<br>E – Inspiration for new research<br>F – Mass customization<br>G – Sustainability and environmental responsibility<br>H – Collaboration and integration between sectors |

Source: Original research data

After the classification of the articles, their bibliometric data were analyzed using the bibliographic data mapping tool VOSviewer v.1.6.17 (VOSviewer, Leiden, Netherlands). VOSViewer was chosen for analysis due to its robust capability to construct and visualize bibliometric networks, making it a reference in this type of analysis.

To ensure more precise and reliable analysis, the Thesaurus tool was employed for keyword and author analysis with different forms of name abbreviation. This measure was important to avoid information duplication, as many of the selected articles were written in English. Thus, it was ensured that similar keywords, such as "Industry 4.0" and "Indústria 4.0," were not counted more than once. The same procedure was carried out with author names to prevent differences in name abbreviation from influencing the results.

To ensure a more rigorous analysis, the attribute "total link strength" was considered. This index indicates the total strength of co-authorship relations of a specific researcher with others, providing a more comprehensive overview of influence and collaboration among authors. Author analysis was based on the criterion of presence in at least two of the selected articles to be considered in the bibliometric analysis conducted in VOSviewer. This analysis helped identify the most relevant and active authors among those present in the selected articles, assisting in understanding the trends and main themes addressed in the selected studies.

For keyword analysis, the 20 most frequent keywords in the chosen articles were selected using the keyword co-occurrence method available in VOSviewer, in terms of occurrences and "total link strength" (connection intensity). Bibliometric analysis is a powerful tool not only for quantifying scientific production and impact but also for identifying the intellectual, conceptual, and social structures of a particular area and its evolution over time. Such analysis allowed for identifying the connections between the main themes and concepts addressed in the selected studies, contributing to the understanding of the most relevant subjects for research

## III. Results And Discussion

Table 3 presents the classification of the 30 articles evaluated in this study, according to the first four criteria of Table 2. The articles are organized in alphabetical order by the last name of the primary author and classified according to the criteria "1 - Industry 4.0 Applications", "2 - Research Methodology", "3 - Analyzed Sector", and "4 - Size of the Researched Companies". This classification enables a more in-depth analysis of the studies, identifying the main applications of Industry 4.0, the most utilized research methods, the sectors most studied, and the size of the researched companies.

**Table 3**. Classification and codes of evaluated articles - Categories 1 to 4 (Continues)

| Article | I4.0 Applications | Research method | Sector Analyzed | Size of Companies Surveyed |
|---|---|---|---|---|
| Alves, et al (2021) | 1C, 1D | 2B, 2F | 3A | 4A |
| Andrade, et al (2016) | 1B, 1E, 1I | 2F | 3A | 4A |
| Brunheroto, et al (2021) | 1D | 2A, 2E | 3B | 4A, 4B, 4C |
| Cortes, et al (2020) | 1D, 1I | 2F | 3A | - |
| da Silva, et al (2021) | 1E | 2C | 3A | - |
| Dall'Agnol, et al (2022) | 1A, 1I | 2B, 2E | 3A | 4A |
| dos Santos, et al. (2019) | - | 2D, 2E | 3A | 4A, 4B |
| dos Santos, et al (2021)a | - | 2D, 2E | 3A | 4A, 4B, 4C |
| dos Santos, et al (2021)b | - | 2D, 2E | 3A | 4A, 4B, 4C |
| Frazzon, et al (2018) | 1C, 1I | 2F | 3A | 4A |
| Fucks, et al (2022) | 1C, 1G, 1I | 2B, 2E | 3B | 4B, 4C |
| Gomes, et al (2018) | 1C, 1D, 1F, 1I | 2B | 3A | - |
| Iaksch, et al (2019) | 1D, 1I | 2B, 2E | 3A | 4A |
| Justus, et al (2018) | 1D, 1I | 2B | 3A | - |
| Lima, Fábio et al (2019) | 1A, 1B, 1D, 1I | 2nd | 3A | 4A |
| Lima, Aila et al (2022) | 1D, 1I | 2B, 2F | 3A | 4A |
| Marum, et al (2022) | 1A, 1D | 2C | 3B | - |
| Mendes, et al (2017) | 1A, 1C, 1D, 1F, 1H, 1I | 2F | 3A | 4A |
| Oliani, et al (2020) | 1B, 1C, 1D, 1F, 1I | 2A, 2E | 3A | - |
| Pacchini, et al (2019) | 1D, 1F, 1G, 1H | 2C, 2F | 3A | 4A |
| Pacchini, et al (2020) | - | 2B, 2F | 3A | 4A, 4B |
| Ramos, Luiz et al (2020) | 1C, 1I | 2F | 3A | 4A |
| Ribeiro, Jorge Eduardo et al (2020) | 1D | 2F | 3A | 4A |
| Ribeiro, Priscilla et al (2020) | 1A, 1D, 1F, 1G | 2B, 2F | 3A | 4A |
| Ruggero, et al (2019) | - | 2D, 2E | 3A | 4A, 4B |
| Santos, et al (2021) | 1C, 1I | 2F | 3A | 4A |
| Takeda-Berger, et al (2022) | 1B, 1C, 1D, 1I | 2F | 3A | 4A |
| Vasconcellos, et al (2021) | 1C | 2B | 3A | 4A, 4B, 4C |
| Venâncio, et al (2022) | 1D, 1I | 2F | 3A | 4A |
| Vido, Marcos, et al (2020) | 1A | 2B, 2F | 3A | 4A |
| Source: Original survey results | | | | |
| | | | | |

Table 4 presents the classification of the 30 articles evaluated in the present study according to the criteria "5 - Supply Chain Link," "6 - Adoption Stage," "7 - Identified Challenges," and "8 - Identified Opportunities." Similar to Table 3, the articles are listed in alphabetical order by the surname of the primary author. This classification enables a clearer visualization and analysis of the results obtained in the systematic mapping study.

**Table 4**. Classification and codes of evaluated articles

| Article | Supply Chain Link | Adoption Stage | Challenges highlighted | Opportunities highlighted |
|---|---|---|---|---|
| Alves et al (2021) | 5B | 6E | 7C, 7D | 8A |
| Andrade et al (2016) | 5B | 6D | - | 8A, 8B, 8C, 8F, 8G |
| Brunheroto et al (2021) | 5A, 5B, 5C | 6C, 6D, 6E | 7H | 8A, 8C |
| Cortes et al (2020) | - | 6C | - | 8A, 8B, 8C |
| da Silva, et al (2021) | - | - | - | 8A, 8C |
| Dall'Agnol et al (2022) | 5A | 6E | 7C, 7D | 8A, 8B, 8C |
| dos Santos, et al. (2019) | 5A, 5B, 5C | 6A, 6B, 6C | 7A, 7C | - |
| dos Santos, et al (2021)a | 5A, 5B, 5C | 6A, 6B, 6D, 6E | 7A, 7C, 7F | 8A, 8B |
| dos Santos, et al (2021)b | 5A, 5B, 5C | - | 7A, 7B, 7D, 7F | 8H |
| Frazzon et al (2018) | 5B | 6D | 7C, 7D, 7G | 8A, 8E |
| Fucks et al (2022) | 5C, 5D | 6C | 7D | 8A, 8B, 8C |
| Gomes et al (2018) | - | 6C | - | 8A, 8B, 8C, 8E |
| Iaksch et al (2019) | - | - | - | 8A, 8C |
| Justus et al (2018) | - | 6D | 7D | 8A, 8C, 8E |
| Lima, Fábio et al (2019) | 5A | 6D | 7A, 7C, 7D, 7G | 8A, 8B, 8C, 8D, 8E |
| Lima, Aila et al (2022) | 5A | 6E | 7A, 7C, 7D | 8A, 8B, 8C |
| Marum et al (2022) | | - | 7C | 8A, 8B, 8F |
| Mendes et al (2017) | 5A | 6E | - | 8A, 8B, 8C |
| Oliani et al (2020) | 5C | 6C | 7A, 7B, 7C, 7D | 8B, 8C, 8G |
| Pacchini et al (2019) | 5B | 6D | - | - |
| Pacchini et al (2020) | 5A, 5B | 6D | 7A, 7B, 7C, 7D, 7G | 8B |
| Ramos, Luiz et al (2020) | 5B | 6D | 7B, 7D | 8A, 8C, 8H |
| Ribeiro, Jorge Eduardo et al (2020) | 5C | 6D | 7A, 7B, 7C, 7D, 7F | 8A, 8B, 8C, 8E, 8G |
| Ribeiro, Priscilla et al (2020) | 5A | 6E | 7A, 7G | 8A, 8B, 8C |
| Ruggero et al (2019) | 5A, 5B, 5C | 6th | 7A, 7C | 8B, 8C |
| Santos et al (2021) | 5A | 6C | 7A, 7B, 7C, 7D | 8A, 8C |
| Takeda-Berger et al (2022) | 5B | - | - | 8A, 8C |
| Vasconcellos et al (2021) | 5B, 5C, 5D | 6B | - | - |
| Venâncio et al (2022) | 5A | 6C | 7D | 8A, 8B, 8C |
| Vido, Marcos et al (2020) | 5B | 6D | - | 8A, 8B, 8C |

Source: Original survey results

Appendix A contains brief summaries of the 30 evaluated articles. These summaries provide additional information about the contributions of each study, enabling a deeper analysis of the results obtained and facilitating access to the main points addressed in each research.

The first criterion analyzed in this mapping was the applications of Industry 4.0 directly cited in the researched articles. Figure 1 highlights the importance of categories D (Industrial Internet of Things) and I (Big Data and Analytics), with 16 occurrences each, followed by horizontal and vertical system integration (C), with 10 occurrences. This result was expected since Industry 4.0 and smart factories presuppose significant connectivity between machines and systems, requiring the collection, analysis, and sharing of data in real-time, enabling process optimization and improvements in decision-making (Kagermann et al, 2013; Rüssman et al, 2015). Additionally, the next most cited categories of automated robots (A), cloud computing (F), and simulation (B), with 6, 5, and 4 occurrences, respectively, are essential for the integration and digitization of production, enabling greater operational efficiency and access to resources and data remotely and at scale (Rüssman et al, 2015).

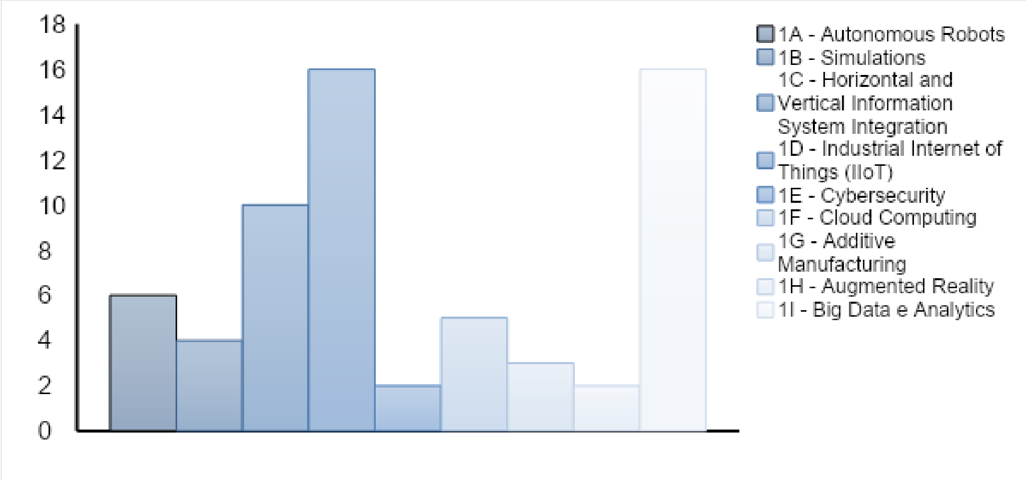


**Figure 1. Category 1 frequency distribution – I4.0 applications**
**Source: Original search results**

Some categories were scarcely mentioned, such as Cybersecurity, Additive Manufacturing, and Augmented Reality. This can be partially explained by Pacchini and colleagues (2019), who proposed a model inspired by the SAE J4000 framework to measure the readiness level of manufacturing companies for the implementation of Industry 4.0-related technologies. Furthermore, significant disparities exist in the adoption of different technologies between automakers and suppliers (dos Santos, Nilza et al, 2021b).

The analysis of the results from Category 2 – Research Methodology, as presented in Table 5, reveals a diversity of methodological approaches applied to the theme of Industry 4.0 in the automotive sector. Case studies predominate among the classified articles, with a frequency of 30%. Adding this value to the frequency of articles that blend them with quantitative and conceptual studies, case studies reach 50% of the total articles analyzed. This predominance is due to the nature of the methodology, which provides a detailed and contextualized insight into specific situations experienced within companies, aiding in the understanding of the best strategies to address the challenges faced by the organization.

## IV. Final Considerations

This study investigated the challenges and opportunities faced by Brazilian automotive companies in the context of Industry 4.0, through a Systematic Mapping (SM). The results showed that Industry 4.0 has the potential for a significant impact on the sector, both in terms of challenges and opportunities, with Industrial Internet of Things (IIoT) and Big Data and Analytics technologies being the most cited. The analysis revealed that, due to the nature of the sector itself, larger and more advanced companies in the supply chain constitute the main object of study. However, there is a research gap focused on smaller companies and those in less advanced links in the technological chain.

The main challenges identified were lack of subject knowledge, qualified workforce, and cost. To overcome these challenges, actions such as public policies and business strategies focused on education, professional training, and access to capital for productive investments are required. Additionally, innovation, intersectoral collaboration, and adoption of Industry 4.0 technologies should be encouraged.

The most cited opportunities in the studies involve improving operational efficiency, data-driven decision-making, and increasing competitiveness in the global market. These potential benefits highlight the importance of overcoming the mentioned challenges and promoting the successful adoption of disruptive Industry 4.0 technologies in the Brazilian automotive sector.

This study emphasizes the need for future research focused on Tier III Suppliers and Aftermarket parts suppliers, as well as on the development of public policies and business strategies aimed at promoting Industry 4.0 in the Brazilian automotive sector. Furthermore, it is important to consider the possibility of investigating synergies with other industrial sectors, research institutes, and universities, as well as addressing the specific challenges and opportunities faced by small and medium-sized enterprises.

This study presents some limitations that should be considered when interpreting the obtained results. Firstly, the research was based on articles published until 2022, which may have excluded more recent studies with relevant information on the topic. Secondly, the analysis focused on the SCOPUS, Web of Science, BASE, and Scielo databases, and it was not possible to access all articles of interest, as some were not freely available or accessible through CAPES Journals. Additionally, the multidisciplinary nature of the Industry 4.0 theme may have led to biases in article selection due to the use of different keywords related to the various subjects involved in this field. Moreover, this study focused on shedding light on the context experienced by companies with manufacturing plants in Brazil, based on a few studies that take into account direct comparison with the industrial context in other countries. A future analysis aiming for more elaborate comparisons with the context of other developing countries (such as China, India, Turkey, and Vietnam) and highly developed countries (such as Germany, the USA, and Japan) would certainly bring even greater clarification of the topic. These limitations can be addressed in future work to enhance and expand knowledge on the challenges and opportunities for the Brazilian automotive sector in the context of Industry 4.0 and how it compares to the same sector in other countries.

In conclusion, this study offers crucial insights for researchers, public policy makers, and industrial leaders, providing a comprehensive view of the challenges and opportunities in the Brazilian automotive sector in the context of Industry 4.0. The results obtained serve as a basis for future research and for the development of public policies and intersectoral collaboration strategies aimed at promoting Industry 4.0 in Brazil, contributing to the competitiveness of the national industry in the global scenario.

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