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Interference Conditions Facing Industry 4.0 Projects: A Managerial Perspective From Brazil

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Abstract:
Background*: This study explores the interference conditions regarding the Industry 4.0 Project in Brazil's context.*
Materials and Methods*: Based on Grounded Theory, the research process includes the perspective of managers who participated and/or are participating in the Industry 4.0 Project's planning/ implementation. Other essential agents were also investigated, such as technology suppliers, technology institutions, associations or universities.*
Results*: We found elements are comprised of external and internal conditions of the Industry 4.0 implementation process.*
Conclusion: *The adoption process of Industry 4.0 Projects occurs mainly due to external pressures and incentives. The internal aspects show critical conditions such as available skills, culture or management and production technology. It highlights the policy implications for government, managers and stakeholders.*
Key Word*: Industry 4.0 Project; Critical Conditions of Implementation; Grounded Theory.*

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I. Introduction

This study explores the interference conditions related to the development of a project for the adoption of the Industry 4.0 model from a managerial perspective in Brazil. Many aspects of implementing Industry 4.0 Projects have been explored in the literature. But, to a lesser extent, under the emerging economies, particularly in the Brazilian industrial context, whose diversity and complexity make it interesting. It highlighted studies focused on digital maturity (Frank et al., 2019; Santos & Martinho, 2019), on the relationship between Industry 4.0 and lean production (Tortorella et al., 2019; Tortorella et al., 2021; Tortorella & Fettermann, 2018), besides on the relationship between different ecosystem agents (Benitez et al., 2020; Rocha et al., 2019).

Institutions are less developed in emerging economies, resulting in less industrial and technological development, mainly limited to the absorption and development of technologies from other centres. The development of the institutional structure is relevant by creating the technological capabilities of firms. On the other hand, it is possible to verify both specific aspects of each company in the innovative process and general characteristics relating to a group of companies (Bell & Pavitt, 1993).

The implementation Industry 4.0 project is reliant on institutions' influence. Three different forms of forces induce organisations in a common sense: coercive isomorphism (pressure from regulations and policies from the government, industry, and other professional associations), mimetic isomorphism (environmental uncertainties lead to successful companies being followed and copied), and normative isomorphism (standards and cognitive structures developed by professionals and employees who are educated and trained) (DiMaggio & Powell, 1983). These aspects influence the company's top management to implement Industry 4.0 (Sony & Aithal, 2020). Implementing Industry 4.0 will create the company's physical, human, organizational, technological, financial, and reputational capital.

This research intends to contribute with a systemic and integrated view, analyzing the implementation of Industry 4.0 Project from the strategic perspective of an emerging country, particularly Brazil. Also, we seek to contribute to the following gaps identified in the literature: a) specific institutional logic or different motivations of different types of organizations when developing Industry 4.0 projects, such as companies, trade unions, suppliers, resources, consumers, regulatory agencies, universities, and governments. This analysis is considered crucial, as it has only been explored in a reduced number of works; and b) different meanings attributed to Industry 4.0 when it spreads in countries with different characteristics, as the ideas are incorporated in a context in which there are other ideas, actors, traditions, etc. (Fogaça et al., 2022).

II. Conceptual Framework

According to the PMBOK Guide (2017, p.37), "projects exist and operate in environments that can influence them." Projects are executed in broader environments than the project itself, so their management should consider the environment more broadly. These environmental influences, as described in the PMBOK (2017), can have favorable or unfavorable impacts on the project and are divided into two categories: Enterprise Environmental Factors (EEFs) and Organizational Process Assets (OPAs). EEFs originate from the external environment of the project, often extending beyond the organizations themselves. Examples of enterprise environmental factors include organizational culture, structure, governance, geographical distribution of facilities and resources, infrastructure, information technology software, employee capabilities. External enterprise environmental factors beyond the organization encompass market conditions, social and cultural influences and issues, legal constraints, governmental and industry standards, financial considerations, among others.

These aspects are particularly relevant in large-scale projects that impact not only the organization as a whole but also the economic sector in which the organization operates, as is the case with projects for the adoption of the Industry 4.0 Model. This model represents what Schumpeter (1911) defined as technical progress, which is intrinsically linked to the ability to create and disseminate innovations that fundamentally transform the economy. This concept highlights the dynamic and disruptive nature of economic development.

Neoshumpeterian approach: Focus on factors that influence technical progress

From the 1980s onwards, Schumpeter's work became a rereading object, with references to Neo-Schumpeterian theoretical constructions appearing in the literature. These scholars aimed to analyze the role of technological change in countries, industrial organizations and economic development, emphasizing the impacts generated by the techno-logical progress of different sectors and nations based on their technical capacity.

The current economists on technological change (University of Sussex) consider these technical and productive asymmetries decisive elements in industrial dynamics, high-lighting factors such as the generation and diffusion of innovations, sectoral and national impacts and structural change (Possas, 1989). Dosi's (1988) central argument consists in the possibility of verifying the sectoral innovation at different levels and that technological innovation can be related to problem-solving, which involves "discovery" and "creation" from previous experiences and formal knowledge. Due to the differences between sectors, each technological paradigm implicates a specific "technology of technological change". In other words, each paradigm consists of search modes, knowledge bases and combinations of technological knowledge forms that are very specific.

Technology involves practical and theoretical knowledge, know-how, previous experiences, methods and procedures, and machines (Dosi, 1982). On the other hand, the new technological paradigms arise from interactions among technological advances, economic and institutional factors, and the technological paths already established. Moreover, technical progress consists of the technological paradigm of continuous problem-solving, which contemplates the technological trajectory. Additionally, the technological paradigm consists of an "information package" and its patterns of solutions.

Innovative theories, such as those presented by Nelson and Winter (1982) and Dosi (1982), assess innovation as path dependent. It depends on the technological trajectory (knowledge, scientific progress, technologies, among others), besides considering market movements. These factors determine which products will be developed and which will succeed, building the economic development trajectory. Thus, superimposing the theories of technological change based on demand pull and technology push.

Innovation and change are directly related, given that innovation introduces new knowledge into the market, enhancing the development of new methods and products. Which does not depend purely on technical knowledge but also other knowledge forms. The different forms of innovation (product, process, marketing and organizational innovation) have different impacts on the market. Therefore, the innovation process also differs between productive sectors in aspects such as access to knowledge, level of technological change and institutional issues (OECD/Eurostat/European Union, 1997).

Regarding the company being the locus of innovation, it must be considered that organizations are not isolated from other economic agents. It is well-known that technological accumulation and technical change are derived from complex agents' interactions, such as suppliers, customers, and other actors in the production chain. However, the technological learning process, despite having the collaboration of the other agents, is built in the form of trajectories. Considering the company´s learning, without the possibility of learning from technological and organizational dimensions, would be very different from those on which it was specialized (Bell and Pavitt, 1993).

This argument corroborates the Dosi (1988) study, which shows that the processes of innovation search, development and adoption consist of the interaction between the incentives and capabilities generated within each company and industry and external aspects of the firm, such as the state of science in other sectors, labor supply, knowledge, competition, financial aspects, macroeconomic trends, public policies, among others.

Bell and Pavitt (1993) argue that the development of the institutional structure is relevant to forming a firm's technological capabilities. On the other hand, it is possible to verify both aspects of each company in the innovative process and aspects shared between a group of companies (such as political issues). They highlight the concepts of sectoral innovation systems and national innovation systems.

In summary, the concept of National Innovation Systems, developed by Freeman (1982) and Lundvall (1985), considers that the different economic and social agents that permeate firms influence the level of learning and the ability to innovate in the national industry (Lundvall, 2007). This includes all economic, social, political, organizational, and institutional factors, among other aspects, that influence innovation development, diffusion and use (Edquist, 2005).

The main actors of a National Innovation System are the firms which invest in R&D, use and supply the technologies; the government, which is responsible for formulating and executing science and technology policies; and institutions such as universities and research centers. These actors constitute the technological infrastructure of a country, and their integrative action structures the potential development (Dathein, 2003).

The concept of a Sectorial System is also evident, comprising interactions, information exchanges, cooperation or competition and considering that companies have a knowledge base, technologies and inputs in common and specific to their sector (Malerba, 2002). Since this, the importance of environments conducive to innovation is highlighted for development to occur; that is, a balance between the different economic agents is required (Feitosa, 2011).

The National Innovation System and the Sectorial System comprise relevant institutional dimensions in the innovation process. Institutions play a fundamental role in the generation, dissemination, and exploitation of technological knowledge and in implementing organizational and strategic changes. Such an evolutionary process results in the different trajectories and growth patterns observed worldwide. Those nations more conducive to changes relevant to new technologies and technological paradigms show more significant growth and can enter a catching-up process. However, those countries that show institutional inertia face the incompatibility of their system with the potential growth of these new technologies, making catching up unfeasible.

In short, the firm's capabilities, routines and innovations depend on a historical (path dependence) and evolutionary process (by experimentation, mistakes, and successes for the organization's survival). The evolution of routines and innovation is related to technological revolutions concerning the company's conduct. This, together with the emerging techno-economic paradigm, defines the technological evolution of a country, that is, technical progress, which can be considered the key element for development. For this, it is required to be aligned with the opportunities of the revolution, in course, to take advantage of the open window in the technological trajectory. Innovations that do not match such a paradigm will not be able to promote development. In this context, project management seems to be influenced by the ongoing or emerging paradigm.

III. Material And Methods

The present research aims to understand the interference conditions in adopting Industry 4.0, exploring the Brazilian industrial companies by applying the research structure based on Grounded Theory -GT- (Corbin & Strauss, 2015). Aligned with the fundamental aspects to determine which aspect of GT to follow (Marchi, 2014), this article con-tributes to filling in a lack of qualitative research on the subject from the perspective of an emergent country.

Data collection

We sought to apply interviews with subjects who participated and planned to implement projects with the scope of Industry 4.0 in medium and large companies (manufacturers of machines, appliances and electrical materials, and manufacturers of electrical equipment). Therefore, there were 18 interviewees, and the data collection process consisted of four phases:

(1) Cycle 1: Three professionals from a science and technology institution providing services for the development of manufacturing processes for companies with Industry 4.0 projects were interviewed.

(2) Cycle 2: The second sample group consisted of companies with Industry 4.0 implementation projects, characterising the sample group of companies (GAE). It was found that other actors contributed to the implementation of these technologies, such as consortia, sectoral associations, and universities, among others, which complemented the sample group of institutions (GAI).

(3) Cycle 3: It had 6 participants and had a more significant presence of GAI members (3 interviewees), 1 interviewee representing the suppliers and 1 interviewee representing the group of 4.0 technologies and solution providers (both considered GAF sample)) and two other participants referring to the GAE.

(4) Cycle 4: Comprised exclusively of GAE participants (2 interviewees).

It is worth mentioning that all interviews were recorded (approximately 15 hours of audio), transcribed, and later coded. We also relied on data collection from other secondary sources to search for convergences and divergences to reveal new facets of the phenomenon studied (Bandeira-De-Mello & Cunha, 2006).

Data coding and analysis

The process of data collection and analysis took place concomitantly, per GT assumptions, through open, axial coding and theoretical integration (Corbin & Strauss, 2015). The analysis process started from the first interview, directing new interviews followed by their analyses. At the same time, it was organised the analysis that directed the data collection. This circular process, over time, led to theoretical saturation, which occurred when data collection did not bring new information (Strauss & Corbin, 2008). Subsequently, the results were validated by the participants and compared with the literature. The approach adopted has three coding phases: open, axial and theoretical integration.

The model of Corbin and Strauss (2015) was applied, and the model developed by Marchi (2014) contributed to the analysis from the perspective of complex adaptive systems. These models support the analytical process in axial coding and theoretical integration, organizing the categories from an internal and external perspective and the process itself.

After having the substantive theory constituted and validated, the next step was to return to the literature, which plays a vital role in concluding the research. From the re-search perspective with GT, the literature helps integrate or contrast with the generated theory. Besides, it helps to validate, refine and encompass the scope of the theory.

IV. Results And Discussion: Conditions For The Development Of Projects For The Adoption Of Industry 4.0

The found elements are comprised of external and internal conditions of the Industry 4.0 implementation process, which are represented in the following sections.

Economic conjuncture

The category "Economic conjuncture" emerged from the data regarding some companies that highlighted the economic conjuncture as essential for the beginning of the implementation process. There is a need for a favourable economic situation for companies to invest in projects and new technologies. The political aspects, exchange rate variation, recession and economic crises culminate in more significant uncertainty regarding investments and their retraction. It is well-known that such aspects are unfavourable for the implementation of Industry 4.0 by companies; however, evidently, moments of crisis reinforce the need for change. These aspects are observed with the confrontation of the COVID-19 pandemic.

The extent to which the pandemic has destabilised the economy as a whole stands out, increasing uncertainty and hampering investments in new technologies. This strategic scenario required actions to preserve companies in the market, whether through anticipation of trends or faster adoption of new technologies and development of new solutions.

Innovation ecosystem

Analysing the external conditions of the companies, it became evident that different external agents constituted through an innovation ecosystem, intervene in the implementation process (Figure 1). The organisations interact under institutional and complex environment aspects, allowing changes and adjustments in institutions, facilitating or hindering their performance.

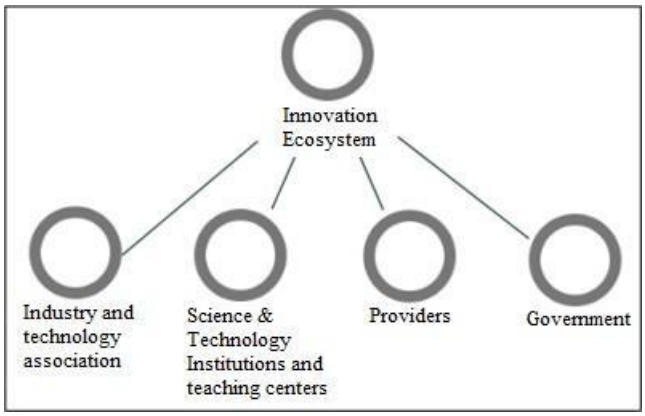

Figure 1. The main evidence of the category "Innovation ecosystem".
Source: research data.

The innovation ecosystem, designated as the set of agents involved in the process, can generate results in technological development. An environment that allows industrial companies to integrate with other agents of

the ecosystem enables them to achieve advantages and benefits in an accelerated way. In contrast, each agent individually contributes with its specific knowledge and objectives.

Industry and technology associations

Among the agents are the sectoral and technological associations, which act for the industrial sector development they comprise or even the development and adoption of specific technologies. The associations can positively impact the implementation of Industry 4.0, and it is observed that some companies usually make efforts to participate. Meanwhile, this association environment allows the company to integrate with the other agents of the ecosystem to which it refers, such as robots, sensors and device manufacturers, solution providers and educational institutions. Thus, given the diversity of agents that compose them, the association enhance value to the member companies through the exchange of information, benchmarking, training, discussions, or lectures.

Science and Technology Institutions and Teaching Centers

Science and technology institutions and teaching centres are relevant for developing Industry 4.0, being agents of innovation systems. These act in two ways: the first refers to the research activity development and promotion of new technologies, products and processes, and the second to the training of specialised labour. The TRL/MRL scale reveals the role of universities in this innovation environment as a critical barrier to the development of new technologies and management models. Most Brazilian companies are technology buyers, and the actions undertaken in R&D activities are scarce. There is a government effort to promote universities towards the development of Industry 4.0 by supporting the internationalisation of academic researchers.

The role of teaching centres and universities as trainers of specialised labour is relevant. The people´s training is parallel to the implementation of technologies; however, in many cases, technological innovations occur quickly, causing a gap in professional training.

Providers

The companies have interactions with their suppliers, which range from technology and solution suppliers to decision support service providers and innovation project implementation. Often, this interaction results in an incentive and learning process, given the sharing of the know-how that the supplier has about the products/services provided.

It is worth mentioning that the degree of interaction between company and supplier varies in each organisation. They keep in mind that some companies prefer to consult the supplier only to acquire technology. In contrast, other companies hire specialised suppliers to carry out the diagnosis of operations for the implementation of projects.

The organisation's role as a supplier is the democratisation of technology adoption. As highlighted, the technologies of Industry 4.0, to a large extent, are not new. However, it is up to suppliers to transform these technologies, apply them and generate value for companies, generating progress in the organisation and the market.

Many interviewees also highlight the role of specific suppliers in the case of startups. Companies of this nature can take new technologies into industrial companies, which are essentially more traditional, and their environment is not prone to innovation. In short, startups are technology disseminators, and other actors in the ecosystem have encouraged this startup-industry integration (the government and the federation). It is noteworthy that the contribution is not limited to startups; other technology-oriented business models are increasingly helping the transformation in the industry.

Highlighting the suppliers' holes, it has observed their efforts in prospecting opportunities and building relationships with their customers. As evidenced earlier, there is a strength to integrate suppliers and companies. However, this context is still permeated by uncertainties and conflicts of interest, given that each agent involved in implementing Industry 4.0 has different interests (the government, suppliers, teaching centres or industrial companies. Meanwhile, companies strive to filter those suppliers and technologies that will add value.

Government

There is a clear perception of the governmental sphere's importance in the phenomenon in those companies where the relationship was maintained. At the same time, the proposition is that the implementation of the new industrial model is not restricted only to the organisation’s internal and operational activities but also to the performance of the agents of the so-called innovation ecosystem. Therefore, it was possible to gather evidence about the indirect interaction of the government with companies, as shown in Figure 2.

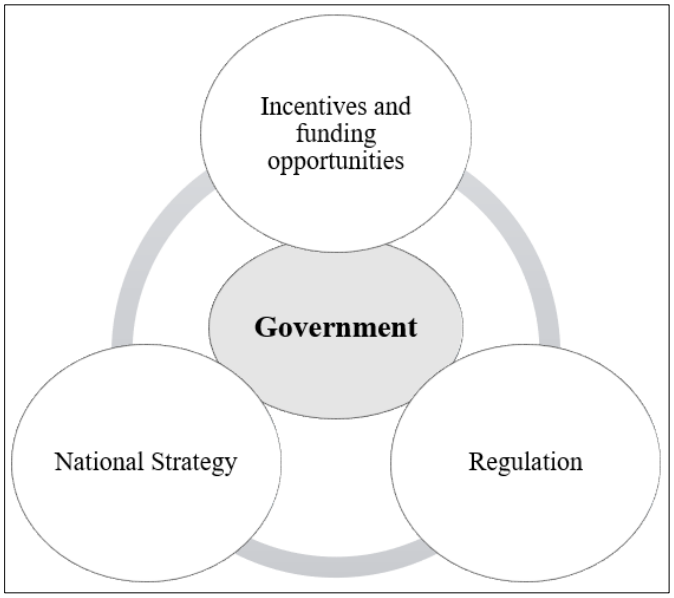

Figure 2. Interactions between government and companies for the implementation of Industry 4.0. Source: research data.

The government's indirect action towards implementing Industry 4.0 in companies consists of three main perspectives: incentives and financing opportunities, regulation, and national strategy. Regarding investment incentives and opportunities, it is evident that the availability of resources for financing and incentives are crucial points that encourage the development of new projects with this scope.

Given the recognition of the resources and incentives availability relevance, there is still a limitation on these aspects. There is a need for more robust incentives to promote innovation for companies to invest in research and development. Furthermore, it was possible to verify initiatives in this sense, such as tax waiver plans and 4.0 financing lines, in addition to ST&I calls aimed at filling technological gaps, which includes the use of public resources in support of research, development and innovation. Other aspects that interfere with access to financial resources made available by the State are bureaucratic obstacles and delays that permeate the financing of innovation projects.

The impacts that obstacles in terms of funding notices provoke a concern with the delay and the loss of the "market window". Besides, it appears that there is a lack of attractiveness of these financing opportunities due to this delay—the extent to which a company can choose to operate in another, more attractive country.

The financing lines are still very much based on traditional models of credit supply. In this regard, there are credit lines in the market aimed at Industry 4.0 due to efforts by Finep[1] and BNDES[2]. Thus, it is observed that there is a maturing of these institutions in favour of the use of credit lines suitable for Industry 4.0. It is also worth noting that this movement took place because of the integration between the association and the financial institution.

Another aspect observed in terms of government action is regulation. The interviewees pointed out that specific projects and the implementation of technologies may be due to legislation or even taxation and legal certainty in the country's influence in the implementation of 4.0 technologies by companies.

There is a conception that technologies such as 5G, collaborative robots and autonomous robots lack regulatory frameworks for their implementation. There are situations in which the norm that regulates the use of technologies has not matured at the speed with which the technology was developed and introduced in the market. On the other hand, it was up to the organisation itself to develop and support the use of this for later requests with the competent bodies of measures.

Another incumbent on the government is the development of a National Strategy. It is possible to verify a demand for a strategic plan for Industry 4.0 in the country. There are different initiatives and studies in the scope of Industry 4.0, in addition to more local actions focused on specific sectors, while a broader vision for the country as a whole is lacking. This National Strategy would facilitate and synchronise the performance of different economic agents to implement industrial modernisation in the country.

[1] Financiadora de Estudos e Projetos (FINEP) is a Brazilian public company that promotes science, technology and innovation in companies, universities, technological institutes and other public or private institutions.

[2] Banco Nacional de Desenvolvimento Econômico e Social (BNDES) is a federal public company whose main objective is long-term financing and investment in all segments of the Brazilian economy.

Age of Complexity

The "Age of Complexity" category emerged from the data, understanding that the company needs to constantly pay attention to market movements and the external environment, which directly impact the demand for its products, as well as future demands.

Competitive Environment

The competitive environment is shown as one of the main factors which requires the condition of investments in new technologies. Managers recognise that there is a movement in search of the survival of companies due to market competitiveness.

Competitiveness is not limited to local aspects, as economies are increasingly globalised; thus, it is observed that the stagnation of the company in technological terms is seen as a condition that results in the difficulty of access to specific markets and chains that are broader and more profitable.

Large companies face pressures, and they are more sensitive to global market trends due to the market in which they operate. On the other hand, the market directs companies towards the implementation of Industry 4.0, which, ultimately, will create conditions for access to specific markets. This force has infiltrated small and medium-sized companies through the production chain. Still, it is also clear that the competitive environment has affected the labour market, which has become global.

Constant Changes

The subcategory "constant changes" emerged from the research data and has revealed the importance of constantly environment understanding. This inconsistency over time significantly affects how the company's actions and strategic path are decided, that is, how business actions are planned, especially regarding the time horizon in which it is planned. Over time, companies have enjoyed moments of stagnation, but sudden changes demand companies' ability to adapt. It should be noted that these changes are seen as inevitable in the current context.

As observed, disruptive events are part of the trajectory of companies and must be recognised as part of the process. In this way, some companies can affect the behaviour of the market in the face of their decisions, that is, be disruptive or try to adapt to the imposed changes. Alternatively, even not making efforts in this direction, risking not surviving in the market development.

Technological development

The category is divided into three subcategories, namely: topic discussion, adoption maturity and benchmarking with previous experiences.

Topic Discussion: the "topic discussion" has different circumstances and contributions because there is an effort from different institutions, suppliers, and federations, among others, to disseminate the concept of Industry 4.0 and to make it known in the Brazilian context. In times of a pandemic, there was an intensification of those actions that were already taking place, however, under a more local scope. Promoting online events, workshops, and lectures strengthened the dissemination and democratisation of such new opportunities. Actions aimed at discussing the topic provide a connection between industrial companies and other agents, in addition to expanding opportunities for the adoption and implementation of these technologies. Being aware of novelties and solutions available in the market or even in the development phase, the discussion of the topic in the ecosystem opens up the frontiers of organisations to technologies.

Adoption Maturity: The subcategory "Adoption maturity" emerged from the data, showing how the degree and maturity with which technologies were used in the general environment influenced their internalisation. Thus, the primary evidence identified consists of the adoption of technologies in the country, the adoption of technologies in the sector in which it operates and the maturity of the technologies, as shown in Figure 3.

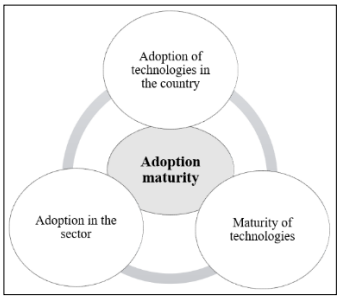

Figure 3. Dimensions of the subcategory "adoption maturity".
Source: research data.

Regarding the maturity of the adoption of technologies in the country, there is the conception that the country is outdated, such as using robots in the industry. However, numerous variables influence these aspects, such as the size and sector of companies in general. However, different agents have moved to mitigate this delay in technology adoption observed in Brazil through incentives for companies to adopt new technologies.

More specifically, the stage of technology adoption in the sector constitutes a significant stimulus in the adoption and monitoring of these innovations. Besides, when envisioning environmental adoption, industrial companies can identify sources of information and knowledge, perform benchmarking and use these technologies in their context. This process, as a whole, provides opportunities for the maturation of companies, suppliers, technologies, and the use of technologies by the country as a result of the efforts of different agents, voluntarily or involuntarily.

The level of technology adoption comes up against the "technology maturity" aspect, based on the argument that different technologies are available on the market that is not yet mature enough for a large-scale implementation in manufacturing. Given the awareness about the maturity of the technology, the TRL scale is commonly used to measure the level of maturity of the technologies with which one is working. It is possible to map the actions necessary for a given technology to reach maturity. The process consists of developing theoretical models, laboratory tests, and pilot and final scale to the market. Therefore, many technology adoption projects within industrial companies follow this scalar evaluation, with greater prominence in developing pilot tests within the plants. Later, the scale adoption or expansion of a particular technology is expected.

Benchmarking with previous experiences: Benchmarking actions, with previous experiences in implementing projects and 4.0 technologies, bring new knowledge to companies prior to the implementation process. From a broad perspective, the use of the tool is not limited to industrial companies. The providers of solutions and technologies also exercise the search for best practices. The core consists of acquiring knowledge about the process, aspects that permeate adopting the solution or technology, or even how that company solves specific problems. It is possible to recognise the environmental establishment of cooperation between organisations, even if temporary. In addition, benchmarking can also occur within the organisation, with no geographical limitations, while multinational companies rely on the experiences of other plants. There is a need for systematisation, or a movement in favour of facilitating this exchange, which ends up taking place mainly through contact with other professionals and participation in events and fairs. The search for previous experiences is highlighted as significant for developing projects since analysing best practices and the mistakes and successes of processes already experienced increase the chance of success of new implementations. This facilitates the implementation and makes the incorporation of technologies into the reality of companies faster.

Culture and people

The development of innovation projects can collide with the company's culture, requiring the alignment between the culture and the strategic decisions taken. Individuals are strategic resources in the project development, and without their participation, there will not be sufficient conditions for change.

Cultural changes may be necessary, but they involve the collective and do not occur "overnight". Among the trends observed with the implementation of Industry 4.0, there is networking, in which there is the involvement and integration of different individuals to achieve specific goals despite the cultural diversity and new ways of sharing information.

There is still a fear on the part of people in adopting technologies and the changes generated from them. Resistance to change, although natural and expected, negatively affects the development of new projects and even an implementation already underway. There are efforts of companies to ensure that people are aware of the circumstances that the implementation process involves, in addition to being open to these changes.

Availability of financial resources

The category "Availability of financial resources" emerged from the need for financial resources to move forward with Industry 4.0 projects. The availability of the budget, whether directed to investments in innovation or not, constitutes a favourable point for the project's development, approval and implementation. It is worth mentioning that in addition to the availability of capital, projects are commonly evaluated from the point of view of feasibility and return.

The unavailability and lack of budget/capital for investment are limiting factors in implementing Industry 4.0 technologies. Investments of this nature are expensive and usually only earn a return in the long term, and such aspects make it even more challenging to approve projects of this nature compared to other possibilities for investments in the company. It is conjectured about the relationship between the company size and its resource availability, given the financial solidity of larger companies. Given the scarcity of resources in smaller companies, the lack of funding sources for these projects is evident.

It is noteworthy that the internal constraints are not dissociated from the external ones. This aspect is evident in the "availability of financial resources" category, given that it also depends on variables in the external context, such as the economic situation and public policies aimed at financing these strategic decisions.

Senior Management (managers and executives)

The "Senior Management" category reflects the understanding that the organisation's executives' and managers' behaviour and attitudes about industry 4.0 projects can reflect both the decision to adopt and the implementation success. So, managers and executives need to be aware of the need for change and, from there, stimulate, believe, and map implementation opportunities. This support provided by the organisation's top management drives the program's success.

The understanding of managers and executives around the need for change, in the sense of developing industry 4.0 projects, starts from their understanding of the concepts and possibilities derived from their adoption. Hence, there is a need for knowledge and information to reach the top of the organisation. An aspect that occurs in different ways is the search by the executives themselves, encouragement from other employees, or from other agents who exchange information with the organisation.

In many organisations studied it was observed that decisions are made and cascaded from the strategic level, confirming that top management plays an important role in implementing Industry 4.0 initiatives. However, it is not limited to this, as there is an opportunity for employees at other organisational levels to provide suggestions for Industry 4.0, thereby raising awareness among top management.

Pre-existing technologies in the company

We can see the importance of the technological package that the company already has. Companies that are more mature in adopting technologies and management models find it easier to apply new technologies. It is worth mentioning that the maturity aspect is not limited to technological aspects within the company; however, in this category, the emphasis is on the company's technological package. The other dimensions, such as people or innovation, are incorporated in the other categories of this model that correspond to the internal conditions.

When more companies are technologically outdated, the implementation of Industry 4.0, or even automation, is a great challenge, unlike companies that already have a more advanced technological base. It is noteworthy that many of the 4.0 technologies depend on prerequisites for their implementation; therefore, companies need to comply with this logical sequence in the development of new projects, first implementing the technologies that will support the others.

Besides, the development of processes within the organisation, in the sense of being leaner and more efficient, constitutes an opportunity for the implementation to become more effective. The pre-existing technologies in the organisation determine the actions taken in favour of the industry. In this way, the maturity stage of the company is commonly measured and analysed (by suppliers, institutions, or even by the company itself) to propose suggestions for project development and technology adoption.

Propensity to Identify Innovation Opportunities

Within the organization's internal environment, the category "propensity to identify innovation opportunities" is characterised by acting directly in the project's development of this nature. Notably, industrial companies tend to be conservative regarding change, including technological innovation or innovation in management models and processes. This aspect is due to the nature of the business and the aversion to risk. In order to break with this paradigm, other organisations and/or agents can influence the identification of opportunities and innovation.

It is required that the organisations are "open to innovation", wanting to break the current situation, being anxious to change things and identify implementation opportunities. Industrial companies are already looking for professionals with these soft skills. Notably, as they work more directly with the manufacturing process, identifying opportunities focuses on the employees and managers of the production areas. However, it should not be limited to these, given that innovation can occur in all departments and processes of the organisation.

Furthermore, the company can make an effort in this direction to create favourable environments and encourage and support the development of these soft skills. The role of the leader in mobilising and directing individuals is listed. Some companies perceive these attitudes in teams that work directly with R&D, and these employees are responsible for identifying opportunities for innovation. On the other hand, developing a responsible area also encourages this behaviour within the organisation.

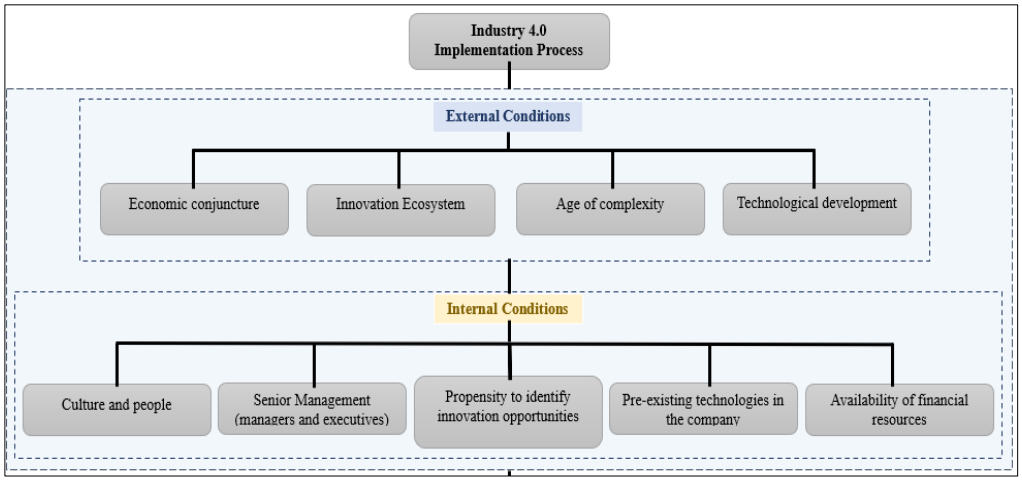

Figure 4. Conditions for implementing Industry 4.0: An emergent country perspective. Source: research data.

Figure 4 summarises the external and internal conditions of the Industry 4.0 implementation projects in industrial companies in Brazil, researched categories previously discussed.

Revisiting the literature

Following the methodological process of Grounded Theory already outlined, this section aims to list approximations with the technical literature. The PMBOK Project Guide (2017) already points out that there can be impacts on project development from internal and external factors, (EEFs and OPAs), which appear in the conditioning factors identified in the conducted research. However, to better explain the constructed substantive theory, we sought to confront it with the Schumpeterian and Neo-Schumpeterian Theories, given the magnitude of Industry 4.0 projects. Besides, other references were also sought that could give greater consistency to the categories presented in the analytical model.

Table 1. Comparison between the categories of substantive theory with the literature. Source: research data.

Analytical model	Category	Approximations
External Conditions	Economic conjuncture	Nelson and Winter (1982); Pavelková *et al.* (2018); Švarcová *et al.* (2019)
	Innovation Ecosystem	Lundvall (1992); Malerba (1992); Nelson (1993); Albuquerque (1996); Coriat and Dosi (2002); Edquist (2005); Benitez, Ayala and Frank (2020); Ghadge *et al.* (2020); Mosconi and D'Ingiullo (2023); Malherbe (2022); Singh *et al.* (2023).
	Age of complexity	Schumpeter (1911, 1939, 1982); Nelson and Winter (1982); Possas (1989); Malerba (1992); Basáñez (2020); Hoyer, Gunawan and Reaiche (2020)
	Technological development	Schumpeter (1911); Dosi (1982); Silverberg, Dosi and Orsenigo (1988); Possas (1989); Malerba (1992); Breschi, Malerba and Orsenigo (2000); Pereira and Dathein (2012); Pasinato and Campana (2020)
Internal Conditions	Culture and people	Nelson and Winter (1982); Bell and Pavitt (1993); Pawłyszyn *et al.* (2020); Tortorella *et al.* (2021)
	Senior Management (managers and executives)	Schumpeter (1939; 1982); Bianco (2020); Pawłyszyn *et al.* (2020)
	Propensity to identify innovation opportunities	Schumpeter (1939, 1982); Malerba, (1992); Teece (2007); Lin, Sheng and Jeng Wang (2020); Kruger and Steyn (2021);
	Pre-existing technologies in the company	Cimoli and Dosi (1992); Breschi, Malerba and Orsenigo (2000); Agostini and Filippini (2019); Hoyer, Gunawan and Reaiche (2020)
	Availability of financial resources	Schumpeter (1939, 1982); O'Sullivan (2007); Ghadge *et al.* (2020); Hoyer, Gunawan and Reaiche (2020); Yuan *et al.* (2021); He *et al.* (2021)

Immersion in Schumpeterian and Neo-Schumpeterian Theory

Among the common elements between the generated theory and Schumpeter's assumptions, it is observed that even if the author assumes the endogeneity of economic changes, he does not disregard external factors that influence economic fluctuations, such as climate change, interest rates, rates, government policies, or demographic changes. At the same time, the internal factors are represented by changes in tastes, production methods, volume of supply of products and productive factors (Calazans, 1992; Schumpeter, 1939). However, in the theory proposed, it is observed that external aspects of the firm, such as the economic situation, political aspects, exchange rate and interest rates, constitute critical external aspects that condition the process of implementing Industry 4.0. Specifically, the current economic context has imposed challenges and opportunities for innovation.

Furthermore, approximations are observed with works focused on the role of the capitalist and the entrepreneur in the innovation process (Schumpeter, 1911, 1939), relying on the importance of capital and the financial system (Schumpeter, 1939, 1982). The neo-Schumpeterian authors show that technical progress is the result of institutional factors. From the evolutionary point of view, the authors suggest the analysis of organisational routines, given their specificities and the heterogeneity observed in their evolution (Dosi & Malerba, 1996). As highlighted by Nelson (2006), the understanding of processes, rules and standards resides in organisational learning. These processes are individual and specific to firms, resulting in great diversity in the innovation process. The neo-Schmpeterian authors evidence the identification of the nature of routines (how they generate, use, absorb, develop and transfer technologies), which are followed by organisations and are composed of their knowledge and skills.

Innovations are determined by the learning process in the firm's internal and interactive environments. Like Coriat and Dosi (2002), the authors show that learning results from internal relationships (such as research and innovation activity) and external relationships to the organisation (and the ability of the organisation to absorb a model or knowledge that was not generated by it) (Coriat & Dosi, 2002; Malerba, 1992). Hodgson (1999) emphasises that knowledge, whether tacit or codified, depends on the individual's ability, as well as on his/her interaction with others. Organisational learning is a collective phenomenon, and it becomes necessary to create a favourable environment for innovation (Dosi & Malerba, 1996). Furthermore, the importance of the SNI for the interactive trajectory of firms stands out.

Other empirical evidence

As evidenced earlier, Industry 4.0, as a research topic, has been extensively explored in the literature in recent years. This section presents the comparison of the generated substantive theory with such literature. Some comprehensive studies that relate to the categories that emerged in this work stand out, such as the works by Ghadge et al. (2020) and Hoyer et al. (2020), who identify different aspects, such as developing specific know-how for Industry 4.0 as well as more specific studies, such as the study by Černe et al. (2023) who evaluated the impact of investments in industry 4.0 technologies, investments in people and organisational performance.

As evidenced by the studies with approximations in several aspects of the substantive theory developed, it is highlighted that several studies approach in a specific way with each generated category. The model developed in this work proposes to expand the understanding of industry 4.0 implementation by integrating the research aspects already addressed in the literature and clarifying the elements that appear in the investigated phenomenon. Finally, the study emphasises that this phenomenon analysed - the implementation of Industry 4.0 in an emergent country - is a complex and non-linear process which occurs within organisations under different influences, which is capable of generating results and influencing the organisational operation systems.

Specificities of the Brazilian Context

In this section, we seek to highlight the specificities of the country's emerging context given the implementation of Industry 4.0. Thus, Table II shows the main aspects observed.

Table 2. Specificities of the Brazilian context. Source: research data.

Industry 4.0: Implementation Process			
External Conditions			
Economic Conjuncture	Innovation Ecosystem	Age of Complexity	Technological Development

Economic recession as a limiting factor Uncertainty in the market Exchange variation disfavoring imports Cost of capital Political aspects Pandemic as a propellant	Integration of agents as a facilitator Development of key technologies within associations Technology buying companies R&D and training carried out within Science and Technology institutions and Teaching Centers Technical training fails to meet market needs. Sharing know-how Deficiency in terms of public funding, regulation and national strategic direction Bureaucracy and slowness in government initiatives	Fierce competition (global, national and regional) Multinational and/or large companies are more exposed to external competition Constant changes in the market Time horizon for action planning Market orientation	Efforts to disseminate the theme Maturity of technologies available on the market Degree of adoption of specific technologies from I4.0 Level of adoption of production technologies in the country Benchmarking with previous experiences Search for best practices	
Internal Conditions				
Culture and people	Senior Management (managers and executives)	Propensity to identify innovation opportunities	Pre-existing technologies in the company	Availability of financial resources
Impacts on the human relationship Alignment between the company's culture and decisions Fear of people adopting technologies (resistance to change)	Need for top management commitment Providing support to drive change	Different levels of openness to change and innovation Conservativeness Startups as innovation enablers Search for professionals with these skills	Technological maturity of the company Presence of technological lag	Budget to invest in technologies Use of own capital Expensive investments with a long-term return

In sum, specificities are observed in different aspects, such as sensitivity to the country's economic and political situation, uncertainty, the high cost of capital, low levels of adoption of technologies, resistance to change, conservatism, or lack of qualified professionals.

V. Conclusion

The present study aimed to understand the conditions that interfere with Industry 4.0 adoptions in an emerging country, in particular, exploring the Brazilian industrial companies. Based on ground theory as a research strategy, interviews were conducted with individuals participating in the project's development aimed at industry 4.0 in medium and large companies, machine manufacturers, electrical appliances and materials, and machinery and equipment manufacturers. The research data came from interviews and contextual secondary data structured on three sample groups: suppliers, companies and institutions (such as universities and associations).

The research described the mechanisms and elements that drive the implementation of the company's new industrial model. It was found that this process is primarily driven by external pressures and incentives such as competition, changes in demand, competitiveness, the economic scenario, and engagement with other agents. As well as internal factors such as the behaviour of managers and employees, available skills, culture, technology, and capital. Additionally, implementing this process is gradual, seen as a "journey" towards Industry 4.0.

The study also sheds light on factors that influence the phenomenon, emphasising the interaction with external agents and the internal aspects that contribute to the establishment and development of the concept within the company. Moreover, the research provides insights into the implementation of this model in emerging countries, in particular Brazil, where it is evident that the economic situation, capital availability, competition, constant changes, and the institutional environment pose significant challenges. The findings align with different perspectives from technical literature, particularly the Schumpeterian and neo-Schumpeterian theories.

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