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STARTUPS 4.0 INNOVATION ECOSYSTEM

From Ideation to Traction: Heading Towards Industry 4.0

Critical Success Factors

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GOPED

GRUPO DE OPERAÇÕES, PRODUTOS E ESTRATÉGIAS DIGITAIS

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PROGRAMA DE PÓS GRADUAÇÃO EM ENGENHARIA DE PRODUÇÃO E SISTEMAS

RESEARCH GROUP

The Group on Operations, Products and Digital Strategies (GOPED), is a research group within the Industrial and Systems Engineering Graduate Program (PPGEPS) at the Pontifical Catholic University of Paraná (PUCPR). The group consists of professors and researchers who engage in applied research related to **digital transformation** and **Industry 4.0**, with a focus on developing digital products, services, and strategies. GOPED combines concepts from Industrial Engineering with multivariate analysis techniques to understand and solve organizational problems.

The group promotes digital transformation initiatives, assisting companies in **product development management, innovation management, operations strategy, and technology management**, with a focus on innovation ecosystems, platforms, and supply chain.

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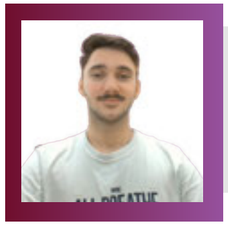

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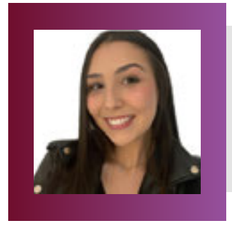

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SUMMARY

1.

IDENTITY, PARTNERS, AND CONTEXTUALIZATION

1.

IDENTITY, PARTNERS AND CONTEXTUALIZATION

The Brazil-Germany Chamber of São Paulo (AHK São Paulo) has been the official representative of the German economy in Brazil for 105 years. It serves as a cornerstone for strengthening and diversifying the businesses of its members, attracting investment to Brazil, expanding bilateral trade and cooperation between both countries.

SPInE (Space of Polytechnic Innovation and Entrepreneurship) is the innovation and entrepreneurship nucleus of the Escola Politécnica da PUCPR. It seeks to encourage and support the development of the entrepreneurial mindset between the computer science and engineering students.

HOTMILK, one of the largest innovation ecosystems in the country. It combines state-of-the-art research with solutions for market demands and operates on 4 main fronts, providing consultancy and connecting large companies and national startups for the development of innovation, and, in addition, provides training for people to generate ideas and solutions. HOTMILK benefits from the educational excellence of PUCPR, ranked as the 4th best private university in Brazil by Times Higher Education in 2023

The Industrial and Systems Engineering Graduate Program (PPGEPS) provides training at master's and doctoral levels for its students. The program focuses on production systems, considering technological, managerial and logistical aspects in an integrated manner, with the objective of increasing the effectiveness of production systems.

2.

INDUSTRY 4.0 AND STARTUPS

2.

INDUSTRY 4.0 AND STARTUPS

Industry 4.0 is one of the topics that has generated the most interest in the market and society in recent years. It is a concept that encompasses the **integration of digital technologies** that, when combined, enable the development of intelligence in production, as well as in products and services offered. Industry 4.0 is a concept that refers to recent technological innovations **aimed at optimizing production and industrial processes, and maximizing the profits of organizations**. It is based on the principle that by connecting machines, systems, and people, intelligent networks are created throughout the production chain.

Within this scenario, companies that can develop and adopt these solutions through Industry 4.0 technologies will have a competitive advantage in the market. Therefore, organizations such as startups can be drivers of Industry 4.0, as they typically offer solutions through the integration of Information and Communication Technologies (ICTs). In the current context, startups are organizations that focus on developing technological solutions related to market trends using foundational technologies of Industry 4.0 such as **Artificial Intelligence, the Internet of Things, Big Data, Cloud Computing, and Blockchain**, as well as emerging technologies like **Virtual and Augmented Reality and 3D printing**, and automation technologies such as **robotics and sensing**.

Despite startups presenting a high-risk business due to uncertainty, the benefits that can be achieved through their solutions will be substantial, as these organizations have the ability to develop integrated solutions using Industry 4.0 technologies. Thus, with the expansion and urgency of using these new technologies, a vast array of new business opportunities opens up for startups that have the desire and agility to address Industry 4.0-related demands. Therefore, **collaborating with startups, which are organizations capable of assisting in the Industry 4.0 roadmap to develop integrated solutions, can be a driver to promote the technological and economic development of a country.**

3.

INNOVATION ECOSYSTEM AND STARTUPS 4.0 EVOLUTIONARY LIFECYCLE

3.

INNOVATION ECOSYSTEM AND STARTUPS 4.0 EVOLUTIONARY CYCLE

Innovation ecosystems are composed of a network of actors that facilitate the creation and dissemination of concepts and technologies. Within these ecosystems, there are actors such as universities, research centers, and startups that encourage technological changes and are also responsible for the ideation, development, maturation, and integration of new technologies into the industry and the market.

It is essential for Industry 4.0 to integrate cutting-edge digital technologies into supply chains and industrial processes. The adoption and dissemination of Industry 4.0 technologies are made possible through networks that connect stakeholders interested in investing resources and knowledge in experimentation and learning. Organizations that make up these innovation ecosystems operate with an Open Innovation methodology, in which market competition goes hand in hand with inter-enterprise collaboration, aiming to expand the use of new methods and technologies developments.

Startups 4.0 operate in a similar manner. The difference between these actors and the others is that their organizational characteristics make it easier to create new technological solutions, given the minimal bureaucracy, low operating costs, and a strong desire for scalability that serve as significant drivers of innovation. As startups are innovative companies in a context of uncertainty, is is necesary good planning and a long-term vision to overcome all challenges. They are like living organisms, with stages ranging from conception to maturity and "death", with the difference that they are designed to grow rapidly. Regardless of the path taken, it consists of observable and predictable stages. In the business and academic context, four maturity stages are recognized for startups: Ideation, MVP (Minimum Viable Product), Traction, and Consolidation.

STARTUPS FOUR STAGES OF MATURITY

IDEATION

From the moment one decides to start a business, the first stage begins. Planning is the initial part of a startup's life and should not be overlooked. This is the time to question why you are getting involved in this segment, what market niche to explore, and how the solution offered is innovative. In other words, this stage corresponds to the moment when the startup develops its business idea and the solution to be developed.

MVP

In this stage, the entrepreneur conducts tests to understand and validate the business idea - the so-called MVP (Minimum Viable Product). It occurs when a product or service is launched with the minimum possible investment to avoid significant losses in case of failures. Essentially, it's the stage in which startups aim to develop their product/solution and gain market presence through testing with potential customers.

TRACTION

In the traction stage, the startup already has a defined business model and solution. This phase corresponds to the moment that involves exploring the market for new partnerships and connections. The goal at this stage is for the startup to leverage its sales and grow within its target market.

CONSOLIDATION

The fourth stage is the phase where the startup aims to achieve a solid business structure, efficient management, and market consolidation through increased sales and gaining market share. At this stage, the startup is fully matured and has a stable and sustainable business within the market.

4.

PURPOSE OF THE STUDY

4.

PURPOSE OF THE STUDY

This study is an initiative of the **Group on Operations, Products, and Digital Strategies (GOPED)** within the Industrial and Systems Engineering Graduate Program at the Pontifical Catholic University of Paraná, in partnership with the **Hotmilk Innovation Ecosystem, the SPInE innovation and entrepreneurship hub, and the Brazil-Germany Chamber of Commerce in São Paulo**, as part of entrepreneurship initiatives and support for startup activities related to the 4th Industrial Revolution. Through this study, GOPED and its partners aim to contribute to the understanding and improvement of the startup landscape in the context of Industry 4.0 in the country, promoting competitiveness, innovation, and sustainability.

THE OBJECTIVE OF THIS RESEARCH IS TO ANALYZE HOW STARTUPS WORKING WITH INDUSTRY 4.0 TECHNOLOGIES AND SOLUTIONS DEVELOP THEIR BUSINESS WITHIN THE INNOVATION ECOSYSTEM BY IDENTIFYING CRITICAL SUCCESS FACTORS, AS WELL AS THE ACTIVITIES AND COMPETENCIES NECESSARY FOR THEIR ENTRY INTO THE MARKET.

To achieve this objective, the methods used for data collection included **27 semi-structured interviews with various stakeholders in the ecosystem** (e.g., government, academia, industry, investors, customers, suppliers, etc.), **follow-ups on projects** within the ecosystem, and a **survey that garnered 120 complete responses from startups 4.0**. The results allowed an understanding of the key activities that startups 4.0 need to develop to enter the market successfully. Based on these findings, recommendations were provided to help startups 4.0 evolve their business within different stages of the evolutionary lifecycle (i.e., Ideation, MVP, and Traction) to develop their business and remain competitive within the country and in the context of Industry 4.0.

5.

METHODOLOGY

5.

METHODOLOGY

To develop the report, the work methodology was organized into two macro-phases divided into: the data collection phase and the data analysis phase. The flowchart in Figure 1 details these two macro-phases and their respective methodological steps. Regarding the data collection phase, three sources were used and correspond to the period during which the research was conducted. For this, the research had the support of the Hotmilk Innovation Ecosystem, the SPInE innovation and entrepreneurship hub at the School of Engineering, and the Brazil-Germany Chamber of Commerce (AHK) in São Paulo, which assisted in data collection.

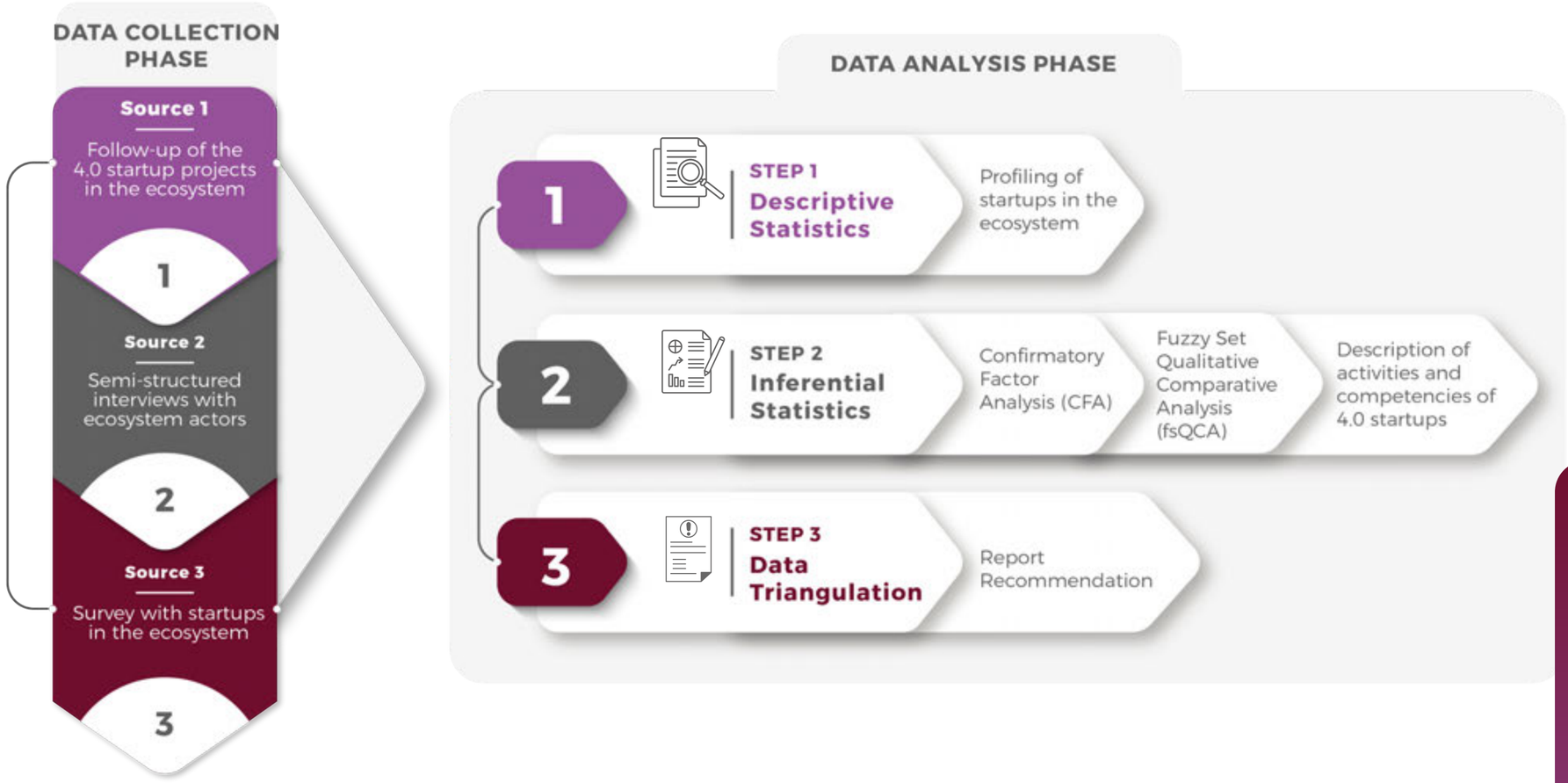


Figure 1 - Details the two macro phases and their respective methodological steps.

5.

METHODOLOGY

Below, the different search sources are explained and justified:

SOURCE 1

Follow-up of the ecosystem's 4.0 startup projects.

To understand the behavior of 4.0 startups from their ideation phase to their first sale in the market, we conducted a tracking of various projects within the ecosystem over a span of 4 years. The objective was to comprehend the activities undertaken by startups during the development of their business, as well as the reasons behind the success or failure of their business growth and scalability.

SOURCE 2

Semi-structured interviews with ecosystem actors.

This source consisted of interviews with **27 stakeholders**[1] in the ecosystem to understand how activities and synergy with other actors for knowledge acquisition took place. This step aided in the understanding of how different actors collaborate with 4.0 startups to help them develop their business within the ecosystem.

SOURCE 3

Survey with ecosystem startups.

Finally, a survey was conducted with **120 startups 4.0** from the ecosystem to gather data for the descriptive and inferential analysis phase of the ecosystem. Seven-point Likert scale questions related to the profile of startups in the ecosystem and the level of development of their practices, activities, and competencies for business leverage were administered.

[1] **Appendix** - Actors interviewed within the ecosystem can be found at the end of the report in "Appendix".

5.

METHODOLOGY

Here, the different steps of data analysis are explained and justified:

STEP 1
Descriptive statistics

This step involves the analysis of the startup profiles based on the data collected from the three sources of the methodology in the report. Through this data, the characteristics of the ecosystem and how Industry 4.0 startups operate in the market were identified and assessed.

STEP 2*
Inferential statistics

This step involved a more in-depth analysis of the data collected from the survey research (Source 3), which was divided into three steps for data analysis: (i) Confirmatory Factor Analysis (CFA); (ii) Fuzzy Set Qualitative Comparative Analysis (fsQCA); and (iii) Descriptive analysis of the activities and competencies of Industry 4.0 startups.

STEP 3
Data triangulation

The final step of the methodology involves the analysis of the overall compilation of collected data to propose recommendations for how Industry 4.0 startups and ecosystem stakeholders can benefit from the activities and competencies developed within the ecosystem.

5.

METHODOLOGY

STAGE 2*
Inferential statistics

*

(i) CFA (Confirmatory Factor Analysis): **Confirmatory Factor Analysis** is a statistical technique used to group questions related to critical success factors that Industry 4.0 startups need to develop their business. This technique allows for the categorization of questions by category and topic. Using this technique, it was possible to group related questions and identify **13 potential critical success factors** for Industry 4.0 startups: **(1) Resources; (2) Ability to identify and interpret changes; (3) Ability to seize opportunities; (4) Capacity for change; (5) Collaboration with partners; (6) Resilience; (7) Self-efficacy; (8) Mentoring; (9) Exploration of external knowledge; (10) Exploration of internal knowledge; (11) Private investments; (12) Government incentives; and (13) University incentives.** Additionally, potential factors such as **(14) Time of existence** and **(15) Headcount in s in startups tartups** were also included.

(ii) fsQCA (Fuzzy Set Qualitative Comparative Analysis): **Fuzzy Set Qualitative Comparative Analysis** was used to understand which configurations of these factors, when present, can help Industry 4.0 startups reach the market. This technique allowed for the identification of configurations with critical success factors that aided Industry 4.0 startups in bringing their solutions to the market. Thus, **it was possible to identify the existing configurations within the ecosystem that help startups develop their business.** The technique used the factors grouped through CFA to determine potential profiles within the ecosystem that assist Industry 4.0 startups in reaching the market.

(iii) Descriptive: After applying fsQCA, it was possible to identify which factors were central and peripheral (non-essential) for Industry 4.0 startups to develop their business based on their frequency of appearance among the configurations found in the statistical analysis. Therefore, the factors constructed through CFA in the first step were reevaluated, and from the main factors selected, it was determined which activities are most frequently developed by Industry 4.0 startups (i.e., only responses on a 5 to 7-point Likert scale were considered) to help them reach the market. This way, it was possible to show, in addition to critical factors, **which activities Industry 4.0 startups commonly engage in to provide 4.0 solutions to the market.**

6.

FINDINGS:
KEY INSIGHTS

1

The main **types** of Industry 4.0 startups that make up the ecosystem are indtechs (21.67%), healthtechs (14.17%), agrotechs (10%), construtechs (6.67%), cleantechs (5.83%), and fintechs (4.17%).

2

The main **technologies/solutions** used are Data Acquisition (10.51%), Data Presentation Software (10.51%), Artificial Intelligence (9.90%), and Internet of Things (8.89%).

3

The main partners with a **high degree of collaboration** to develop the business of Industry 4.0 startups are Customers (75.83%), Other Companies (56.67%), Incubators (47.51%), Universities/Research Centers (43.34%), and Angel Investors (42.50%).

4

The main ways in which universities typically **assist high-impact** Industry 4.0 startups are through entrepreneurial capacity (33.33%), providing incubators and laboratories (32.50%), and granting access to technology (29.17%).

5

The main ways in which the private sector **typically contributes significantly** to Industry 4.0 startups are through angel investment (29.17%), seed capital (25.83%), and the use of accelerators (25%).

6

The main ways in which the government **typically makes significant contributions t**o Industry 4.0 startups are through grants (17.50%) and the provision of infrastructure (9.17%).

7

Critical success factors for Industry 4.0 startups to scale their business were identified as Resources in 100% of the cases, with social resources (63.33%) and information resources (50%) being the most relevant.

8

In 87.50% of cases, **critical success factors** include the ability to identify and evaluate opportunities, mobilization capacity to capture value from opportunities, collaboration, resilience, self-efficacy, mentoring, exploration of external knowledge, exploration of internal knowledge, and private investments.

9

The main activities (> 90% of the time) that Industry 4.0 startups usually undertake to enter the market are related to updating and seeking new information, incorporating new technological knowledge, and seizing market opportunities.

10

Other relevant activities include accepting and implementing new ideas, conducting analysis to solve problems, identifying creative ways to seek solutions with limited resources, and the ability to improvise.

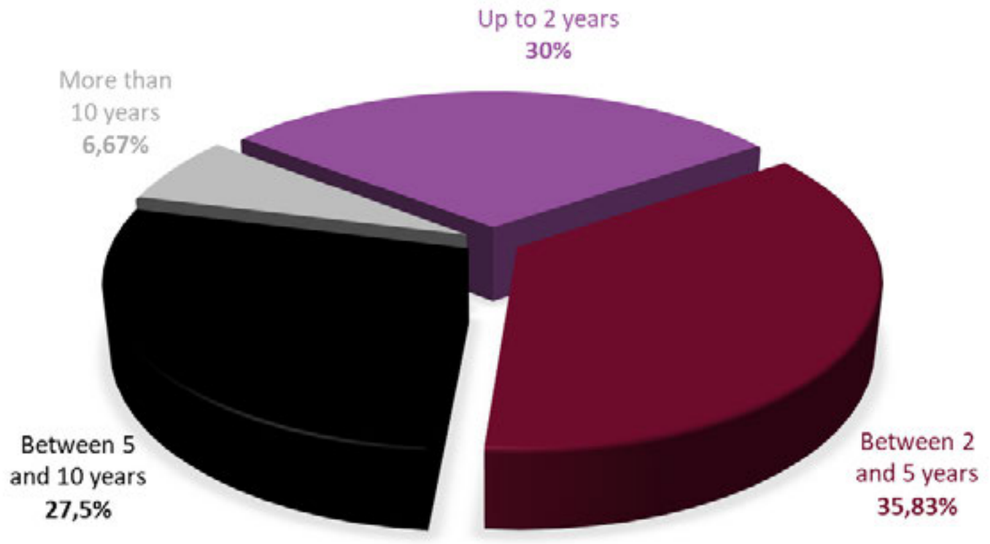
7.

FINDINGS:
STARTUP 4.0 PROFILE

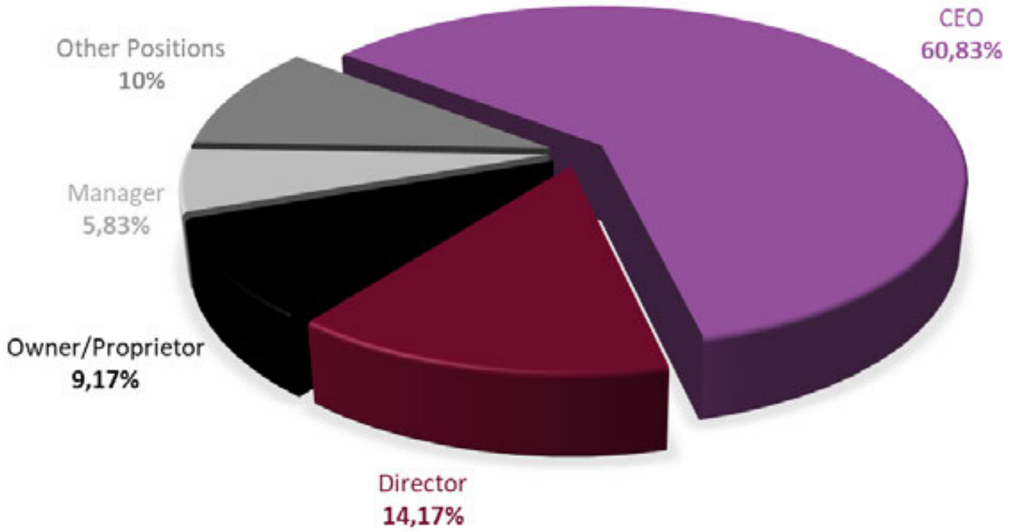
The highest concentration of Industry 4.0 startups in the innovation ecosystem is located in the **Southern region of the country (64.17%)**, with Paraná being the most predominant state (55 Industry 4.0 startups operating in the ecosystem). In the Southeast, it was the second most predominant region with 31.67% of Industry 4.0 startups, and São Paulo had the highest number of startups (25 operating in the ecosystem). States such as Santa Catarina (11 startups), Rio Grande do Sul (10 startups), and Minas Gerais (8 startups) also had a significant number of Industry 4.0 startups operating in the ecosystem.

The majority of respondents are **CEOs and directors**, accounting for 75% of the cases. Regarding the length of existence, most **Industry 4.0 startups have been active for up to 10 years, representing 93.33% of the cases**, with a similar distribution across periods of up to 2 years, 2 to 5 years, and 5 to 10 years. The majority of Industry 4.0 startups already have an annual revenue (at least 93.34% of the cases) of up to R$ 300 million BRL, indicating that a significant portion is already established in the ecosystem market.

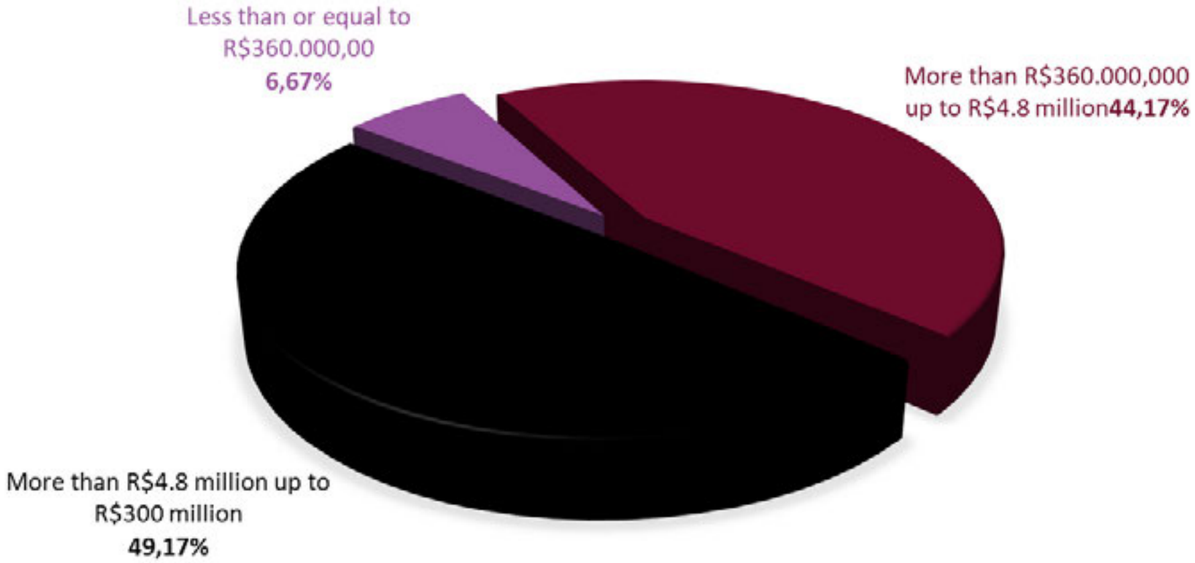
EXISTENCE TIME



RESPONDENT'S POSITION

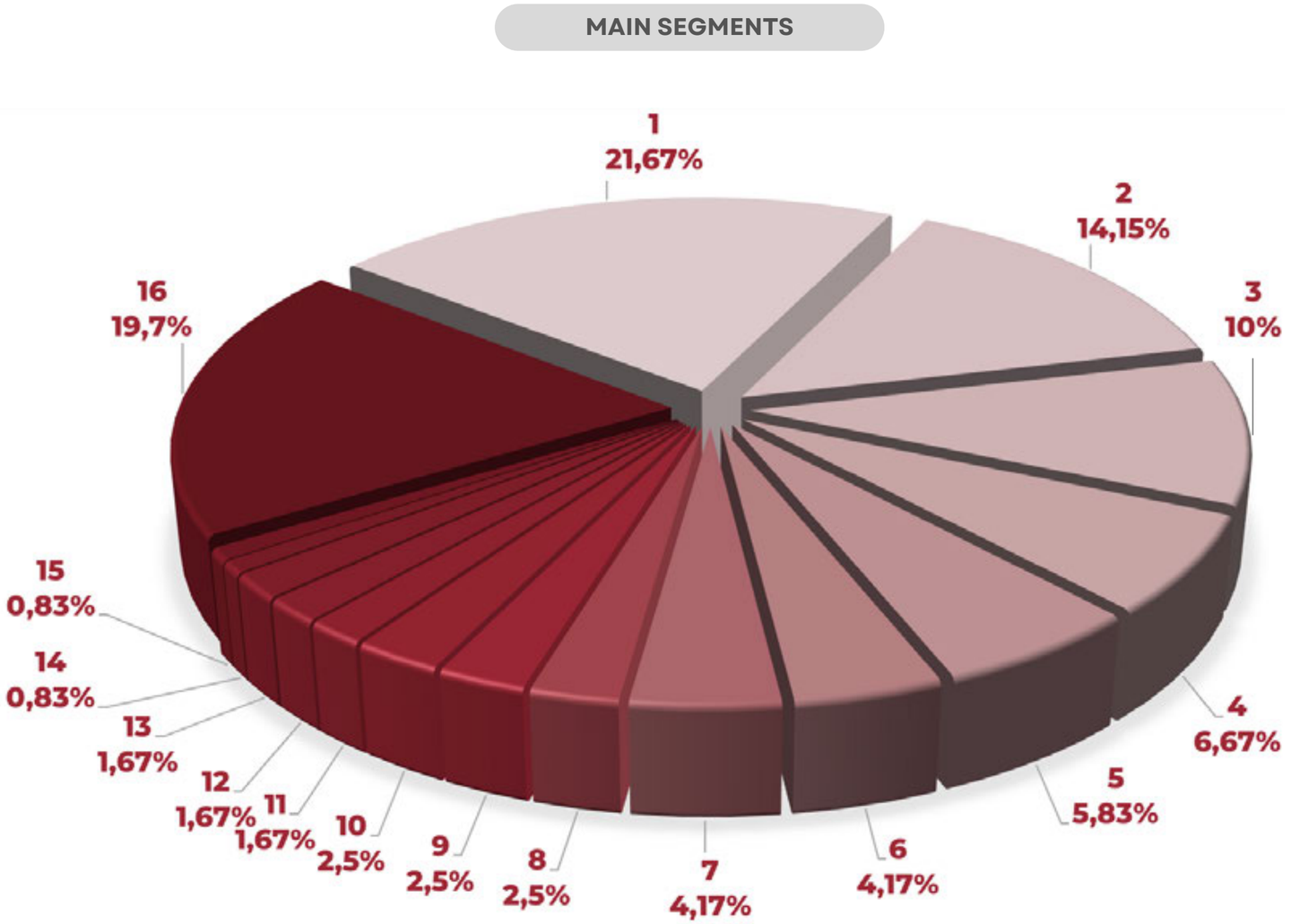


ANNUAL TURNOVER

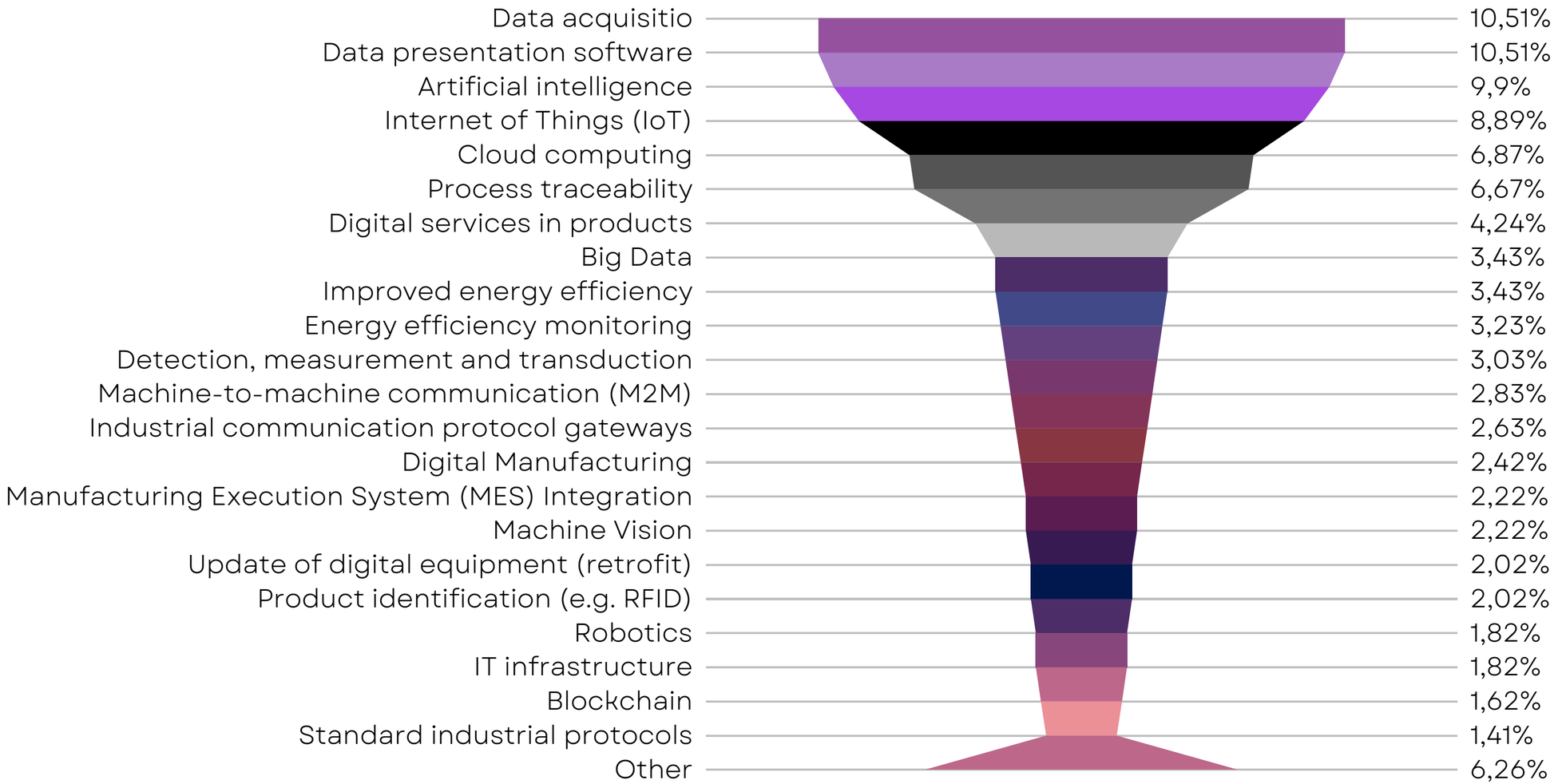


The **main sectors of operation for Industry 4.0 startups** are related to indtechs, which develop solutions for the industry, healthtechs, which develop solutions for healthcare, agrotechs, which develop solutions for agriculture, construtechs, which develop solutions for the construction industry, and cleantechs, which develop solutions for the environment.

1 - Indtechs (Industry)
2 - Healthtechs (Healthcare)
3 - Agrotechs (Agriculture)
4 - Construtechs (Construction)
5 - Cleantechs (Renewable Energy/Environmental)
6 - Biotechs (Biotechnology)
7 - Fintechs (Finance)
8 - HR techs (Human Resources)
9 - Legaltechs (Legal)
10 - Retailtechs (Retail)
11 - Edtechs (Education)
12 - Insurtechs (Insurance)
13 - Martechs (Marketing)
14 - Funtechs (Entertainment)
15 - Regtechs (Compliance)
16 - Other Segments

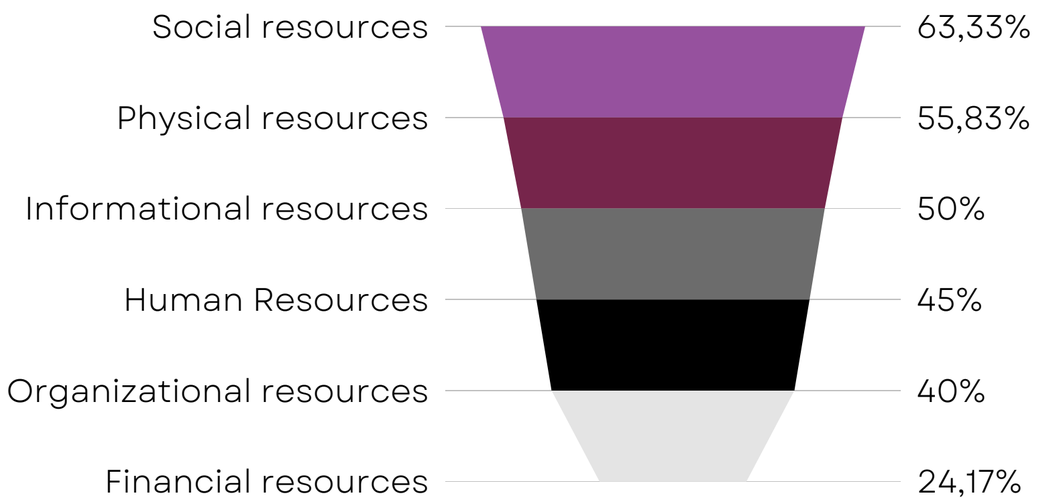


The main **technologies/solutions developed** are related to data acquisition, data presentation, Artificial Intelligence, Internet of Things, Cloud Computing, and process traceability, representing 53.05% of the solutions oriented towards Industry 4.0 within the ecosystem.

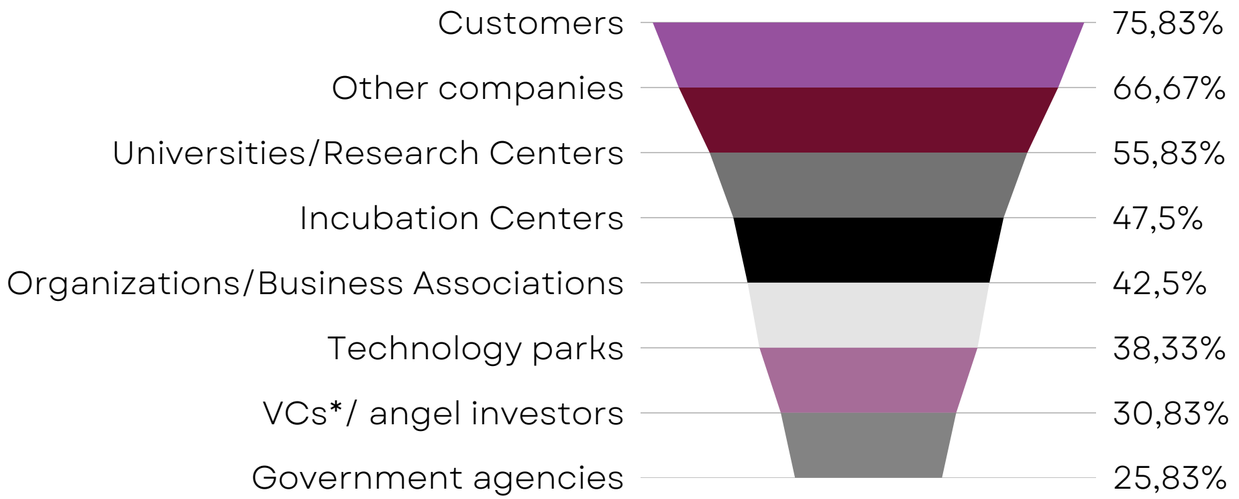


Industry 4.0 startups **primarily develop** social resources (63.33%), related to networking and relationships with potential partners, and physical resources (55.83%), such as equipment development/use, technology, space, etc. Additionally, they seek resources related to information (50%). In terms of partners, the key actors that typically collaborate with startups are their customers (75.83%), other companies (66.67%), and universities and research centers (55.83%).

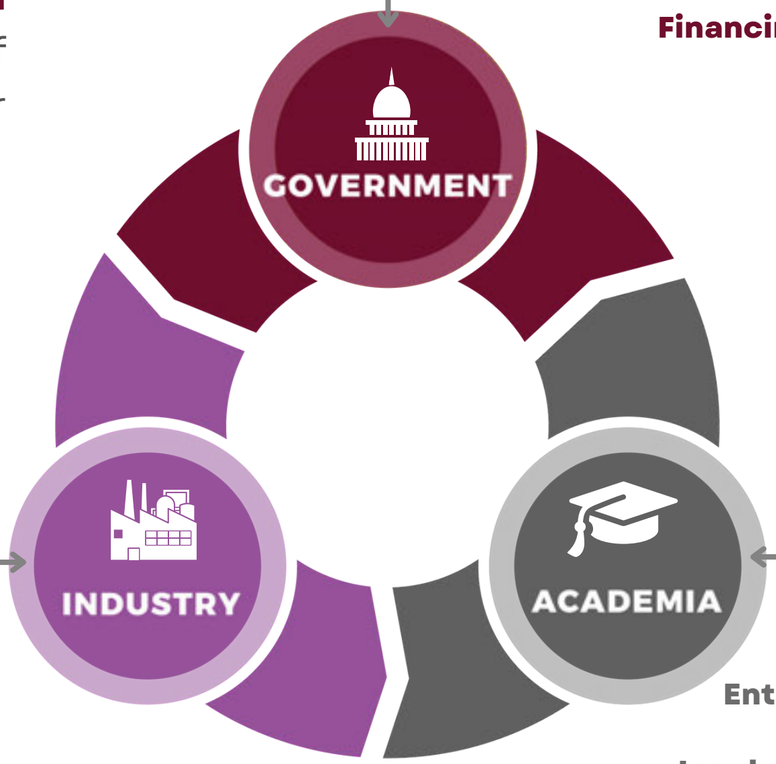
MAIN FEATURES DEVELOPED



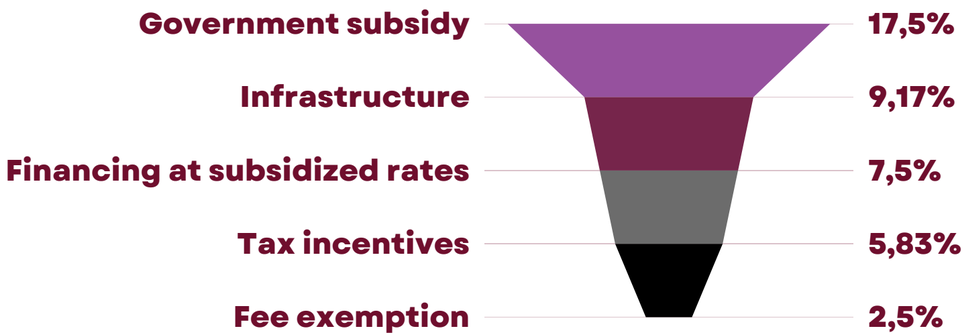
MAIN PARTNERS



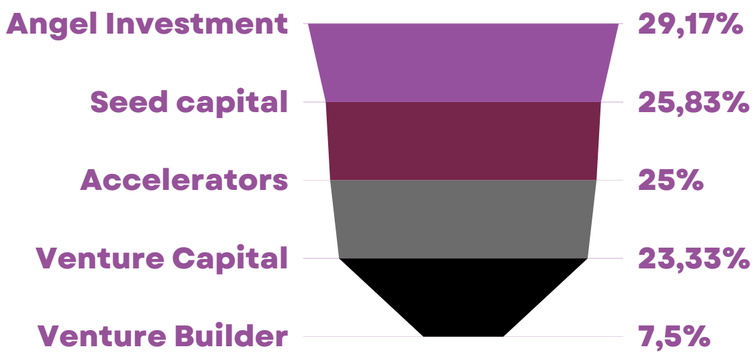
Within the triple-helix model that suggests the synergy of three major players in an ecosystem, typically **government, academia, and industry,** the primary outcomes of investments and incentives for Industry 4.0 startups are emphasized.



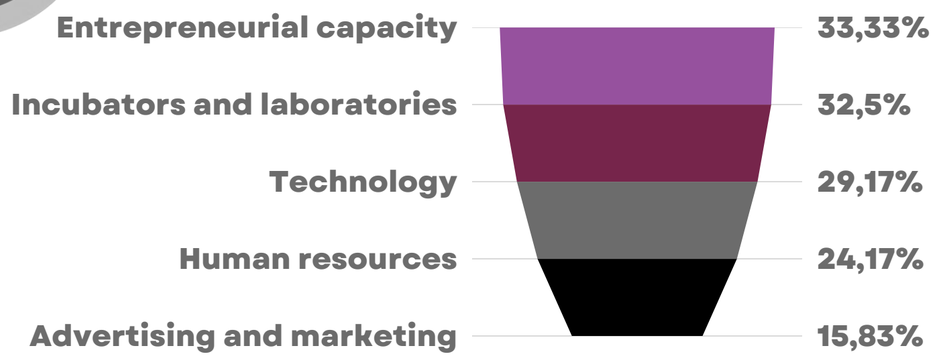
MAIN FORMS OF GOVERNMENT SUPPORT



MAIN PRIVATE INVESTMENTS



MAIN FORMS OF UNIVERSITY SUPPORT

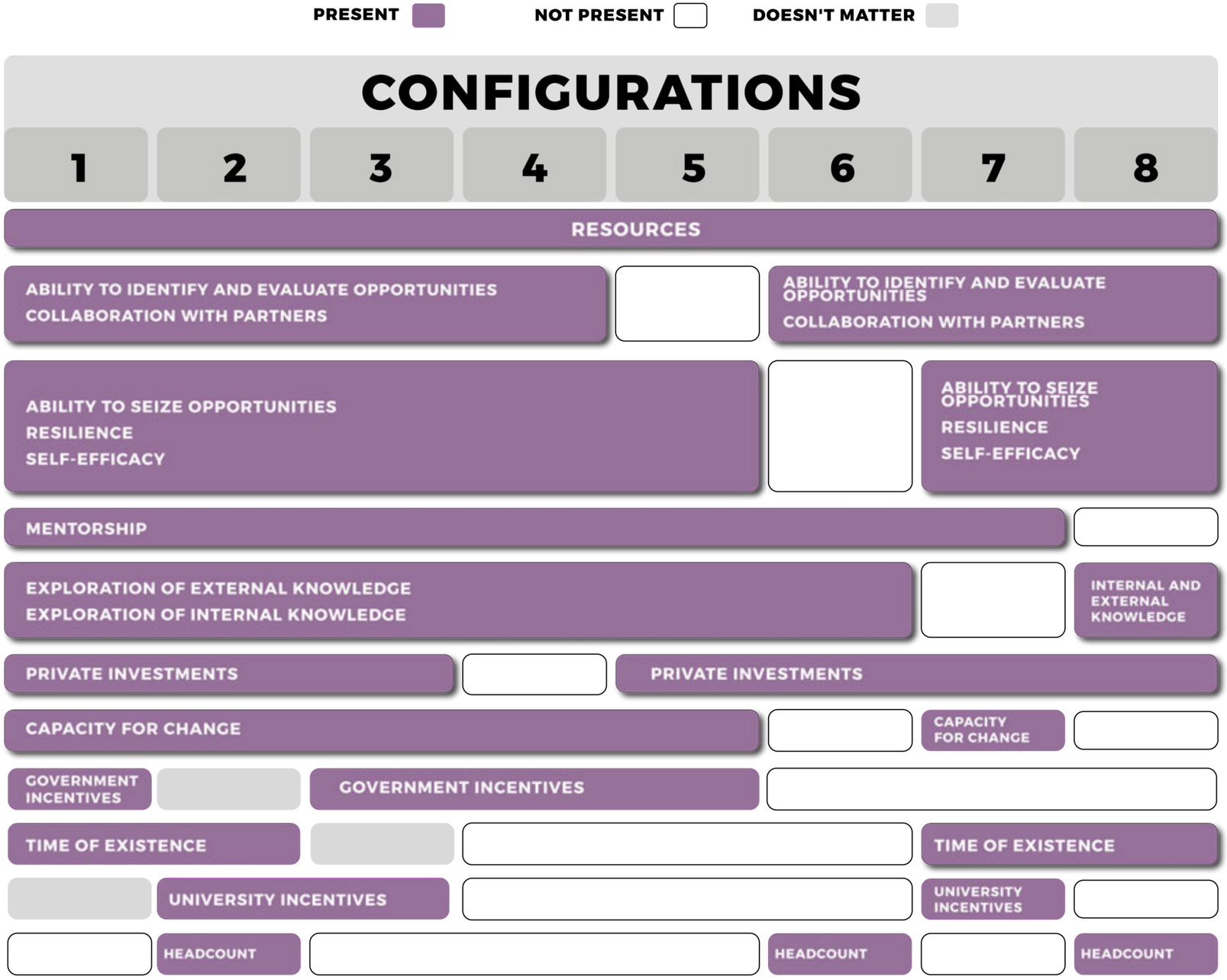


8.

FINDINGS: CRITICAL SUCCESS FACTORS FOR STARTUPS 4.0

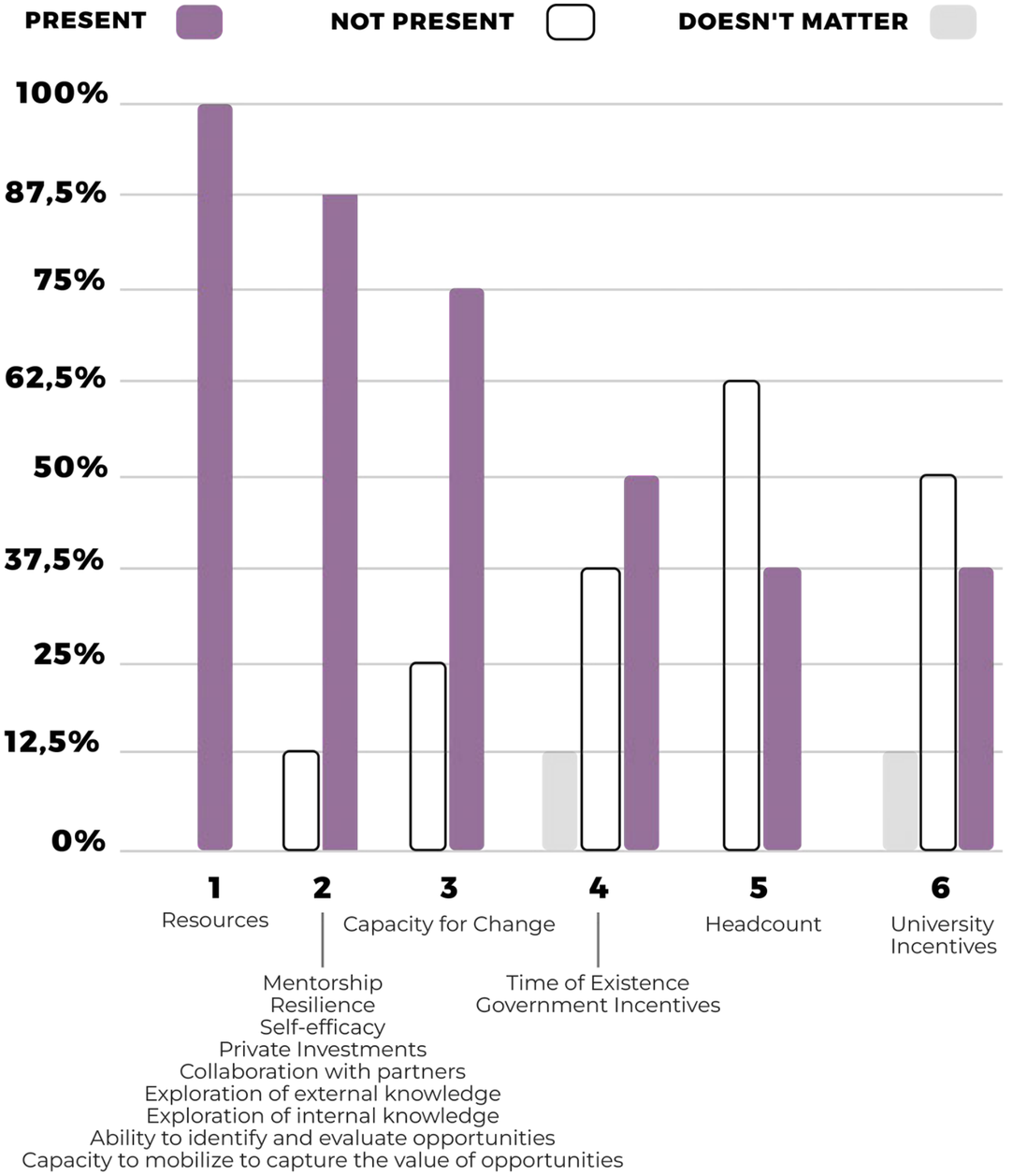
Following the methodology of combining multivariate techniques with the descriptive part of the data report, 15 potential critical success factors for Industry 4.0 startups within the innovation ecosystem were analyzed. The image illustrates various configurations with central and peripheral factors that helped Industry 4.0 startups develop their business.

This image helps understand the capacities/activities that Industry 4.0 startups developed to enter the market.



Through the identification of these factors, the table alongside was developed, **which presents the percentage presence of the 15 factors for the analyzed startups**. It was possible to identify that 11 factors (>50%) are necessary conditions for startups within the ecosystem to develop their business successfully. Among the key factors are the need for Industry 4.0 startups to have **Resources (100%), the ability to identify and interpret changes (87.50%), the ability to seize opportunities (87.50%), Collaboration with partners (87.50%), Resilience (87.50%), Self-efficacy (87.50%), Mentoring (87.50%), Exploration of external knowledge (87.50%), Exploration of internal knowledge (87.50%), Private investments (87.50%), and Capacity for Change (75%)**.

The findings help us understand the necessary conditions for Industry 4.0 startups to mature their business and reach the market. As the factors were statistically grouped as described in the methodology section to better understand which activities are typically performed within each critical success factor, the factors were disaggregated, and the percentage of development of each individual activity that startups typically perform to reach the market was analyzed.



RESOURCES

This factor pertains to the use of resources for Industry 4.0 startups to develop their business. All organizations require resources to develop their business, and naturally, when analyzing the results, it was evident that this is a necessary factor in 100% of cases **(see graph on page 32)** for startups that develop solutions for Industry 4.0.

By breaking down this factor based on the percentage of startups that have a high level of development, it was possible to identify the main resources that they should develop to mature their business and reach the market. The table alongside shows that the main resources that Industry 4.0 startups should develop are related to networking and social practices (63.33% of cases), followed by resources related to information (50% of cases).

MAIN RESOURCES	STRONG PREVALENCE	N°*
Social Features (useful relationships with other people or companies, networking, etc.).	63.33%	76
Information Resources (information systems convenient to needs, market data API, etc.).	50.00%	60
Human Resources (individual education, training, experience, skills, etc.).	45.00%	54
Organizational features (formal and informal planning systems, routines, etc.).	40.00%	48
Financial resources (amount of financial resources we raise/acquire).	24.17%	29

* Number of total 4.0 startups representing the percentage.

CAPABILITY TO IDENTIFY AND EVALUATE OPPORTUNITIES

This factor is closely related to the dynamic capability of startups to identify existing market opportunities for developing their business. This factor appeared as necessary in 87.50% of cases **(see the graph on page 32)** for Industry 4.0 startups to succeed in developing their business. It was identified that all these capabilities are crucial for Industry 4.0 startups to identify and assess which market opportunities can be leveraged for their business. In other words, for Industry 4.0 startups to mature their business, they must regularly monitor and control the current market situation, seek new information, and engage in competitive benchmarking.

MAIN CAPABILITIES	STRONG PREVALENCE	Nº*
Our startup is **up-to-date on the current market situation.**	95.83%	115
Our startup systematically **seeks information about the current market situation.**	90.83%	109
Our startup knows **how to access new information.**	89.17%	107
Our startup **quickly perceives market changes.**	86.67%	104
Our startup **always keeps an eye on our competitors' activities.**	82.50%	99

* Number of total 4.0 startups representing the percentage.

MOBILIZATION CAPACITY TO CAPTURE VALUE FROM OPPORTUNITIES

This factor is related to the dynamic capability[4] of startups to mobilize their resources for value creation in the development of their business. This factor appeared as necessary in 87.50% of cases **(see graph on page 32)** for Industry 4.0 startups to succeed in developing their business. It was identified that all the capabilities presented in the table alongside are crucial for Industry 4.0 startups to identify and assess which market opportunities can be leveraged for their business. The following capabilities reflect the activities that Industry 4.0 startups should develop to capitalize on the knowledge acquired from market opportunities.

MAIN CAPABILITIES	STRONG PREVALENCE	Nº*
Our startup can **develop processes and innovative products based on new technological knowledge.**	96.97%	116
Our startup evolves **rapidly with new external knowledge.**	91.67%	110
Our startup recognizes **which new information can be utilized.**	90.83%	109
Changes in our startup can be **efficiently** implemented.	80.00%	96

* Number of total 4.0 startups representing the percentage.

COLLABORATION WITH PARTNERS

This factor is related to the level of collaboration of Industry 4.0 startups with different ecosystem actors for the development of their business. This factor appeared as necessary in 87.50% of cases **(see the graph on page 32)** for Industry 4.0 startups to succeed in developing their business. The table alongside confirms that most of the time, startups seek to collaborate with their key customers and other companies to develop their solutions for the market. What is also noteworthy is that despite the overall low level of collaboration, alliances with business associations, technology parks, investors, and government agencies can be differentiators for startups to reach the market in the context of Industry 4.0.

MAIN ACTORS	STRONG PREVALENCE	Nº*
Our startup has **alliances with key customers.**	75.83%	91
Our startup has **alliances with other companies.**	66.67%	80
Our startup has **alliances with business organizations/associations.**	42.50%	51
Our startup has **alliances with technology parks.**	38.33%	46
Our startup has **alliances with VCs*/angel investors.**	30.83%	37
Our startup has **alliances with government agencies.**	25.83%	31

* Venture Capital or risk capital, is an investment modality with the expectation of rapid growth and high profitability.

* Number of total 4.0 startups representing the percentage.

RESILIENCE

This factor is related to the ability of Industry 4.0 startups to adapt to obstacles and difficult situations to sustain and develop their business. This factor appeared as necessary in 87.50% of cases **(see the graph on page 32)** for Industry 4.0 startups to succeed in sustaining/developing their business. The table alongside allows us to affirm that all the key activities grouped within this factor are typically developed by startups that have managed to enter the market and achieve maturity in their businesses.

MAIN ACTIVITIES	STRONG PREVALENCE	Nº*
Our startup is alert **to seize new opportunities in the market.**	95.00%	114
Our startup **adapts, accepts, and implements new ideas.**	94.17%	113
Our startup strives to **outperform competitors** in the development of new products.	90.00%	108
When faced with obstacles, **we remember moments when our startup encountered similar challenges and overcame them.**	85.83%	103
Our startup **encourages its employees to launch products/services aiming for market leadership.**	75.83%	91
Our startup is the **first to take action, ahead of competitors.**	66.67%	80

* Number of total 4.0 startups representing the percentage.

SELF-EFFICIENCY

This factor pertains to the ability of Industry 4.0 startups to acquire knowledge and master skills necessary for developing their business. This factor appeared as necessary in 87.50% of cases **(see the graph on page 32)** for Industry 4.0 startups to succeed in developing their business. The table alongside allows us to affirm that all the key activities grouped within this factor are typically developed by startups that have managed to enter the market and achieve maturity in their businesses.

MAIN ACTIVITIES	STRONG PREVALENCE	N°*
It can **perform analyses** to solve a problem.	96.67%	116
It can **identify creative ways** to do things with limited resources.	95.83%	115
It can **improvise when it's unclear what the correct action** or decision should be in a situation or problem.	92.50%	111
It has the **knowledge, skills, and experience** necessary to start a new business.	91.67%	110
It can **identify and organize sources of resources.**	80.83%	97

* Number of total 4.0 startups representing the percentage.

MENTORING

This factor pertains to the assistance of mentorship that Industry 4.0 startups received to develop their business. This factor appeared as necessary in 87.50% of cases **(see the graph on page 32)** for Industry 4.0 startups to succeed in developing their business. The table alongside allows us to affirm that the main activities related to mentorship include access to networking (80.83%), training and workshops for capacity building (77.50%), and access to infrastructure for business development (70.83%).

MAIN ACTIVITIES	STRONG PREVALENCE	N°*
It has had the **opportunity to interact** with other startups and access to experts, customers, and investors.	80.83%	97
It has had access to **experienced mentors**, training, and workshops.	77.50%	93
It has had access to **appropriate physical resources**, including office space and shared facilities or equipment.	70.83%	85
It has had **access to various forms of financing.**	50.00%	60

* Number of total 4.0 startups representing the percentage.

EXPLORATION OF EXTERNAL KNOWLEDGE

This factor relates to how Industry 4.0 startups acquire external knowledge to develop their business. This factor appeared as necessary in 87.50% of cases **(see the graph on page 32)** for Industry 4.0 startups to succeed in developing their business. The table alongside allows us to affirm that all the key activities grouped within this factor are typically developed by startups that have managed to enter the market and achieve maturity in their businesses.

MAIN ACTIVITIES	STRONG PREVALENCE	Nº*
Our startup has **the capacity to seek external knowledge and information.**	94.17%	113
Our startup a**cquires knowledge through various sources.**	94.17%	113
We disseminate external knowledge throughout our startup.	84.17%	101
Our startup was **motivated to use external knowledge.**	80.00%	96

* Number of total 4.0 startups representing the percentage.

EXPLORATION OF INTERNAL KNOWLEDGE

This factor relates to how Industry 4.0 startups leverage/create internal expertise to develop their business. This factor appeared as necessary in 87.50% of cases **(see the graph on page 32)** for Industry 4.0 startups to succeed in developing their business. The table alongside allows us to affirm that all the key activities grouped within this factor are typically developed by startups that have managed to enter the market and achieve maturity in their businesses.

MAIN ACTIVITIES	STRONG PREVALENCE	N°*
In our startup, **new applications were facilitated** through new knowledge for practical uses.	91.67%	110
Our startup **created new knowledge** through the recombination of existing knowledge.	90.00%	108
Our startup **applied newly generated knowledge** for commercial purposes.	88.33%	106
Our startup **used the new knowledge** flexibly to enhance business activities.	88.33%	106

* Number of total 4.0 startups representing the percentage.

PRIVATE INVESTMENTS

This factor pertains to the primary sources of private investment that help Industry 4.0 startups develop their business. This factor appeared as necessary in 87.50% of cases **(see graph on page 32)** for Industry 4.0 startups to succeed in developing their business. However, even though it is a critical success factor, few startups receive this type of financial support to develop their business, as shown in the table alongside. Nevertheless, it can be observed that angel investors, seed capital, and accelerators have high potential to contribute to the development of startups' businesses, but these initiatives are still relatively low in the context of Industry 4.0 startups

MAIN ACTIVITIES	STRONG PREVALENCE	N°*
Angel investment.	29.17%	35
Seed capital.*	25.83%	31
Accelerators.	25.00%	30
Venture Builder.*	7.50%	9

* Seed capital is a financing model for entrepreneurs who are seeking resources even before the establishment and development of the company.

* Venture builders are organizations that create, validate, and accelerate multiple startups simultaneously.

* Number of total 4.0 startups representing the percentage.

CAPACITY FOR CHANGE

This factor is strongly related to the dynamic capability[4] of transformation startups in response to changes and barriers imposed on their business. This factor appeared as necessary in 75% of cases **(see graph on page 32)** for Industry 4.0 startups to develop their business. It was identified that all the capabilities presented in the table on the side are crucial for Industry 4.0 startups to reconfigure their business. In other words, for Industry 4.0 startups to stay in the market, they need to act quickly in response to changes, define change plans, maintain consistency in changes, and anticipate and standardize activities.

MAIN ACTIVITIES	STRONG PREVALENCE	N°*
The environment of our startup **requires a quick response** to the changes that occur.	80.83%	97
By clearly defining the responsibilities of each team member, we successfully implement **change plans in our startup**.	73.33%	88
Even when unexpected events occur, **changes are made consistently** in our startup.	68.33%	82
Typically, our startup has **prior knowledge of the changes that will occur in the environment**.	65.83%	79
Our startup changes the core **operational capacity** through a routine method.	51.67%	62

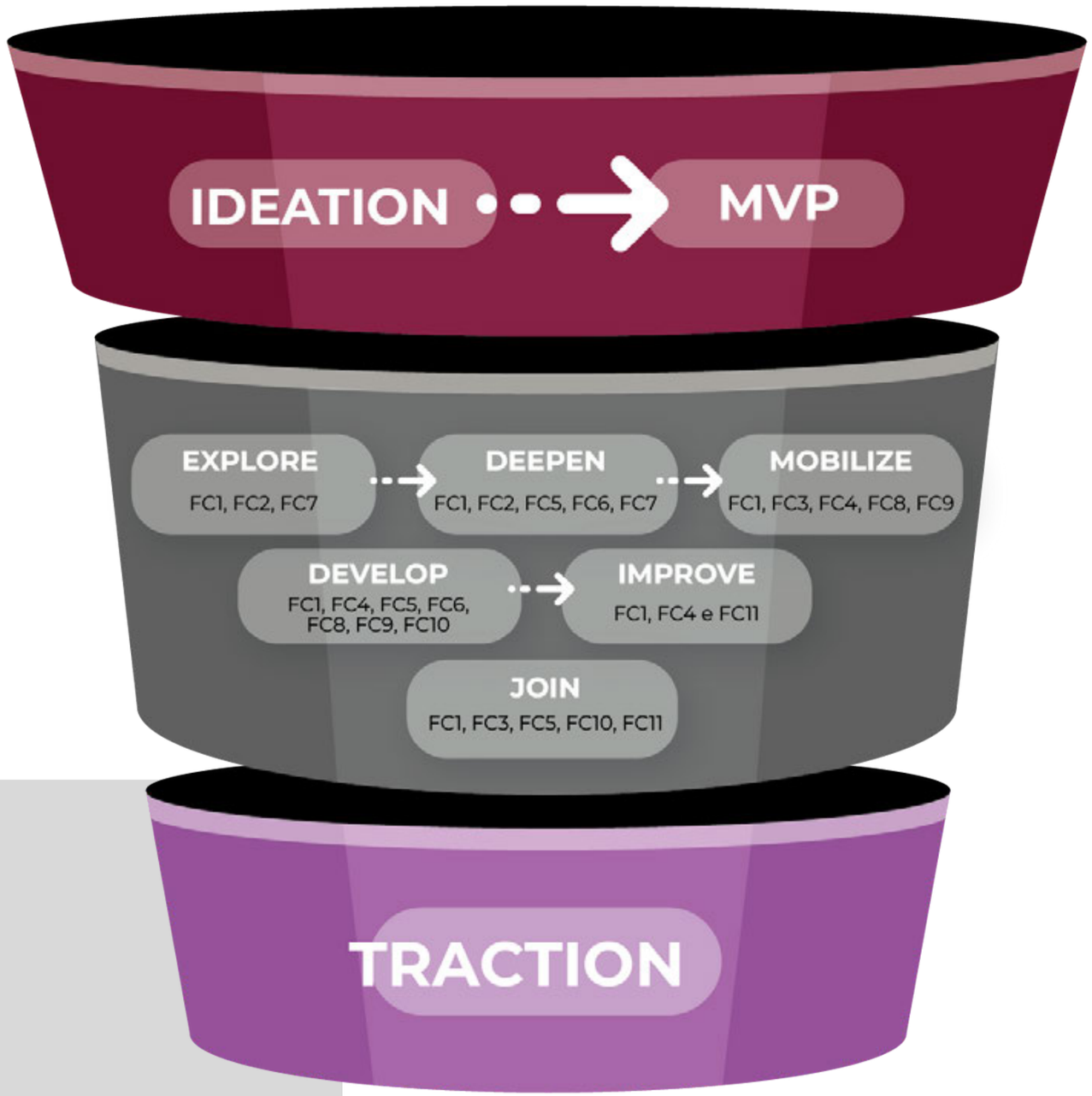
* Number of total 4.0 startups representing the percentage.

9.

RECOMMENDATIONS

STARTUPS CYCLICAL FUNNEL

Given the presented results, it is advisable for these startups to follow recommendations and best practices to achieve success and reach the traction stage. It is important to note that success is influenced by various factors, and what will be presented are not rules but rather trends based on research data. Based on the results, we propose the Startup Cyclical Funnel with action recommendations considering the critical success factors identified, which can assist Industry 4.0 startups in reaching the market. The funnel considers how a startup can mature its idea, starting from the Ideation phase and reaching the traction stage, where it already has a developed product or solution and seeks scalability in the market.



- **FC1: RESOURCES**
- **FC2: ABILITY TO IDENTIFY AND ASSESS OPPORTUNITIES**
- **FC3: ABILITY TO CAPTURE VALUE FROM OPPORTUNITIES**
- **FC4: COLLABORATION WITH PARTNERS**
- **FC5: RESILIENCE**
- **FC6: SELF-EFFICACY**
- **FC7: MENTORING**
- **FC8: EXPLORATION OF EXTERNAL KNOWLEDGE**
- **FC9: EXPLORATION OF INTERNAL KNOWLEDGE**
- **FC10: PRIVATE INVESTMENTS**
- **FC11: ABILITY TO CHANGE**

6 MACRO-PHASES

The funnel is divided into 6 macro-phases that, when combined, can assist Industry 4.0 startups in progressing from the Ideation stage to Traction. In summary, when there is a desire to enter the Industry 4.0 startup market and achieve success by scaling through all maturity phases in this business context, it is encouraged that startups align their expectations and missions with all stakeholders in their business ecosystem and make the best use of the recommendations proposed here, based on their judgment and application. Thus, as suggestions for actions by stages, they can be characterized as follows:

1 EXPLORE

This stage constitutes the initial stage for Industry 4.0 startups, which have an idea but still need to develop it. To do this, working with **social and informational resources (FC1)** in conjunction with the ability to **identify and evaluate opportunities (FC2)** and having good **mentorship (FC7)** can assist Industry 4.0 startups in moving forward with their idea.

2 DEEPEN

After filtering in the 'Explore' phase, it is required that Industry 4.0 startups delve deeper into their ideas. To do this, working with available **resources (RC1)**, having the ability to **identify and evaluate market opportunities (FC2)**, and having qualified **mentorship (FC7)** remain crucial. However, there is also a need for startups to be **self-efficacious (FC6)** to deepen and develop their **knowledge and resilient (FC5)** to adapt to conditions and implement their ideas.

3 MOBILIZE

With a clear idea of what they want to develop, it is recommended to move to the 'Mobilization' stage, where Industry 4.0 startups should mobilize their **resources (FC1)**, **partners (FC4)**, **external knowledge (FC8)**, **internal knowledge (FC9)**, and have the **ability to capture value from opportunities (FC3)** to acquire all the necessary elements to transition to the MVP.

6 MACRO-PHASES

4 DEVELOP

This phase involves the construction or creation of the MVP, where startups must align many of the critical factors to succeed in the development of their solution. To do this, it is necessary to use **resources (FC1)**, **partners (FC4)**, possess **resilience (FC5)** to adapt to changes, **self-efficacy (FC6)** to develop their solution, **explore external (FC8)** and **internal (FC9)** knowledge, and **secure private investments (FC10)** to inject funds into the idea.

5 IMPROVE

After the 'Develop' phase, the 'Refine' phase follows, where the startup has already developed a proof of concept (PoC) or MVP of the solution and needs to refine their idea by testing it in the market. In this stage, r**esources (FC1)** and collaboration with **partners (FC4)**, along with the **ability to adapt (FC11)**, are essential for Industry 4.0 startups to improve their solution and adapt to the market.

6 JOIN

The final stage encompasses the moment when the startup has already developed its idea/concept and seeks scalability in the market. To achieve this, it is recommended that **resources (FC1)**, **mobilization capacity (FC3)**, **resilience (FC5)**, **private investments (FC10)**, and **adaptability (FC11)** be the focus for Industry 4.0 startups to penetrate the market. When developed in conjunction, these factors can enable Industry 4.0 startups to have a greater ability to adapt their solution to the market.

10.

NEXT STEPS

1

Our results show which factors should be considered for Industry 4.0 startups to mature their ideas and progress from ideation to the traction stage to reach the market. The factors identified and presented provide guidance for entrepreneurs to understand which activities can assist in the development of their business. However, in a context where more than 80% of startups fail in the first year[5] and many struggle to achieve the desired market scalability, some questions still remain unanswered in the realm of startup entrepreneurship. Questions such as achieving success in the market, scaling your business, and the steps that must be followed to at least reach the market from an idea still lack a comprehensive answer.

2

To this end, as future studies, the first goal is to develop an entrepreneurship methodology based on simplified and modular stages that assist entrepreneurs in maturing their ideas, developing their solutions, and reaching the market. The proposal is to develop a simplified methodology to help startups reach the market. In other words, the aim is to develop a methodology that reduces the percentage of startups that fail before reaching the market.

3

Finally, to complete the analysis, in other words, how startups that have reached the market can grow their business, future work also aims to study Industry 4.0 startups that are in the evolutionary stages of traction and consolidation. Studying these cycles is essential to understand what sets apart a successful Industry 4.0 startup from one that failed to scale their business. To achieve this, we aim to comprehend, using the Product Lifecycle Management (PLM) methodology, the differences between the solutions and behaviors of these successful startups compared to those still striving for success in the market.

11.

REFERENCES

11.

REFERENCES

[1] Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. ***International Journal of Production Economics***, 210, 15-26.

[2] Benitez, G. B., Ayala, N. F., & Frank, A. G. (2020). Industry 4.0 innovation ecosystems: An evolutionary perspective on value cocreation. ***International Journal of Production Economics***, 228, 107735.

[3] Steve, B. (2006). ***The four steps to the Epiphany***. California: K & S Ranch.

[4] Teece, D. J. (2018). Business models and dynamic capabilities. ***Long range planning***, 51(1), 40-49.

[5] Hyder, S., & Lussier, R. N. (2016). Why businesses succeed or fail: a study on small businesses in Pakistan.***Journal of Entrepreneurship in Emerging Economies***, 8(1), 82-100.

12.

APPENDIX

Ecosystem actors	Description	Summary
State and Municipal Government	State of the southern region of Brazil and its capital	Responsible for the development of policies and actions for entrepreneurship and innovation for socioeconomic and technological development.
Universities	Higher education institutions with undergraduate and graduate programs.	The institutions work in education, research, and extension activities focused on responsible socioeconomic development.
Association business	A private non-profit business association focused on providing social services for business development.	It offers various programs for startups, depending on their stage in the lifecycle, and plays a significant role in supporting startups.
Incubators and Accelerators"	Incubators and accelerators connecting with startups from all over Brazil and supporting the development of these startups.	Incubation and acceleration of startups within the ecosystem of the southern region of Brazil.
Entrepreneurship and Innovation Hubs	Innovation and entrepreneurship center that seeks to promote and support the development of early-stage projects and startups.	Collaborates with projects and startups in the ideation phase, contributes to the development and mastery of Industry 4.0 technology, and the business model until it is mature enough to be referred to Incubators and Accelerators.
Investors	Angel investors network.	Active investors with the goal of transforming startups through knowledge, networking, and angel investment.
Suppliers	• Small technology company. • 3D printer manufacturing and sales company. • Energy distribution company.	Providing Industry 4.0 technological development services to early-stage startups in the MVP development stage.
Customers	• Energy sector company. • Automotive sector company. • Manufacturing sector company.	They have their own incubator, accelerator, and venture capital, support programs for ideas/concepts, MVPs, businesses, management, and others for startups to develop Industry 4.0 technology solutions for the challenges faced by the company through PoCs, and in the end, the startups become a supplier.

Table 1 - Actors interviewed within the ecosystem.

Ecosystem actors	Description	Summary
Startup I4.0 – 01	Agrotech	Ideation stage, 2 years, robotics.
Startup I4.0 – 02	Funtech	MVP stage, 1 years, blockchain.
Startup I4.0 – 03	Healthtech	MVP stage, 3 years, deep learning e 3D print.
Startup I4.0 – 04	Healthtech	Traction stage, 3 years, 3D print.
Startup I4.0 – 05	Healthtech	Ideation/MVP stage (transition), 8 years, virtual and augmented reality.
Startup I4.0 – 06	Construtech	Traction/consolidation stage (transition), 5 years, IoT.
Startup I4.0 – 07	Agrotech	Traction stage, 3 years, product with Manufacturing Execution Systems (MES).
Startup I4.0 – 08	Indtech	MVP/traction stage (transition), 2 years, cloud computing - mini grid.
Startup I4.0 – 09	Agrotech	Traction/consolidation stage (transition), 5 years, use sensors and IoT.
Startup I4.0 – 10	Healthtech	MVP stage, 2 years, Big Data Analytics and Artificial Intelligence.
Startup I4.0 – 11	Fintech	Consolidation stage, 11 years, Big Data Analytics, Artificial Intelligence, automation and robotics.

Table 1 - Actors interviewed within the ecosystem.

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