

Lean Startup Methodology Application: Evidence from Brazilian Technological Startups

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Abstract

Considering the need to find ways to improve startup results in extremely uncertain scenarios and the fact that entrepreneurs suffer from high failure rates, this article re-searched the Lean Startup methodology in the Brazilian startup context, to analyze its effectiveness. First, exploratory research was carried out that had a descriptive and quantitative aspect, applied, hypothetical-deductive, and with research procedures that involved bibliographic research and survey through a questionnaire that aimed to raise questions that sought to identify practices aligned with the methodology, and statistical analysis. It was found that seven out of twelve dependent variables that were studied contributed significantly to companies being able to scale their business. Those who claimed to be fond of methodology showed that they apply its principles in their management practices. This research contribution revolves around the demonstration through a statistical basis for the adaptation of lean startups to the corporate reality of Brazilian startups.

Keywords: Startups, Innovation, Technology sector, Entrepreneurship, Performance .

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I. Introduction

The risks related to entrepreneurship activities and the development of a new business are extreme. Approximately a third of all startups are closed within their first two years, and fifty percent of them are shut down within five years, according to [1]. At

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the same time, micro and small-sized companies are essential drivers of growth in the current economic paradigm [2].

Regarding the Brazilian context, almost 40 million people are undertaking entrepreneurs, which places the country in the fourth position in the world ranking in the absolute number of active business people, behind China, India, and Nigeria. The prospect of new ventures has been of strategic importance for the national economy [3]. Many authors argue that entrepreneurship is a strong ally for economic development, mainly for supporting the market innovations it has offered. Investing in an environment that fosters new project ideas means promoting a sustainable, efficient, and innovative economy, directly affecting employment, income, and gross domestic product rates. Therefore, there is an enormous demand for a method that can decrease the risks of bringing a new business to profit and longevity [4]. Lean Startup (LS) is proposed as being such a methodology to fill this gap.

LS is a tendency proposed in 2008, and it has gained popularity, since 2011, with the book entitled The Lean Startup released by [5]. The concepts proposed by the author were defined according to the Japanese Lean Manufacturing approach, whose goal is to eliminate wasting based on continuous learning through quick iteration cycles. By applying them, startup companies can guarantee that resources are being spent on what is necessary – generating a new product or service that fulfills a customer's need and is willing to pay for. By doing so, startups can reduce the market risk and expand their possibilities of becoming prosperous [6].

Notable universities worldwide - such as Stanford, Harvard, and Columbia, among others - have started embracing the methodology and including it in their curriculum [7]. It is not just the academic world that has started to apply LS, accelerators and incubators also are adopting it as a methodology for developing new business.

The FAPESP, Saõ Paulo research foundation is assuming LS as the principal methodology for developing and accelerating business through its program PIPE (Innovative Research in Small Business), which

aims to support scientific and technological research carried out in startups and small innovative companies [8]. So, there is no doubt that the methodology has become widespread either in the academic or professional world in a short time.

Similarly, to any other methodology, the LS method has criticisms. Many authors have been discussing if the lean startup method has not yet confronted the test of time because of its relative recentness and the volume of studies published to problematize and evaluate its efficiency for creating and developing new business [9].

In response to the research scarcity on this subject, this study proposes to position the authors' contribution at the intersections of the above discussion and gaps in practice by investigating how the LS methodology application impacts Brazilian technological startups to reduce the failure rate in environments of extreme uncertainty, eliminating waste of resources such as workers' skills, supplies and time. Moreover, it also synthesizes the opportunities related to the use of the LS method in startups and how it contributes to decision-making for the companies' future to advance the business model to develop a sustainable business in the long term.

Regarding such a perspective, given the need to contribute to advances in the study of entrepreneurship in the Brazilian market, the LS methodology, proposed by [5], might be considered an appropriate tool to assist this process. Then, this paper presents its main hypothesis that there is a direct relationship between a startup implementing a learnable, scalable business model that reduces waste and inefficiencies and its results in an environment of extreme uncertainty.

From the early hypothesis, the paper aims to answer the following research questions:

1. Do factors such as the entrepreneur's experience, number of companies founded, business development stage, and affinity with the LS methodology have a direct relationship with the application of its principles in management practices?
2. Does the implementation of the LS methodology improve the results of a startup in the Brazilian context?

To answer them, the proposed methodology established aims to verify the feasibility of LS methodology in the Brazilian context through the following steps: 1) Mapping LS methodology proposed principles to startups according to literature; 2) Subsequent application of a questionnaire form that correlates objective questions with guided practices, as well as mapping of a single latent trait, the undertake skill; 3) Proposal of a model based on the Item Response Theory (IRT), which aims to analyze entrepreneurs answers and; 4) Perform a descriptive analysis, considering their answers, testing the statistical impact of independent variables (Experience as an entrepreneur, Company development phase, Number of companies founded and Affinity with LS methodology) in the dependent variable that concatenates the LS methodology principles.

This paper begins by describing the theoretical background at the basis of the investigation in Section 2. Section 3 characterizes the Technology-based entrepreneurship sector in Brazil. Section 4 describes the methodology proposed to answer the research questions. Section 5 shows the results and the respective analysis. Finally, in Section 6 the conclusion has been presented and a brief discussion about future research is introduced.

II. Theoretical background

Lean theory and its principles arose in the manufacturing field [10] after World War II ended. This is the outcome of the customer's demand for the development of more distinguished value in the products, coupled with the company's increasingly diversified offer. This meaningful redirection of the production system to customer value is reviewed in the five principles of lean [11], which are described as follows:

1. Create value for the customer: it is created when waste decreases internally and costs are diminished consequently. Value is increased by offering innovative services and products with new functionalities appreciated by customers.
2. Identify the value stream: it must not be hidden behind a wall of vagueness. The prices of each company must be transparent to all associates in the supply chain.
3. Create flow: the purpose of building flow is the intention of avoiding any stoppage in the value stream by restricting the main causes (i.e. changes in production, disruptions, wrong batches in terms of volume or timing, lack of relevant information, and re-entrant loops).
4. Produce just what is pulled by the customer: this principle implies high responsiveness while producing the most important quality products in an effective and valuable way.
5. Pursue perfection by continuously recognizing and discarding waste.

As arises from the principles, lean is described as a customer and value-centric method for building a flow of actions that continuously produce customer value and innovation by reducing non-value-adding actions or waste

[12].

While the lean theory emerged in the manufacturing domain, new efforts have been made to enlarge its employment and impact on other fields. For instance, lean principles are extensively employed in the healthcare area due to the need to apply techniques to improve quality, patient safety, cost, waiting time, and staff satisfaction in an environment where hospitals are encountering a growing number of external pressures and challenges [13].

Likewise, [5, 14] attempted to modify and link the lean manufacturing theory and its principles to business development in startups by elaborating on Lean Startup and “Customer Development” methods, respectively. Therefore, adopting the overall description of lean manufacturing, LS is defined as the startup’s effort to decrease its waste understood as all the actions and processes which the purpose customer does not want or does not ask for [15].

LS consists of a systematic, hypothesis-driven method to entrepreneurship, in which business people translate their concept - i.e. business idea - into hypotheses that are set in the first version of a business model. These hypotheses then are experimented with through a set of Minimum Viable Products (MVPs), which are defined as the smallest set of actions required to refute or accept a hypothesis [16].

In compliance with the scientific method, the hypothesis tests are performed through experiments that include “early adopters”, which is a skillful people who can provide valuable feedback to the startup. Immediately including evangelists to test ideas and MVPs - rather than basing one’s evaluations only on secondary data or “desk research”

- is a clear example of the “get out of the building” approach defended by [14].

Based on the test outcomes, business people come across three main options: 1) To persist on their planned business model - if the hypotheses are proven to be right; 2) To change to an updated business model, where the parameters endorsed by the tests are maintained and the others are improved on; or 3) To pivot, that is, abandon the idea and, in turn, the startup that was to have been launched around it. The method is repeated until all key hypotheses are verified or confirmed through MVP tests. When such a condition is reached, the startup has reached its “product-market fit” [17], which indicates that the value plan created and iteratively reviewed by the startup meets the needs of its target customers [18].

Then, product-market fit describes a prosperous conclusion of the “build-measure-learn” loop, in which a startup creates an MVP and associated tests, measures its outcomes and customer feedback, and learns how to adjust its business idea and business model. Similarly, customer development believes that business people are first called to search for a scalable and replicable business model during the periods of customer development, for instance, identification of “early adopters” - and validation, for experimenting and testing the MVP [14]. Such search is accompanied by the execution phase, in which the startups solidify and scale up their business model through customer creation and company building, i.e. the structuring of company teams and activities.

To comprehend how the LS methodology is adopted by Brazilian companies and how it affects business results, the item response theory has been used to do so.

IRT analytical models estimate items and respondent parameters to set a quantitative measurement scale. To determine these parameters, it is necessary to describe a set of variables that cannot be measured directly but represent a theoretical concept defined by “construct” or “latent traits”, such as the impacts of LS methodology to be answered for a sample of entrepreneurs of technological startups in Brazil. The IRT is a robust instrument that facilitates the development of scales from a set of items by using mathematical models [19]. Furthermore, IRT presents analytical models for the latent traits, suggesting forms for expressing the relation between the respondent’s probability to give an accurate response to an item, its latent trait, and item parameters in the knowledge area studied [20]. A significant benefit of IRT is the principle of invariance, i.e., the item parameters do not rely on the respondent’s latent traits, and the individual’s parameters do not rely on the items displayed [21].

The IRT use allows the development of a simple questionnaire to identify companies’ practices aligned with the methodology, and consequently, the application of statistical analysis to support the research answers with robustness.

III. The scenario of Technological-Based Startups in Brazil

Technology-based entrepreneurship gains noted academic recognition for staying at the core of economic growth led by innovation [22]. Regarding this scenario, entrepreneurship initiatives should be at the heart of the innovation policies to promote and stimulate innovation activities. Technology-based companies work intensively in the application of scientific and technical expertise to offer goods and services to create advantages over actual products in the market, which commonly creates a high-aggregated value for them.

In the case of Brazilian companies, the opportunities are mainly in the domestic market because of making business complexity in the country is a barrier to the small outsiders’ competitor’s insertion. Moreover,

in terms of internationalization, the Brazilian companies' opportunities are essentially in markets where the national demand is too small to maintain the internalization of the big foreign competitors' operations, and in markets of developed countries that do not present enough interest for the performance of more structured companies, being the niches of potential success for Brazilian companies [23].

Taking into account the scenery earlier mentioned, a diagnosis is needed to understand the companies' reality. First, mostly, 83% of the technology-based companies are mostly located in São Paulo (42%), Rio Grande do Sul (12%), Rio de Janeiro (9%), Minas Gerais (7%), Paraná (7%), and Santa Catarina (5%), with the Southeast region emerging as the best region for startups, entrepreneurship and innovation ecosystems.

São Paulo is the state with the highest number of startups, and its capital, the city of São Paulo, is the twelfth most attractive city in the world for technology companies. What turns cities into ecosystems that are helpful to innovation is the ability to work together with different areas of government, reducing bureaucracy and establishing agreements among all the actors involved in this process. Furthermore, other features that contribute to this scenery are the availability of skilled workers and access to private and public funds to support the entrepreneurs.

Thereby, as for fundraising, the overwhelming majority of startups (91.8%) have as their principal source of funds the shareholders' equity, where only 20% of companies exceeded the range of R\$500, 000.00 in the initial budget, which is a situation of extreme difficulty in establishing themselves on the market. Such a problem is demonstrated by the fact that 46.2% of startups are still spending more money than making and only 13% are already showing profits in their operations, while only 16% have reached or are still close to breakeven, that is, the balance between income and expenses, with the most expensive phases, operation, and traction, being those that consume the most resources of entrepreneurs.

The sectors that most demand innovative products are Financial Institutions, e-Commerce, Retail, and Education, where 34.05% of companies are involved in business-to-business (B2B), that is, a company promoting business for another company; 24.35% with business-to-consumer (B2C), that is, a company promoting business directly for the final product and 22% are participating in business-to-business-to-consumer (B2B2C), that is, a company promoting business for another company whose goal is to serve an end customer.

Companies with a traditional profile indicate which roles they want to insert themselves in the startup ecosystem: 20% will hire services or purchase startup products, another 20% want to be suppliers to the ecosystem, 19% want to create new startups, 18% want to incubate or accelerate startups, 12% aim to invest in startups and 11% aim to acquire and incorporate new startups.

This brief description concludes with these data that the scenario of the Brazilian startup ecosystem is promising, despite the substantial amount of adversity that must be faced, namely: finding qualified employees, lack of investments, and lack of government incentives and regulation.

IV. Materials And Methods

Lean startup principles that have been introduced so far are not independent of each other. To comprehend Lean startup applied to Brazilian startups, the inter-relationships between its drivers need to be considered. Furthermore, Lean startup principles exert their influences simultaneously, and variation in dependent variables is a result of the simultaneous impact of all the drivers. Therefore, to prove the conceptualization of inter-dependency and simultaneity, a six-stage methodological approach has been developed and applied in this research, as follows:

1. Bibliographic research and questionnaire development - this research seeks to consolidate the teachings proposed by [5] to establish central points of the LS methodology, which are considered the constructs to be investigated among all respondents, then, the main goal is to develop a questionnaire form that works as a bridge between the variables not directly observables and entrepreneurs' responses. Therefore, the defined form is divided into three sections: "About the company", "About management practices" and "About the entrepreneur", where the section "About management practices" aims to investigate how well the respondents are aligned with the LS methodology, that is, represent the constructs, while the sections "About the company" and "About the entrepreneur" served subsidy to investigate qualitative issues, as well as predictive variables;

2. Definition and operationalization of variables - in this stage the goal is to establish the way each variable is measured and also the relationship among them. According to [24], in quantitative studies, operationally defined hypotheses and their planned variables are pre-established and must be clearly outlined. Consequently, a precise and objective measurement should be advocated, meant to avoid relevant distortions in data analysis, ensuring levels of confidence are safe for inferences. Therefore, this research starts from the following hypothesis: H_0

- there is no relationship between the independent variables and convergence with LS methodology, represented by the concatenation of the 12 determined dependent variables. It must be noted that all variables will be

detailed in the next sections;

3. Sampling - a non-probabilistic approach has been chosen for convenience, due to the need of respondents' voluntariness. Such a technique is well accepted in exploratory research since it is not intended to specify generalizations that would take statistical reliability away from the research [25]. The sample size is defined according to the method proposed by [26]. For a 95% confidence interval and margin of error of 5.63%, sample should consist of a minimum of 296 respondents for an approximate population of 12700 startups in Brazil [27];

4. Collection instrument and procedure - The Google Forms tool has been selected to host the questionnaire electronically and centralize responses from participants from 4227 companies to which the questionnaire is offered for response, either in the operation, traction, or scaleup phase, belonging to the database <https://startupbase.com.br/>.

This research is aimed at entrepreneurs who manage startups. As a result, negative responses are common under the argument of being a company of a different nature. The following feedback by one of the respondents stands out: "As we are not startups, it is difficult to answer some research questions, e.g.: do we do not carry out the flow of investment cycles with equity dilution, very common to startups";

5. Item response theory development - once the responses by the entrepreneurs are obtained, this research aspires to develop an IRT model to investigate the quality of the questionnaire items that assess the ability of respondents in a single latent trait (skill in undertaking). So, it is possible to verify this unidimensionality through the scree graph and the dimensionality test by using Samejima's package on the R software ®. This model has been chosen due to the convergence of the results offered by the questionnaire. It also allows construct verification that better discriminates the latent trait of each respondent for undertaking, through the definition of the dependent variables. Furthermore, this package model also offers graphic development for analyzing how much each variable contributes to the total information of the questionnaire, as well as makes this tool available to estimate the total score of a given respondent given his latent trait, the ability as an entrepreneur;

6. Data analysis - this stage aims to infer relevant data through information obtained so far, informing conclusions and supporting decision making. Such analysis helped the results studies to reach an appropriate conclusion for current research. Moreover, it must be noted that the data analysis is divided between descriptive analysis and multivariate statistical analysis.

Regarding the step number 2, all variables are defined according to the methodology described below. First, the qualitative variables are outlined. They are especially important once they allow post-reduction sample stratification for the 12 independent variables. After removing independent variables without relevant factor loading, it is possible to compare whether the respondent profile alignment to the LS methodology is maintained or not. Fig. 1 illustrates the qualitative variables defined for the current research.



Figure 1: Qualitative variables defined for the research.

Afterward, dependent variables are structured in questions to be used as constructs to principles proposed by [5] in the LS methodology. By constructs, it means interpretations and explanations of reality.

Thus, in the proposed questionnaire, the answers obey the 5-point Likert-type scale. The responses closest to 5 (completely agree) are the ones that best follow the recommended principles, while those closer to 1 (completely disagree) are the ones that are least close to the LS methodology. Points 4, 3, and 2 are "partially agree", "neither agree nor disagree" and "partially disagree", respectively. Such questions are presented in Table 1 and the questionnaire is available at <https://url.gratis/1bQp2v>. Finally, it must be noted that all the respondents gave their written consent for participation in the questionnaire.

Finally, the independent variables are determined. Such variables should be ma-

Table 1: Correlation of Dependent Variables and the theoretical framework proposed by [5].

Dependent Variables (Constructs)	Theoretical Framework
V ₁ - Is the level of uncertainty in my company environment too high?	Startups are inserted in environments of extreme uncertainty
V ₂ - Do I seek to apply managerial techniques, even if it implies bureaucratizing the procedures?	Entrepreneurship demands a science
V ₃ - The learning obtained with the client is the main objective of the company	Learning is the main objective of a startup
V ₄ - I test my company's performance through tests comparisons between customer groups	Cohort analysis is a tool of Accounting for Innovation
V ₅ - I prefer to carry out the first tests with less demanding customers	Initial testing should be performed with early adopters
V ₆ - I tend to choose to include both qualitative and quantitative research in the company	Quantitative research should support qualitative research
V ₇ - I prioritize agility when testing business premises with customers	The feedback loop must be accelerated
V ₈ - I do not care about refining the prototype as much as possible before testing it with customers	MVP should be tested as soon as possible
V ₉ - I am open to sudden changes in the planning and management of my company	The number of pivots that a company can still perform corresponds to the time it has to take off
V ₁₀ - I prefer to work with smaller batches, even if it means losing in scale	Small batch power
V ₁₁ - In order to solve the company's problems, I seek to delve into the real cause, without being convinced by the more obvious	Acceleration control by identifying the real cause of problems. The 5 whys techniques
V ₁₂ - I try to form determined teams to be in charge of innovation, through a formal control of the process	Creation of a restricted area (sandbox) for innovation

nipulated to investigate the theory that these characteristics of the entrepreneur would somehow impact the convergence with the constructs of the dependent variables that

link the LS methodology. These variables are also known as predictive, due to their experimental nature, which aims to corroborate a certain suspicion. In the case of the current research, the conjecture is the respondents who presented a better performance in organizational results, considered here: larger companies, more time in business, several companies founded, and a positive perception of the LS methodology would; also present better scores in the dependent variables, constructs that are correlated to the teachings of the LS methodology. The variable "Experimentation as an entrepreneur" has been defined according to [28] because an experienced entrepreneur is likely to follow better paths since he has already learned from mistakes and deals well with unexpected situations. Experience leads to better skills, in other words, skill comes out of experience.

On the other hand, the "Number of companies Founded" variable relates to the fact that entrepreneurs must be willing to face the risks and must be tolerant of failures that will occur, and that can often lead to bankruptcy. Therefore, this characteristic related to persistence is seen positively according to [29].

The "Company development phase" is associated with what is advocated by [30], who state that startups must pay attention to growth and scalability. The same authors add that, for this reason, accelerators,

investors, mentors, and the press also play an important role in startup development.

Ultimately, the independent variable “Affinity with the LS methodology” denotes the respondent’s inclination to implement a learnable and scalable business model that reduces waste and inefficiencies and leads their company to improve the results in an environment of extreme uncertainty [14, 5].

These variables, as well as the dependent variables, are represented on a Likert-type scale, that is the traditional grading proposed by Likert (1932) with a median (neither agree nor disagree) dividing the response possibilities into two groups (agree and dis- agree) was not adopted, but a single scalar gradation, which may or may not be numer- ical. Independent variables characteristics are examined through the section “About you” (first 3 questions), as well as in the last question of the “About the company” section questionnaire made available to entrepreneurs. The independent variables pro- posed for the current research are presented in Table 2.

Table 2: Correlation of Independent Variables and the theoretical framework proposed by [5]

Independent variables (Constructs)	Theoretical Framework
Company development stage	The startup’s focus is scalability
Experimentation as an entrepreneur	Skill comes from experience
Number of companies founded	Good entrepreneurs are fault-tolerant
Affinity with the LS methodology	A learnable and scalable business model that re- duces waste, improves results

Concerning the stage number 6, it must be noticed that statistical analysis has been defined in steps, where initially it is possible to observe the consolidated responses through graphs and tables, as well as attesting how the data are normally distributed in addition to verifying the measurement instrument accuracy through α reliability test of Cronbach.

After the introductory statistics data analysis processing, a multivariate statistical analysis was presented: means difference between the questionnaire results regarding the predictive variables (correlated with the implementation of the LS methodology) were mathematically tested: “Experience as an entrepreneur”, ”Company development phase”, ”Number of companies founded”, ”Affinity with LS methodology” and a variable that concatenates the answers of the respondents to the 12 questions on a Likert scale made available throughout section 2 questionnaire form, to identify the viable re- lation between those variables and adherence to the methodology. To investigate these differences, the Kruskal-Wallis H test is used, a non-parametric version of the analysis of variance (ANOVA) to test H_0 .

For rejection, a lower than 0.05 as a p -value, adopted, α , is required, so it is concluded that the independent variable studied would converge with LS methodology implementation by the entrepreneurs.

Afterward, by verifying which variables are different and statistically significant, that is, for which variable the significance does not reach the value of 0.05, Bonferroni’s post-hoc multiple comparisons test was used to identify where the mean difference impact inside the variable itself. Thus, it is possible to test the hypothesis of independent variables having a relationship or not with the investigated constructs of dependent variables.

V. Results and Discussion

Results from the proposed research method are presented as a combination of the IRT model, descriptive analysis, and statistical analysis from the twelve research ques- tions designed according to the knowledge and premises studied in the bibliographic research conducted. To do so, first, the variables were defined, the non-probabilistic sampling approach was proposed, the instrument for data collecting was created, and finally, the 296 questionnaire answers were collected electronically to facilitate data analysis.

1.1. IRT Model Analysis

Initially, to ensure that the questionnaire converged its measurement into a single latent trait, tests were carried out to allow safe levels to be attained that pointed to unidimensionality.

As proposed previously, the tool chosen to unidimensionality sample analysis was the Scree Plot, whose results of the eigenvalues of factors and components are shown in Fig. 2.

Scree plot is an alternative to cut factors that did not absorb relevant information, for those that can be ignored the once substantial amount of information will not be lost. In this technique, eigenvalues (y-axis) are plotted versus their factors (x-axis), and an inflection point is verified suggesting direction change. Factors beyond the “elbow” curve have no consistent information, leading to the conclusion that only one factor must be kept. Thus,

the unidimensionality is settled.

According to the results shown in Table 3, it was still possible to confirm or not the adequacy of the items to the unidimensional model through the dimensionality test in the R software @after selecting the Graded Response Model as the chosen model.

As it is also illustrated in Table 3, all items in the third column had a ρ -value greater than the significance of 0.05, failing to reject the null hypothesis, in other words, accepting the hypothesis: H_0 for dimensionality: **Data is contained in a single dimension.**

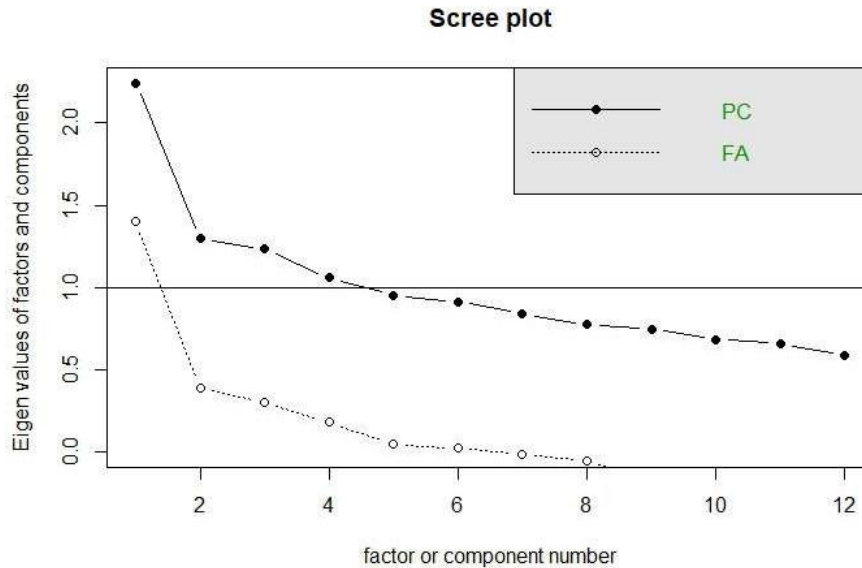


Figure 2: Scree plot showing the eigenvalues for each factor.

Aiming to evaluate the respondent’s probability of giving a correct response to a determined questionnaire item, the GRM model has been processed by using R software @. The R’s model output did not indicate significant values for guessing in any of the 12 questions of the questionnaire, which is why Table 4 shows the processing results and it does not present the column referring to guessing (c). It consolidates the values of discrimination (a_i) and difficulty referring to the boundaries between the five possible answer points for each question (d_i, k).

The item shaded in red, the fifth question (V5) “I would rather carry out first tests with less demanding clients”, has the least discrimination. That is, all respondents, regardless of their skill level as an entrepreneur, have equal chances of answering the item correctly. For the case in question, answering correctly or answering according to the LS methodology implies giving a high answer on the Likert-type scale. Items like those could be removed from the questionnaire without major statistical implications for the study since they are questions that do not express whether the respondents are

Table 3: Dimensionality test

Dimensionality test	Item	ρ -value
1	V_1	0.920
2	V_2	0.086
3	V_3	0.716
4	V_4	0.108
5	V_5	0.713
6	V_6	0.804
7	V_7	0.931
8	V_8	0.092
9	V_9	0.226

10	V_{10}	0.173
11	V_{11}	0.218
12	V_{12}	0.277

Table 4: GRM

	a_1	d_1	d_2	d_3	d_4
V_1	0.192	1.843	0.638	-0.800	-2.355
V_2	0.550	3.597	1.835	0.238	-1.464
V_3	0.745	4.329	3.047	1.409	-0.350
V_4	0.977	2.130	0.972	-0.231	-1.860
V_5	0.093	0.662	-0.240	-1.410	-2.385
V_6	1.148	3.289	2.337	0.868	-0.393
V_7	1.225	4.381	3.358	1.266	-0.549
V_8	0.705	1.294	3.358	-0.780	-1.944
V_9	0.902	4.947	3.415	1.746	-0.170
V_{10}	0.533	2.419	1.253	-0.331	-1.871
V_{11}	1.050	4.794	3.324	1.136	-0.740
V_{12}	0.452	2.343	1.346	-0.077	-1.204

or are not aligned with the object of the study.

Question number five (V_5) requires deeper analysis to estimate the probability of a respondent's skill to answer it and, from the model processing, the analysis results are depicted by the curves P1 to P5, with P1 "totally disagree" and P5 "totally agree". In the case in question, a skilled respondent (6.0) would have about 15% of answering "strongly agree", while a less skilled respondent (-6.0) has about 5% of answering "I agree". I agree", that is, a 5% chance of giving the most correct answer possible, which means that the question was not well formulated. As this is an item that cannot distinguish skilled from unskilled respondents, it is not possible to know through this question which respondents are aligned with the LS methodology. Fig. 3 illustrates the curve of probabilities after processing.

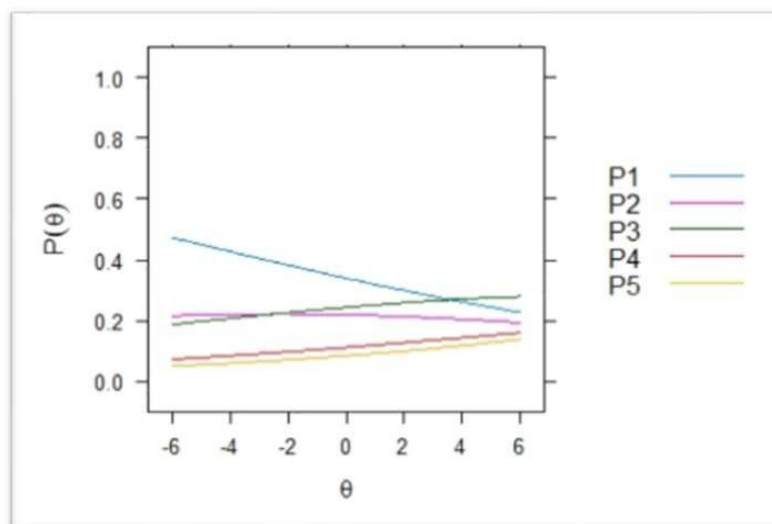


Figure 3: Probability versus ability to answer question number 5.

As for the item shaded in green, the fifth question (V_7) “I prioritize agility when testing business premises with customers” is the question that best discriminates respondents, that is, it is the one that best distinguishes respondents in line with the methodology LS of those who are in dissonance. In questions with a high degree of discrimination, such as V_6 , V_7 , and V_{11} , respondents with a high degree of skill tend to answer correctly (“strongly agree” or “strongly disagree”), while unskilled respondents tend to answer the question wrongly.

Fig. 4 displays P2, P3, and P4 (“partially disagree”, “neither disagree nor agree” and “partially agree”, respectively) as curves with a trend towards normality, which is expected in items of high discrimination, since those respondents of medium ability tend to opt for intermediate answers. Low-skill respondents (-5 to -6) have more than 80% of answering “strongly disagree”, while more skilled respondents (2 to 6) have more than 80% chance of answering “strongly agree”.

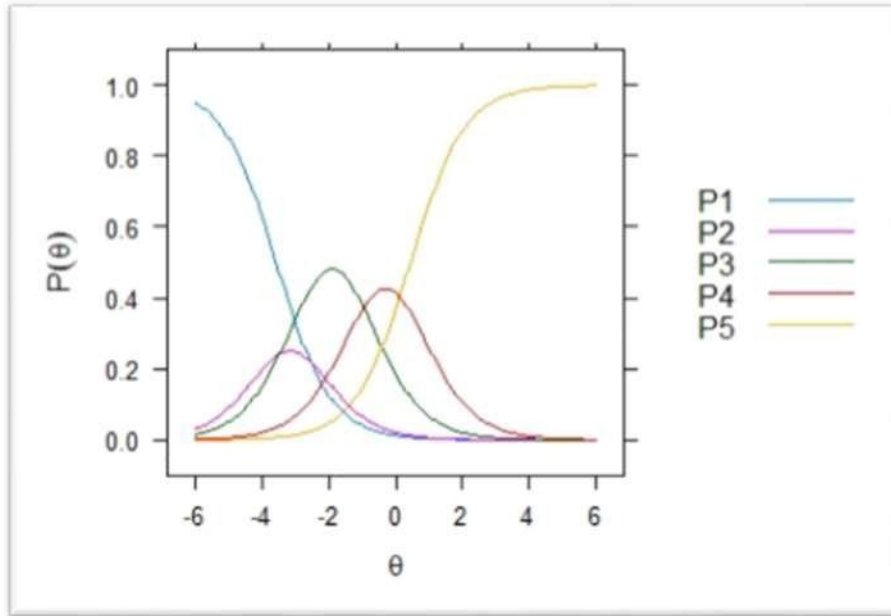


Figure 4: Probability versus the ability to answer question number 7.

Fig. 5, on the other hand, compiles all the “hit probability versus ability” graphs referring to the 12 questions of the questionnaire. The graphical analysis alone makes it clear which are the best and worst questions regarding discrimination: V_1 , V_2 , V_5 , V_{10} , and V_{12} .

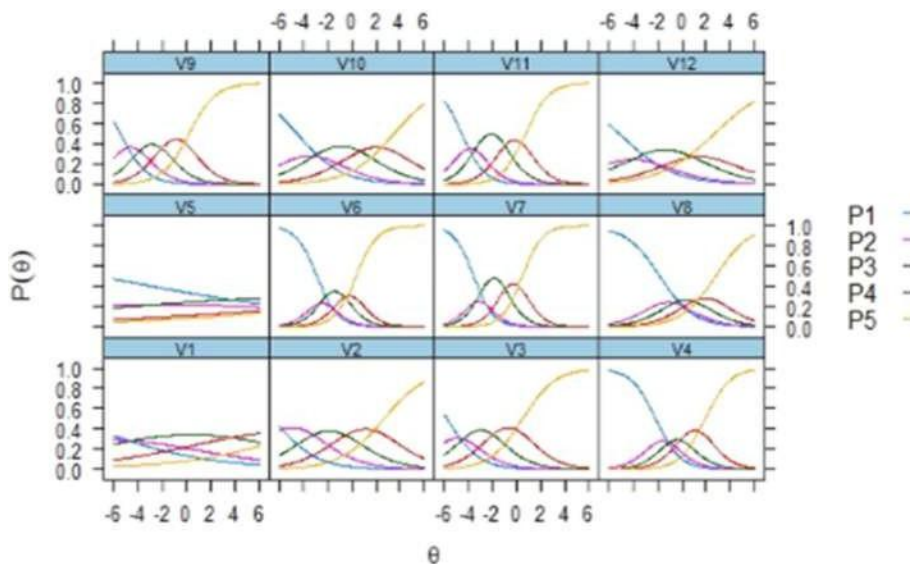


Figure 5: Probability versus ability to answer question number 7.

Lastly, to conclude the IRT Model Analysis another method used to discern which items are useful for the research is the factor analysis. To define whether a question is suitable for the model, it is necessary not to reject H_0 , that is, the value of the null hypothesis needed to be greater than the significance. Under this criterion, the questions V_1 and V_5 with H_0 below significance, 0.013 and 0.003 respectively, while V_2 , V_{10} , and V_{12} also present worrying values close to significance, as shown in Table 5.

The items contributed unequally to the factor: the higher the loading factor, the greater the contribution of the item to the factor. All items that did not reach the value of 0.32 in the loading factor were disregarded. Therefore, they are shaded in orange.

Graphically, it is possible to see the difference between the factor loadings of the twelve items. Fig. 6 represents the “Factor Loadings versus item” plot. It brings the questions that did not reach 0.32 in blue, while those that did are indicated in black.

The total information provided by the test is given by the sum of the information functions of each item. Fig. 7 illustrates the sum and the amount of information available for each skill range.

Table 5: Factor Analysis.

Factor Analysis	Factor Loading	H_0
V_1	-	0.013
V_2	-	0.095
V_3	0.401	0.161
V_4	0.498	0.248
V_5	-	0.003
V_6	0.559	0.313
V_7	0.584	0.341
V_8	0.382	0.146
V_9	0.468	0.219
V_{10}	NA	0.089
V_{11}	0.525	0.276
V_{12}	NA	0.066

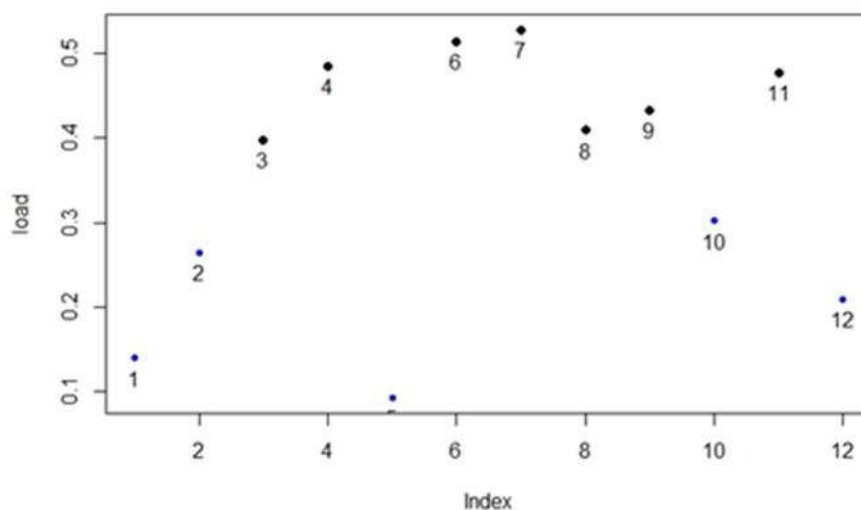


Figure 6: Chart of the Factor Loading from V_1 to V_{12} .

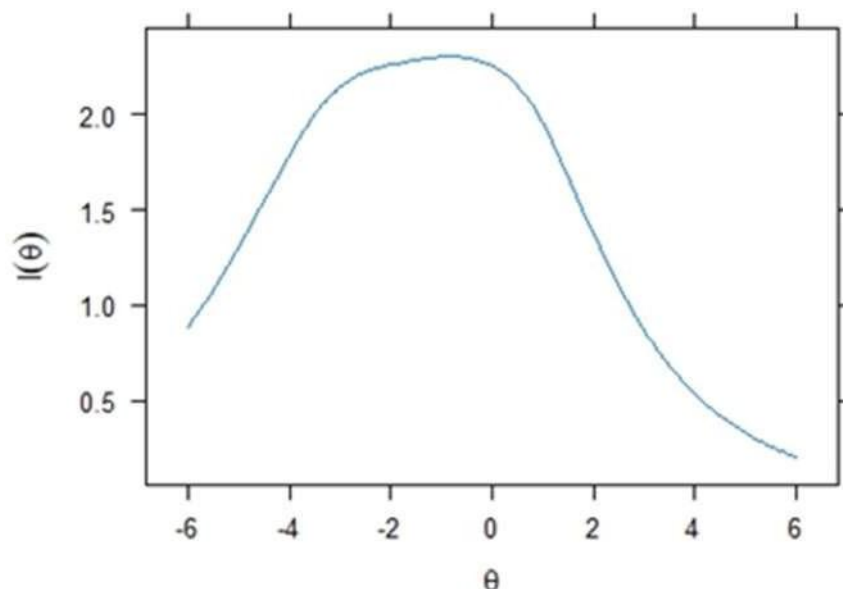


Figure 7: Chart of the Factor Loading from V_1 to V_{12} .

It is noteworthy that this evaluation questionnaire is more suitable for measuring the latent trait of individuals who have a skill level between -3 and 1 , since in this skill range the graph curve reached its inflection point, surpassing the mark number 2 on the ordinate, the y-axis.

By analyzing each graph section shown in Fig. 8, an information graph compilation regarding each question, it is possible to verify which questions provide considerable information and which questions do not contribute substantially. Positively stand out V_4 , V_6 , V_7 , and V_{11} . Items V_1 , V_5 , V_{10} , and V_{12} , on the other hand, report very poor or almost nothing information.

In a nutshell, this section initially aimed to verify the questionnaire developed uni-dimensionality since the IRT requires that all items in a test evaluate a single trait. A test is said to be one-dimensional when it measures a single skill, such as the ability to undertake. The scree plot pointed to a curve tending to an "elbow", suggesting unidimensionality. Similarly, it was possible to calculate the significance of each dependent variable, with all results above 0.05, which confirmed the null hypothesis that the data

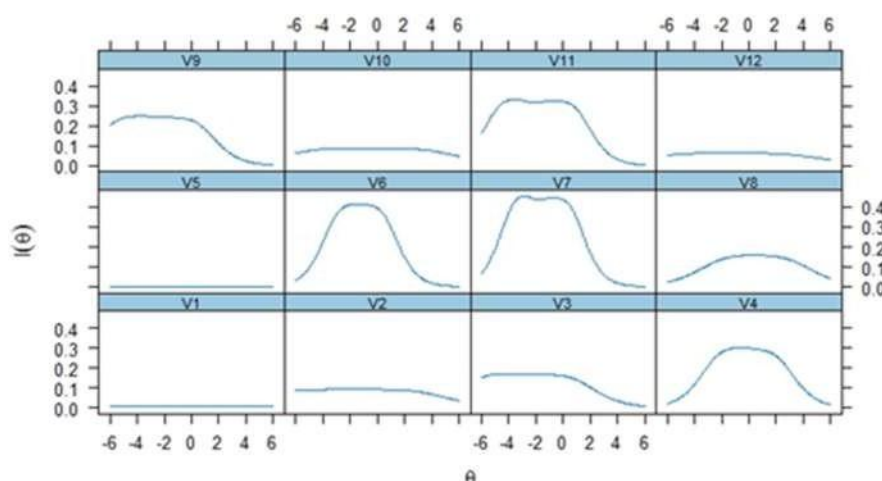


Figure 8: Chart of the Factor Loading from V_1 to V_{12} .

are contained in a single dimension.

Subsequently, the GRM polytomous model was tested and it presented a low number of Akaike, being, therefore, validated to delineate the sample. The GRM model is composed of factors such as difficulty, discrimination, and guessing. As the third did not present significant values, the values referring to difficulty and discrimination were calculated, which allowed the design of a latent trait versus probability graph for each of the 12 questions. Afterward, the factor analysis of 12 dependent variables was carried out to verify which were the questions with a low factorial loading that could be removed later (i.e., that do not contribute to the

estimation of the latent trait).

1.2. Descriptive Analysis

This section aims to differentiate the most varied profiles of respondents through basic information, within the same population studied: entrepreneurs who lead startups. It is divided into descriptive analysis and factor analysis after factor reduction.

The descriptive analysis aims to bring the results regarding the questions presented to the respondents in the "About the company" questionnaire section, except for the last question: "Company development phase". These revolve around the venture size, contemplation in incentive programs, and the source of funding which are key questions for profiling the sample. Such analysis considers all 12 dependent variables, without any consideration of the score of each respondent in the questionnaire.

A summary of the data collected among the 296 right answer is described as follows:

1. **Federative State:** Regarding the geographic location of the startup respondent, the state of São Paulo stood out, with most of the occurrences, 35%. The same was followed by Santa Catarina, 12%, Rio Grande do Sul, 10% and Minas Gerais, 10%.

2. **Companies' invoicing:** at this point, it must be noticed that there are two responses regarding the invoice, the revenue in the first year of operation and the current ones. For the first option, 93.2% of the responses indicated that the company is classified as a micro-enterprise whose annual revenue is less than or equal to R\$360 thousand, 6.1% classifies the company as a small company, whose annual revenue was greater than R\$360 thousand and less than or equal to R\$4.8 million, while only 0, 7% classifies itself as a medium-sized company. In the second response, the current revenue, 62% of the companies continues as small companies, 34% are classified as a micro-enterprise and 4% as a medium-sized company. Therefore, as a conclusion, it can be stated that 37, 68% of the consulted companies increased their revenues and consequently changed their respective status in terms of income.

3. **Companies' size:** When asked about the number of employees in the first year of existence, this research outlined an approximate result that 97% of respondents had up to 9 employees. It stands out the low incidence of companies with more than 49 employees in the first year of existence, with only 1 occurrence. Considering the current number of employees, 72.3% of respondents still have up to 9 employees, 24.3% have from 10 to 49 employees, while only 3.4% present more than 50 workers.

4. **Incentive programs:** the questionnaire also sought to identify those companies that received state incentives to support innovation, either in the form of tax incentives or receiving contributions in the form of financial investment. As a result, only 25% of companies were able to count on state incentives for their businesses, corroborating the study by [31], which indicated that the Brazilian government should seek better alternatives that foster the country's innovation environment.

The nature of the initial investment: regarding such an important business feature for a new business, about 87% of entrepreneurs used their capital to raise funds to make the venture viable, 8% received an initial amount from angel investors, while the 5% remaining raised funds either from loans or state-owned.

The analysis, after factor reduction, aims to use the reduction suggested by the factor analysis to relate, among the remaining dependent variables (V_3 , V_4 , V_6 , V_7 , V_8 , V_9 , and V_{11}), demographic characteristics of respondents with good performance. As the Likert-type scale has 5 points, each question was scored up to a maximum score of 5, indicating greater convergence with the methodology. Fig. 9 illustrates the number of responding entrepreneurs separated according to the respective score range.

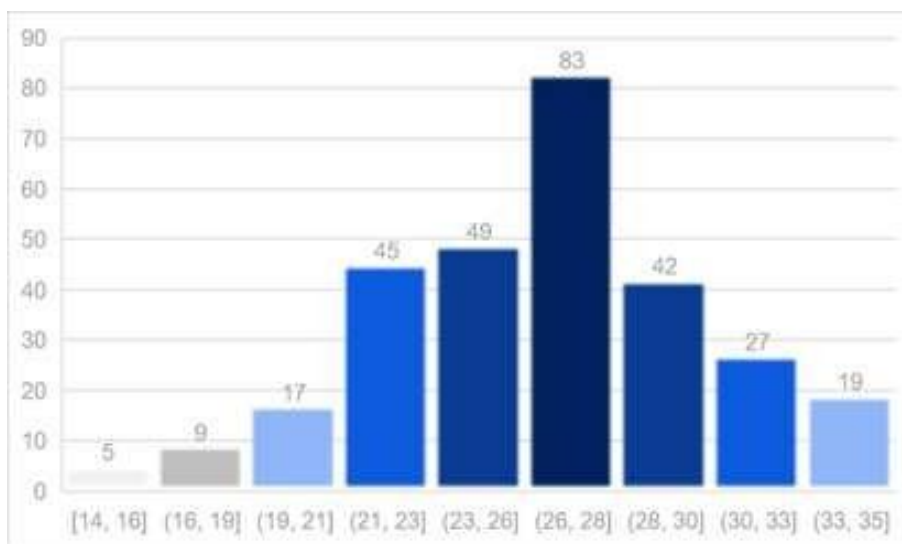


Figure 9: Graph of Entrepreneurs versus score range.

As the data shown in Fig. 9 were normally distributed, the average score of 26.21 was used as a cutoff parameter to define the respondents with the best performance in the questionnaire. Moreover, only 143 of 296 respondents have scored 27 out of 35 or higher. Regarding only the data collected among these selected respondents, a summary is described as follows:

1. **Federative State:** Among 143 respondents who performed above average, 80 are located in São Paulo, Minas Gerais, and Rio de Janeiro. If the states of Santa Catarina, Rio Grande do Sul, and Paraná are added, this number rises to 114. There remain, then, 29 respondents who are distributed in other federative units of the country.
2. **Companies' invoicing:** among the companies that performed well in the questionnaire, in the first year of operation, only 13 companies left the status of micro-enterprise. Considering the current numbers, it is increased to 57 entrepreneurs.
3. **Companies' size:** a similar result was found in the data on the number of employees among those companies that performed above average: in the first year, only 6 companies out of 143 had more than 9 employees, this number jumps to 44 currently.
4. **Incentive programs:** as for incentive programs, the data denotes a higher occurrence of entrepreneurs who had the accelerators and/or incubators collaboration compared to state-owned inventions, where only 38 companies had state incentives, while 69 were incubated and/or accelerated.
5. **The nature of the initial investment:** the investment initially made, in the vast majority of cases, was derived from the entrepreneur's resources, as well. Among the 143 participating surveys with good performance in the questionnaire, only 16 could count on other sources of funds, such as state support and support from angel investors.

1.3. Statistical Analysis

The data raised in this research were tabulated to facilitate the interpretation by those who will access and manipulate them. This is the reason why the answers were centralized in Google Forms®. This program returned a table in .xlsx format with the research results. From then, the data were exported to the programs R® and SPSS®, to perform the statistical analysis of the data. Furthermore, the standard level of significance value like 0.05 or 5% has been selected according to the literature to prove or not the hypothesis.

First, descriptive statistics have been described. Since the numbers on the Likert-type scale have no numerical sense itself because they are a qualitative-ordinal measurement level, it would not make sense to calculate standard and mean deviation values. For this reason, the current research uses only the median and mode as centrality measures.

Table 6 illustrates the measures of centrality processed, which calculated the median, the central value of the distribution for each of the questions, and the mode, the most frequent value of the distribution. As for the median, in 50% of the questions (6 occurrences), the answer was "partially agree", demonstrating convergence with the LS methodology. This inference is reinforced by the occurrence of only one answer

(8.3%) "partially disagree", disagreeing with the LS methodology.

The same trend was repeated in the mode analysis: in only two questions the answer "totally disagree"

predominated, while in 7 occurrences the answers “partially agree” and “totally agree” prevailed. Among the 7 questions, 4 showed total convergence with the methodology when presenting an answer “totally agree”. Moreover, column *n* represents the number of respondents.

Also, through the SPSS software®, it was possible to generate a table with the consolidated values of the frequencies with which each question receives a certain answer. Fig. 10 shows the proportional consolidated values.

Fig. 10 brings the proportional frequency for each question, whose arrangement was from the question with the least convergence with the LS methodology (I would rather carry out first tests with less demanding clients) to the question with the greatest convergence (I am open to sudden changes in my company’s planning and management). The Y-axis presented the 12 questions on a Likert scale (V1 to 12), and the x-axis, in turn, indicated the respective percentage of appearance of the answer. The bars presented 5 colors about the response possibilities according to the Likert-type

Table 6: measures of centrality after processing.

Variables (Constructs)	Valid <i>n</i>	Not-Valid <i>n</i>	Median	Mode
V ₁ - The level of uncertainty of the environment in which my company is inserted is very high	296	0	3,00	3
V ₂ - I seek to apply managerial techniques, even if it implies bureaucratizing procedures	296	0	4,00	4
V ₃ - The learning obtained with the client is the main objective of the company	296	0	4,00	5
V ₄ - I test my company’s performance through test comparisons between customer groups	296	0	3,00	4
V ₅ - I would rather carry out first tests with less demanding clients	296	0	2,00	1
V ₆ - I tend to choose to include both qualitative and quantitative research in the company	296	0	4,00	5
V ₇ - I prioritize agility when testing business premises with customers	296	0	4,00	5
V ₈ - I do not care about refining the prototype as much as possible before testing it with customers	296	0	3,00	1
V ₉ - I am open to sudden changes in the planning and management of my company	296	0	4,00	5
V ₁₀ - I prefer to work with smaller batches, even if it means losing in scale	296	0	3,00	3
V ₁₁ - In order to solve the company’s problems, I seek to delve into the real cause, without being convinced by the more obvious	296	0	4,00	4
V ₁₂ - I try to form determined teams to be in charge of innovation, through a formal control of the process	296	0	3,00	3

scale. The sections of each bar in red indicated divergence with the methodology, the parts in gray denoted a neutral behavior, while the blue ones indicated agreement with

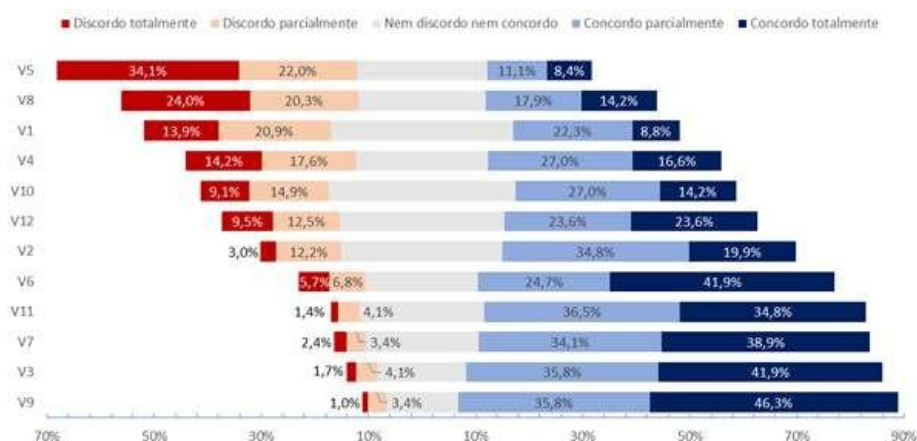


Figure 10: Chart of the Factor Loading from V1 to V12.

the practices proposed by the methodology.

Among all 12 questions, only 3 of them (V5, V8, and V1) showed a predominance of red color, indicating disagreement with the methodology. They were, respectively: “I would rather carry out first tests with less demanding clients.”, “I don’t worry about perfecting the prototype before testing it with customers.” and “The level of uncertainty in the environment in which my company operates is very high.”. Graphically, it was also noticed that the presence of the answers “totally disagree” / “partially disagree”, in red, and “partially agree” / “totally agree”, in blue, formed two pyramids: The first inverted, red, with a thin appearance compared to the blue pyramid: robust. This difference pointed to an agreement with what was proposed by [5].

This convergence became even clearer when all the 296 responses were aggregated, where 53.4% of the responses presented by the entrepreneurs agree with the

methodology, while only 21.8% of them contradict its teachings. Table 7 shows the data consolidated.

Finally, a test of normality has been processed to concatenate, through the additive method, all 296 responses to the 12 dependent variables in a single variable test. This procedure also allowed us to verify the normality of the data offered by the entrepreneurs. The verification of normality occurred through the Shapiro-Wilk test, as

Table 7: Dimensionality test

General frequency (%)	n responses	Percentage
I totally disagree	355	10,0%
I partially disagree	420	11,8%
I neither disagree nor agree	882	24,8%
I partially agree	979	27,6%
I totally agree	916	25,8%
Total	3552	100,0%

shown in Table 8.

Table 8: Test of normality result.

Statistics	Degrees of freedom (df)	Sig. (p-value)
0.993	296	0.227

In conclusion, With an α greater than the established significance, it can be stated that the null hypothesis must be accepted. Therefore, H_0 for normality: Data is normally distributed. This fact can also be concluded through Fig. 9: Graph of Entrepreneurs versus score range

1.4. *Multivariate Statistical Analysis*

This section presents the results concerning the investigation of independent variables' impact in this research. These variables, namely: "Experience as an entrepreneur", "Company development stage", "Number of companies founded" and "Affinity with the LS methodology", were selected because of their potential possibility to successfully correlate entrepreneurs with those that present outstanding performance in the same questions. In other words, it was expected that an entrepreneur who presents good results is experienced, who manages consolidated companies, and who has founded several companies is also fond of the Lean Startup methodology. This paper wants to answer the following problem question: "The implementation of LS methodology improve the results of a startup in the Brazilian context?"

Summarizing the 296 responses for the four independent variables: "Experience as an entrepreneur", "Company development stage", "Number of companies founded" and "Affinity with the LS methodology", it can be stated that: 1) in terms of the experience, 54% of the respondents declared themselves to have more than 6 years of experience, while only 10% of the entrepreneurs said they had up to 2 years of experience; 2) As for the startup's maturity stage, 48% of the respondents are in the Traction or Scaleup phase, while only 12% attest to going through the ideation phase or out of operation; 3) Regarding the number of companies founded, 63% of the respondents said they had founded up to two companies, while only 6% more than 4 companies; 4) Ultimately, about the entrepreneurs' affinity with the LS methodology, only 26% said they did not know the method, while 35% expressed they knew and applied it.

The independent variables aforementioned were investigated using a Likert-type scale, a qualitative-ordinal measurement tool, and for this reason, it does not make sense to use the mean as the data informer. Thereby, it is possible to use the Kruskal Wallis Test, which uses the comparison between medians as a basis.

The test seeks to compare the independent variables versus a variable aiming to represent the use of the LS methodology by entrepreneurs. This variable is constructed using the additive method, whose goal is to create a variable that concatenates the 12 dependent variables to show how entrepreneurs are aligned with the LS methodology, as each dependent variable represents a construct about a principle developed in their theory.

Table 9

Table 9: Kruskal Wallis Test results.

Results\Variable	Experience as an entrepreneur	Company development stage	Number of companies founded	Affinity with the LS methodology
H statistic	0.651	5.662	8.445	12.729
degrees of freedom	4	4	4	4
p-value	0.957	0.226	0.077	0.013

For the first independent variable, "Experience as an entrepreneur", the output generated by the software processing appointed a significance of 0.957, an index well above α . Thus, the null hypothesis was not rejected. Therefore, as a conclusion, this variable had no impact on the use of the LS methodology. In other words, an entrepreneur can be experienced and still not apply the methodology.

The variable "Company development phase", the second one, despite the p-value processed, was significantly lower than the first one, 0.226, it was still well above α . Therefore, the null hypothesis was not rejected, and can be inferred that the variable "Company development phase" had no impact on the use of the LS methodology. It means that a company, even mature, does not apply the methodology or that a newly created company is aligned with it.

Subsequently, the result of the variable "Number of companies founded" presented a significance close to the established α , but still higher, 0.077, as indicated in Table 9, leading to the non-rejection of the null hypothesis due to mere convention. Consequently, it is accepted that the variable has no impact on the use of the LS methodology. That is, it is plausible to expect that even an entrepreneur who founded several companies does not apply the method.

Yet, the independent variable "Affinity with the LS methodology" proved to be a characteristic that impacts the convergence with the LS methodology. In other words, the entrepreneur responding that he/she knows and applies the methodology implies answers for dependent variables that also agree with [5]. This reasoning could

be confirmed by the result presented by the test, which has a significance level in the order of 13 thousandths. In the previous test, the main conclusion was that only the independent variable “Affinity with the LS methodology” is related to the dependent variable that concatenates the 12 constructs. Therefore, it is plausible to infer that not an experienced entrepreneur or one who has founded several companies uses the method, nor does a mature startup necessarily apply the principles proposed by the LS methodology. On the other hand, entrepreneurs who said they had an affinity with the methodology implemented it in their business once the results presented by the concatenated dependent variable pointed to this scenario.

Once the Kruskal-Wallis H statistic values are significant, it is necessary to verify the signature in the two-by-two comparisons using the Bonferroni criterion: groups that are different from each other are those that present an index less than the p -value. So, to verify where this impact is in the dependent variable itself, namely, inside the concatenated variable that seeks to find the alignment of entrepreneurs with the principles of the LS methodology, this research used the Bonferroni post hoc test of multiple comparisons.

The Bonferroni test aims to compare if there are no significant differences between respondents who chose the five different response possibilities concerning the dependent variable with the significance α adopted equal to 0.05.

The test result showed no significant differences between respondents who chose the five different response possibilities concerning the dependent variable since all relationships had a significance greater than 5%. The relationship with the greatest difference was between those who answered “I know and apply their teachings” and those who answered “I’ve heard about it, but I don’t apply it”, once the first has more average, more value (score), it has more positive results regarding the dependent variable. So, it is an almost significant difference since the adopted α is 0.05 and the significance found is slightly higher 0.056. That is, the only statistically reliable information is those who answered: “I know and apply your teachings” have better adherence to the LS methodology. In other words, respondents who chose “I know and apply their teachings”, compared to those who chose “I’ve heard about it, but I don’t apply it”, obtained better scores in the questionnaire (they apply the principles of the LS methodology).

1.5. Results Analysis

This research sought to develop an Item Response Theory model that would fit the 296 respondent entrepreneurs’ sample that had been obtained through the proposed questionnaire. Hence, the sample’s unidimensionality was verified, either through the scree graph or the dimensionality test of the GRM model. It has been chosen because of its better fit and lower Akaike number. This model presented results referring to the values of discrimination (ai) and difficulty (d_i, k).

The results allowed series plots and analysis construction, as follows: 1) probability versus latent trait plots; 2) plot of factor loading versus dependent variable; 3) information versus latent trait; 4) test score versus latent trait. In all these measures, the variables V_1 , V_2 , V_5 , V_{10} , and V_{12} showed low performance, such as they did not discriminate between capable entrepreneurs and bad entrepreneurs, they do not have statistical relevance in comparison with the other constructs, they do not adequately portray the content of the test, and they do not contribute substantially to a respondent’s total test score.

Afterward, a descriptive analysis was performed. It was divided into absolute analysis, which considers all 12 factors related to the constructs represented by the dependent variables, and post-factorial analysis, which disregarded V_1 , V_2 , V_5 , V_{10} , and V_{12} . The first of them showed a higher occurrence of micro-enterprises with up to 9 employees, derived from the South-Southeast axis that did not have state incentives or did not access services from either accelerators or business incubators, whose initial funding came from their resources. Among the 296 respondents, 143 scored 27

points (77.14%) or more for a total of 35 points. Within these, there was no significant difference in sample profile: greater occurrence of micro-enterprises with up to 9 employees, derived from the South-Southeast axis that did not have state incentives or access to services either from accelerators or business incubators, whose Initial funding came solely from own resources.

Later, a statistical analysis was performed. First, descriptive statistics introduced the median and mode for each of the 12 dependent variables, whose results tended to agree with the initial affinity of the respondents with the LS methodology. Second, inferential statistics presented, in the form of a graph and table, the frequency of responses in the questionnaire, the aggregate result, and the reliability analysis through Cronbach’s Alpha. Therefore, the results confirmed that the sample is normally parameterized.

Towards Multivariate Statistical Analysis, consolidated results were presented regarding the independent variables “Experience as an entrepreneur”, “Company development phase”, “Number of companies founded” and “Affinity with the LS methodology”. The results indicated the following trend: entrepreneurs with

more than 8 years of experience, leading companies in the operational phase, which have already founded a single company and in fond with the LS methodology have more likelihood of obtaining success in the Brazilian scenery of technological startups.

To test the following hypothesis:

H_0 : there is no relationship between the independent variables and the convergence with the methodology, represented by the concatenation of the 12 dependent variables.

The Kruskal-Wallis test was used to test each independent variable by joining the 12 dependent variables into a single one, to investigate the relationship between them. Statistically, only the variable "Affinity with the LS methodology", with a sig. (p -

value) of 0.013, was shown to converge with the presented constructs. Likewise, the

variable "Number of companies founded" obtained sig. (p -value) of 0.077, a value close to the p -value (5%) established in the current research.

Therefore, for the independent variable "Affinity with the LS methodology", the Bonferroni correction was applied and it was verified that there were no significant differences between respondents who opted for the five different response patterns. On the other hand, those who answered "I know and apply their teachings" have a higher average (3.02137) than those who answered "I've heard about it, but I don't apply it"

and this difference is very close to being significant (5.6%).

So, it is possible to answer the proposed research questions:

RQ_1 : "Do factors such as the entrepreneur's experience, number of companies founded, business development stage, and affinity with the LS methodology have a direct relationship with the application of its principles in management practices?"

RQ_2 : "Does the implementation of the LS methodology improve the results of a startup in the Brazilian context?"

Among the dependent variables studied, only the affinity with the LS methodology is directly related to the use of LS principles (considering the significance level truncated to the second decimal place: 0.05). In this variable, a statistically significant mean difference was identified among those who answered "I know and apply their teachings" to the detriment of those who answered, "I've heard about it, but I don't apply it". Still, there are safe statistical levels (sig. p -value 0.077) to state that as the entrepreneur finds successive companies, it is more likely to use the LS methodology. With that, it is correct to say that this work was successful in reaching its general purpose since it was possible to verify that the LS methodology is viable in the Brazilian context, a fact subsidized, also, by the fact that most of its principles (dependent

variables) obtained a factor loading greater than 0.32.

Regarding the international context of the current research, other research with a similar methodology has not been found in the literature, therefore, a direct comparison cannot be performed for a proper comparison with other markets. However, the results presented in [32], indicate that, in small and medium-sized companies in different fields in Croatia, a significant number of the examined companies implement some of the lean startup principles and the results show an advantage for them, which suggests that companies are implementing lean principles to adapt themselves to new market conditions using a systematic approach to perform better, pivoting to a greater extent to a new idea becomes a feasible product to be released in the market according to the customer's needs. In a nutshell, such results corroborate with the current research results, which indicate that the lean startup method improves the outcomes of startup companies in Brazil and probably in other similar environments of developing countries around the world.

VI. Conclusion

This article was developed considering the need to improve startup results in the Brazilian market, and the research goal was to analyze the Lean Startup methodology viability in the Brazilian environment, which was hit because it was verified that seven out of twelve dependent variables were investigated ($V_3, V_4, V_6, V_7, V_8, V_9, V_{11}$) are statically significant in the business environment, contributing to startups to escalate their business.

Questionnaire respondents, in general, were fond of LS principles and presented the following demographic profile: They run micro-enterprises with up to 9 employees, derived from the South-Southeast axis that did not have state incentives or access to the accelerator and/or incubator services, whose initial financing came from their resources. Considering the independent variables investigated, only "Affinity with the LS methodology" showed a correlation with the application of the principles of the LS methodology. The main obstacle was finding available entrepreneurs willing to answer the questions. Only 296 out of 5000 did.

Among those who answered "I know and apply their teachings", they obtained a higher average than those who answered "I have heard about it, but I do not apply it" and this difference was statistically significant (p -value of 5.6%). These data showed that the lean manufacturing adaptation to the business reality of Brazilian technology

startups was successful.

The results were reached through the IRT model and statistical tests that correlated the dependent and independent variables and evaluated whether there was a significant difference among those who obtained the highest scores on the questionnaire. Therefore, this paper's contribution involves the rejection, at conservative levels, of the hypothesis initially established: H0: there is no relationship between the independent variables and the convergence with the methodology, represented by the concatenation of the 12 dependent variables.

In other words, there is a direct relationship between a startup implementing a learnable, scalable business model that reduces waste and inefficiencies and improves its results in an environment of extreme uncertainty. Finally, this system of practices improves the company's results. It makes corporate procedures more professional and it makes the business less dependent on specialized employees who play exponent roles.

Finally, in future research, the same methodology used in this research can be used in other fields of developing and developed countries to establish the correlation between the level of implementation of the lean startup methodology and business success. Moreover, the business success can be measured with financial data and the companies' life expectancy to understand whether the lean startup methodology has robustness enough in the long term when the startups need to shift their business model according to the new internal dynamic and external market demand.

2. Declarations

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Conflict of interest The authors declare no competing interests.

Availability of data and material No data generated or analyzed during this study are included in this published article.

Code availability No code generated during this study is available in this published article.

Ethics approval Not applicable. **Consent to participate** Not applicable. **Consent for publication** Not applicable.

References

- [1]. D. Richard, A. Erik, Lean startup—a practical evaluation of a vacation home renting service.
- [2]. J. Obi, A. S. Ibdunni, A. Tolulope, M. A. Olokundun, A. B. Amaihian, T. T. Borishade, P. Fred, Contribution of small and medium enterprises to economic development: Evidence from a transiting economy, *Data in brief* 18 (2018) 835–839.
- [3]. J. C. A. DORNELAS, Empreendedorismo: transformando ideias em negócios. 5ª (2001).
- [4]. C. Donaldson, Intentions resurrected: a systematic review of entrepreneurial intention research from 2014 to 2018 and future research agenda, *International Entrepreneurship and Management Journal* 15 (3) (2019) 953–975.
- [5]. E. Ries, *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*, Currency, 2011.
- [6]. R. R. Suryono, I. Budi, B. Purwandari, Detection of fintech p2p lending issues in Indonesia, *Heliyon* 7 (4) (2021) e06782.
- [7]. S. Blank, B. Dorf, *The startup owner's manual: The step-by-step guide for building a great company*, John Wiley & Sons, 2020.
- [8]. D. A. Reis, A. L. Fleury, M. M. de Carvalho, Toward a recursive stage-based framework for supporting startup business initiation: An exploratory study with entrepreneurs, *IEEE Transactions on Engineering Management* 68 (4) (2019) 999–1013.
- [9]. X. Yang, S. L. Sun, X. Zhao, Search and execution: examining the entrepreneurial cognitions behind the lean startup model, *Small Business Economics* 52 (3) (2019) 667–679.
- [10]. J. Kilpatrick, *Lean principles*, Utah Manufacturing Extension Partnership 68 (1) (2003) 1–5.
- [11]. J. P. Womack, D. T. Jones, *Lean thinking—banish waste and create wealth in your corporation*, Journal of the Operational Research Society 48 (11) (1997) 1148–1148.
- [12]. I. Daniyan, A. Adeodu, K. Mpofu, R. Maladzhi, M. G. K.-K. Katumba, Application of lean six sigma methodology using DMAIC approach for the improvement of bogie assembly process in the railcar industry, *Heliyon* 8 (3) (2022) e09043.
- [13]. M. Graban, J. Toussaint, *Lean hospitals: improving quality, patient safety, and employee engagement*, Productivity Press, 2018.
- [14]. S. Blank, Why the lean start-up changes everything, *Harvard business review* 91 (5) (2013) 63–72.
- [15]. D. J. Hansen, J. H. Deacon, V. Pascal, Z. Sethna, The future is in the past: A framework for the marketing-entrepreneurship interface (mei), *Journal of Business Research* 113 (2020) 198–208.
- [16]. D. Olsen, *The lean product playbook: How to innovate with minimum viable products and rapid customer feedback*, John Wiley & Sons, 2015.
- [17]. T. Eisenmann, *Business model analysis for entrepreneurs*. Harvard Business School.
- [18]. J. Bicheno, M. Holweg, *The lean toolbox*, Vol. 4, PICSIE books Buckingham, 2000.
- [19]. M. Uto, M. Ueno, Empirical comparison of item response theory models with rater's parameters, *Heliyon* 4 (5) (2018) e00622.
- [20]. A. A. Bichi, R. Talib, Item response theory: An introduction to latent trait models to test and item development., *International Journal of Evaluation and Research in Education* 7 (2) (2018) 142–151.
- [21]. K. Sijtsma, L. A. van der Ark, A tutorial on how to do a Mokken scale analysis on your test and questionnaire data, *British Journal of Mathematical and Statistical Psychology* 70 (1) (2017) 137–158.
- [22]. E. Stokan, L. Thompson, R. J. Mahu, Testing the differential effect of business incubators on firm growth, *Economic Development Quarterly* 29 (4) (2015) 317–327.
- [23]. F. F. Ribeiro, M. M. Oliveira Jr, F. M. Borini, Accelerated internationalization of technology-based firms: The case of Brazilian born-globals, *Revista de Administração Contemporânea* 16 (6) (2012) 866–888.
- [24]. A. S. Godoy, Introdução à pesquisa qualitativa e suas possibilidades, *Revista de Administração de Empresas* 35 (2) (1995) 57–63.
- [25]. T. d. Oliveira, Amostragem na probabilidade: adequação de situações para uso e limitações de amostras por conveniência, julgamento e quotas, *Administração on line* 2 (3) (2001) 01–10.

- [27]. A. Dean, Openepi: open source epidemiologic statistics for public health, [http://www. OpenEpi. com](http://www.OpenEpi.com).
- [28]. R. L. La Rovere, G. de Oliveira Santos, B. L. X. Vasconcellos, Desafios para a mensuração de ecossistemas de inovação e de ecossistemas de empreendedorismo no brasil, *Revista de Empreendedorismo e Gestão de Pequenas Empresas* 10 (1) (2021) 6.
- [29]. F. Kon, D. Cukier, C. Melo, O. Hazzan, H. Yuklea, A panorama of the israeli software startup ecosystem, Available at SSRN 2441157.
- [30]. P. KALLBERG, An analysis of brazil's startup ecosystems as a nurturing force for internet-based startups: Friend or foe, Trabalho de Conclusão de Curso (Bachelor of Science degree)-The School of Business, University of Warwick.
- [31]. G. R. Manfrinatto, L. P. Striquer, A. S. Wolf, Análise e controle do crescimento de startups, *Caderno PAIC* 21 (1) (2020) 97–112.
- [32]. L. Silva, M. Rapini, S. Schultz, et al., Instrumentos financeiros de apoio à inovação: como é a participação das empresas mineiras., *Anais do Seminário sobre a Economia Mineira* 14.
- [33]. M. K. Čalopa, K. Kokot, I. . Kokotec, Level of knowledge and implementation of lean methodology in small and medium-sized croatian companies, *TEM Journal* 9 (1) (2020) 276–285.