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A proposal of indicators for the development of Brazilian scientific research in the perception of specialists

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Abstract

This study proposes indicators that guide the induction, contraction and monitoring of scientific research whose funding source is government resources. The bibliographic research methodology enabled the mapping of a set of variables through the application of questionnaires to specialists and the use of the Fuzzy Delphi technique in order to analyze the selected variables selected validated by the specialists. The results identified 34 important indicators that can guide the induction, contracting, monitoring and results of scientific research to reduce any discrepancies in the analysis of research projects financed by organizations and instances that promote scientific research. Such validated indicators can serve as important public policy indicators to optimize the use of research resources. It is possible to conclude that the proposal favors the development of a research project management flow as reflected in the systematic use of indicators.

Keywords: Fuzzy Delphi method, Management indicators, Scientific research.

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1. Introduction

The worldwide scientists work can be verified by the different themes and their metrics which are published annually by the Organization for Economic Cooperation and Development (OECD) in its reports which are classified as one of the most credible sources on comparative evolution. Various research indicators provide the legal basis for defining public research policies in Brazil [1, 2].

The OECD is organized by countries that discuss public and economic policies with the aim of contributing to the development of the economy and the social well-being of people around the world, defining some standards to guide analysis, discussions and decisions for the implementation of solutions to possible problems [3]. For this reason, the following lists of indicators were found that served as a basis for the development of scientific research: Resources applied to research [4, 5], human resources in scientific research [5-7], measure of scientific production [8, 9], number of patents developed [10], impacts of scientific and technological activities in the market [7, 10-12] and economic series [13, 14].

In order to elaborate an effective analysis, the mentioned indicators were presented to the specialists who are necessary to unfold the study and identify indicators and sub-indicators that ensure the analysis of projects in addition to human and technological development, guarantee the technical, scientific and institutional legitimacy of research. The existing consensus in the literature is that the use of these indicators needs to be improved in order to favour an increase in invested resources and the internationalization of science for the sustainable development of countries [15]. In the opposite direction from the current policy of financial investment by national and international development agencies, these indicators are insufficient and made difficult by the identification of common aspects among different areas which has an impact on the operational structure of scientific and technological activities as production measures [16]. In 2018, Brazil invested only 1.16% of its gross international product in research and development (R&D) while the world average is 2.21% [17].

A gap is observed in indicators that guide the induction, contracting, monitoring and results in the analysis of scientific research projects financed by research institutions and instances of scientific research promotion as there is a difficulty in equalizing the interests of the various areas of knowledge [18].

Belcher, et al. [19] noted that the Brazilian context presents a lack of indicators that support managers in making decision about the development of research. As a result, it is difficult to verify the effectiveness of scientific results that influenced the verification of the alignment between the development of research and the aspirations of society [19].

For this reason, it is necessary to analyse in detail the motivation for adopting research policies and the relationship between the different origins of research incentive policies with any possible variations that may occur between the mechanisms used that favour understanding the dynamics and factors of the research.

Thus, science, technology and information (STI) policies must provide an environment that favours new modes of governance with the inclusion of new approaches to collaboration overlooking the concept that all collaboration is good and contributes to progress [22, 23].

2. Development of Scientific Research

The process of training human resources throughout the development of scientific research is still a challenge. Thus, it is possible to verify the formative path by which the researcher develops a particular topic or field as he already has the intellectual foundations for the construction of robust studies guiding the academic career from scientific initiation (SI) to doctorate [24, 25].

The benefits of training human resources are also noticeable in the region where the promotion is used as resource efficiency and human capital expenditure are good investments for the social context. Recent studies have found that eliminating side effects reduces social returns [25].

The training of professionals for scientific research is not limited to the academy. Although it is difficult to financially quantify the application of resources to research. it is observed that factors related to the process influence the recruitment of labour such as the heating up of the labour market [26]. Investment in SI is the main program for training human resources for research in low-income countries such as Brazil is perceived as a differential in performance as it reinforces the importance of prioritizing and measuring actions in regions with the lowest levels of education systems [25].

The evolution of science contributes to the routine reassessment of the aspects that include the scientific production that are not limited to knowledge. In this context, there is a demand for a research product that can also serve to reassess the quantification and standards of the indicators used [27-29].

It is worth mentioning that the Brazilian Ministry of Science, Technology and Innovation NCSTD does not mention the economic impact because these indicators are specific to OECD reports. The difficulties faced by Brazil are related to the distant link established by "path dependent" in which the country's low economic development stimulates economic isolation and distances the business world from the challenges of following the economic series, culminating in low productivity in the number of patents developed, a low competitiveness, a low technological level and growing social inequality [30].

Therefore, the use of technological and scientific activities in the development of research favours the strengthening of the coordinators' leadership and its management committee to generate trust among the institutes members, companies and government representatives, favouring the alignment with a collaborative and innovative culture with space for proposing new ideas and valuing knowledge and management which facilitates national development through the transfer of knowledge and technology [31].

The agreements between the institutions are an important element in this cooperation process as they formalizes the research network, increase the accuracy of information on the state of scientific agreement and increase the impacts of scientific and technological activities on the market [32, 33]. The topic has already been advanced and discussed in higher education.

Thus, it is observed for the development of scientific research, it is important to use clear and distinguishable indicators by society generating participation in a virtuous circle of scientific and technological dependence on the country.

3. Materials and Methods

Bibliographic research is the basis of the methodology of this study through which a set of variables was mapped, from which the empirical research was developed, with the application of questionnaires to specialists and the use of the Fuzzy Delphi technique in order to analyse the variables selected and validated by the researchers or specialists who composed the sample of this study.

Therefore, the methodology used in this research can be classified as mixed, since it maps and organizes the variables (qualitative research) and establishes their importance and strengths (quantitative research) and thus seeks to avoid the use

of fragmented information as it is insufficient to understand reality. Whenever methods become obsolete, there is a need to implement new models that cover more current research [34, 35].

Researchers with a productivity grant from the National Council for Scientific and Technological Development (NCSTD) formed samples, the main government organization responsible for formulating research policies, contributing to advance the frontiers of knowledge, sustainable development and national sovereignty at levels 1 and 2 (who need to be outstanding in their research areas to receive the benefit), with experience in the management of results through the promotion of research either in their higher education institutions (HEIs) or in funding agencies. All are participating in graduate programs (PGP) and some are part of the faculty of programs of excellence in the evaluations of the Coordination for the Improvement of Higher Education Personnel (CIHEP).

In this research, stratified random sampling was used as this technique allows statistical calculations to be carried out in two stages. The first consists of identifying the levels of scholarship holders and the second involves directing a specific instrument for each group. The stratification can be presented naturally or be performed according to the researcher's indicators [36].

The bibliographic research for the documentary survey of the literature was based on a collection of recent scientific articles. Therefore, this research was based on publications with a good impact factor providing the ability to enrich the material with current and relevant data [37]. A thorough analysis of this literature was essential to minimize failures and contribute to the planning of work with new questions related to the topic and the area of knowledge [38].

The next step used in this research was to administer three questionnaires (Q1, Q2 and Q3) through three surveys. A set of 60 indicators was used to guide decision-making related to the development of scientific research. Initially, the indicators were presented to the group of researchers in category 1 of the NCSTD levels A and B (Q1) with closed-ended questions. In the second questionnaire (Q2), category 2 researchers were presented with a list of indicators and asked which of these would have more adherence to the construct in which these researchers were inserted, with the purpose of identifying the level of importance and use, eliminating those that were not mentioned. For the last questionnaire (Q3), the group of researchers from category 1 (level A) was presented with the results of Q2 asking them to classify the level of importance as “low”, “medium” and “high.

Figure 1 presents an outline of the research development along the phases.

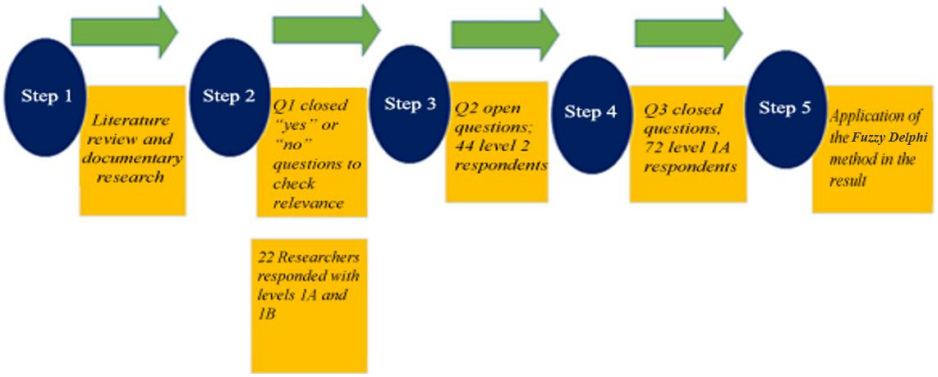

Figure 1.
Search protocol.

The protocol was important to guide and organize the sample of professors and researchers at the NCSTD productivity level whose comments were observed for the construction of the research which was a differential since decision-making power is concentrated in those who have category 1 (levels A and B). Thus, it was possible to process the data mapped in the literature and perform the presentation in the middle of the routine submission of research projects by researchers at different levels, a moment that characterized the pre-test. In the Q1 pre-test, comments from three researchers were noted. In this way, it was possible to guide the application of the three subsequent questionnaires, Q1, Q2 and Q3 in which the indicators formed the basis on which the Fuzzy Delphi technique was used.

Triangular Fuzzy numbers were used to evaluate performance indicators. In addition, we adopted a geometric mean model [39] to determine the Fuzzy weights of the specialists' answers as shown in the formula below.

$$W_j = (a_{jL},\ b_{jM},\ c_{jN}) = \left(min_k a^k_{jL},\ (\prod_{k=1}^{k} b^k_{jM})^{\frac{1}{k}},\ max_k c^k_{jN} \right) \quad (1)$$

Equation 1 presents the three elements that need to be identified to apply the Fuzzy Delphi method namely: “a” is the minimum value, “b” is the average of signals and “c” is the maximum value. The specialist’s contribution to each criterion was converted into Fuzzy numbers that correspond to the j-th criterion provided by the i-th expert and are represented as: $Z_{ij} = (p_{ij}, q_{ij}, r_{ij})$ para i = 1, 2, 3, ...*n* and j = 1, 2, 3, ...*m*

Where n is the number of specialists and m is the number of indicators.

Finally, the average method is used to calculate the defuzzification value Pj according to the following formula:

$$P_{j=\frac{a_{jL}+b_{jM}+c_{jN}}{3}} \quad (2)$$

In Equation 2, after identifying the elements that make up the approval, it is possible by means of the simple average "Pj" to advance in the analysis using a threshold (α) to select or reject indicators. If Sj ≥ α, then select the criterion. If Sj <α, the criterion is not accepted.

For the analysis to be effective, only the frequencies of the variables validated by the Fuzzy Delphi were worked on called "clean frequencies" which were coded in 1-5 where 1 was low, 2 was low, 3 medium, 4 was high and 5 was extremely relevant.

3.1. Results

The empirical study was carried out through the application of questionnaires to select group of specialists with experience in the preparation of public notices and calls that guide the recognition of academic merit.

On the other hand, the application of the questionnaire was guided by carrying out a pre-test in June 2022 with three professors having more than 20 years of research in a Productivity Scholarship in Technological Development and Innovative Extension from NCSTD at category 1 and responsible for defining calls for the application of resources intended for research in their HEI to guide the adequacy and clarity of the questions . Therefore, with this contribution it was possible to filter some items and take advantage of the indicators presented.

As a result, items with characteristics of bias, redundancy and dubiousness were removed. Once the material was ready, it served as the basis for the construction of Q1. After these filters guided through the Google Forms tool which allows the customization of questionnaires and provides the access link, it was possible to build the research instrument for the preparation and application of online questionnaires.

Results obtained at each stage of the research process are presented below.

Table 1.
Basis of the literature in the identification of the 60 indicators.

No	Indicator	References
1	Identification of adherence to the theme	[40]
2	Identification of the knowledge area	[40]
3	Identification of the scientific production of each researcher under observation over a period of time	[40]
4	Number of ongoing research projects whose objectives or products are directly linked to society's priorities from the perspective of technology	[41-43]
5	Number of ongoing research whose objectives or products are directly linked to society's priorities, from the perspective of regional demands	[44]
6	Percentage of ideas approved in collaboration with customers	[45, 46]
7	Search with multi-country themes	[47, 48]
8	Resources executed in previous projects (%)	[6, 7, 49, 50]
9	Number of qualified demands for projects by area of knowledge	[6, 7, 49, 50]
10	Number of multifunctional equipment working	[49-54]
11	Number of international teams	[55, 56]
12	Number of teams trained in multi-user equipment	[49-54, 57]
13	Number of managers trained in management methods and tools	[50, 58]
14	Number of non-conformities of contractors for the project fulfilling all contracting stages	[10]
15	Number of new searches versus ongoing searches	[6, 7, 49, 50]
16	There are not enough researchers per activity	[49-54, 57]
17	Number of projects by knowledge area	[6, 7, 49, 50]
18	Number of human capital stock	[49-54, 57]
19	Percentage of new ideas generated versus the total submitted	[45]
20	Percentage of equipment users at other institutions versus total users	[59]
21	The value and proportion of research funding from public sources versus private capital	[50]
22	Amount and proportion of financial resources applied to research versus total ministry of science, technology and innovation budget	[60, 61]
23	There were activities to organize courses, events in the project area	[3]
24	Number of innovations compatible with current attitudes and work or personal routine	[62]
25	Number of absenteeism among the research team	[49-54, 57]
26	Number of R&D assets and strategies	[50, 63, 64]
27	Number of equipment and tools or technology availability	[65]

No	Indicator	References
28	Number of external financings that make up the remuneration	[49-54, 57]
29	Number of internal and external sources of knowledge and information	[66, 67]
30	Number of hours required to complete the project	[68]
31	Number of ideas generated externally	[45]
32	Number of ideas not initially foreseen in the project or number of ideas implemented	[69]
33	Number of innovations carried out	[45, 70-72]
34	Number of corrective maintenance	[56]
35	Number of unconventional means used	[50, 73]
36	Number of new environments	[50, 73]
37	Number of support requests	[45, 58, 74]
38	Number of agile processes Teamwork	[68]
39	Number of processes not submitted to the ethics committee	[10]
40	Number of theses and dissertations produced by the research	[6, 7]
41	Number of returns on investment with innovations	[74]
42	Percentage of projects versus amount of labour employed	[49, 50, 75]
43	Number of articles or papers published by the research project	[6]
44	Team turnover	[6, 7]
45	Verification of products obtained	[76]
46	Annual cost of tools	[77-79]
47	Identification of technical requirements and operational costs for implementation of results and recommendations	[80]
48	Number of actions for the dissemination of knowledge	[81, 82]
49	Number of alliances in R&D	[83, 84]
50	Number of knowledge and technology transfer activities with a research institution or higher education institutions	[85, 86]
51	Number of hours dedicated by managers to process innovation compared to legacy operational tasks	[68, 87]
52	Number of individuals or groups influenced	[50, 73]
53	Number of international partnerships and agreements	[58, 75, 88]
54	Number of internationalized PGPs	[1, 24, 89, 90]
55	Number of problems identified in the product, process etc.	[58, 91]
56	Number of technical publications	[58, 75]
57	Percentage of achievement of research in economic series versus what was proposed in the initial project	[13]
58	Percentage of approved research projects with clearly defined results and recommendations	[92]
59	Percentage of approved amounts that were not executed versus total cost	[75, 93]
60	Proportion of products with patent registration	[10, 62]

3.1.1. Step 1 - Mapping of Variables in the Literature

Applicability focused on literature review and documental research in databases and institutional websites enabling the identification of 60 indicators that make up the research promotion process namely, induction, contracting, monitoring and results encompassing the documental part and the scientific material, generating the construction of four dimensions to support the process of evaluating research development as shown in Table 1.

A bibliometric verification that accompanied the literature review contributed to citation analysis and has an increasingly prominent place in research governance at the international, national and institutional levels [94]. The analysis was developed on the proposed theme after the consolidation research carried out in the current literature. This analysis was based on the text mining model of *web bliomining* proposed by Costa [95] to systematize and guide the structuring of the bibliographic review.

The three most important citation databases in the world were used to develop the bibliographic survey of the data namely: SCOPUS, SciELO and Web of Science. They allow analysis through filters and combinations that lead to understanding through the indexing of dissertation articles and publications in journals.

Thus, these bases were used for the development of the research to identify the general quantity of publications. Initially, using the selected bases as entry criteria into the system, the keywords were composed by crossing the central words resulting from the Boolean combination of the words (*research funding*) and (*selection criteria)* or (*regional development*). The search result took place between January and March 2022. As a result, the number of items was reduced from 1.658.325 to 28 articles used to structure Table 1.

3.1.2. Step 2: Application of the Q1

The Q1 was answered in January 2022 by the e-mail triggering functionality with the previously defined list of participants. A letter from the doctoral student was sent by the coordinator in the first section of the form to the researchers involved.

The introductory part of the questionnaire explains its objective and the target audience; a call to participate in the research emphasizing these elements contributes essential elements to the proposition of a system that guides the distribution of research grants in the Brazilian scenario.

For Q1, the sample consisted of 12 professors who act as productivity researchers of category 1 (level A) with capacity in the continuous training of human resources and in the management of development agencies in their regions, in addition to being or having already exercised the function of coordinators of a graduate program, knowing and maintaining a close relationship with the indicators widely used today to measure research development.

The questionnaire consisted of 60 closed-ended questions (yes or no) whose objective was to assess the level of adherence of the indicators to the research topic. Therefore, 12 indicators were chosen by the respondents. It was possible to indicate and evaluate the level of adherence of the indicators to the research topic, qualifying the number of items to be evaluated in the next step.

3.1.3. Step 3: Application of the Q2

The reduction of indicators, based on the analysis of the results obtained with the application of qustion 1 gave rise to question 2. As a sample, 44 professors were chosen. Most of them have more than 10 years of experience in research and a current productivity scholarship in research category 2 in which there is no specific level to characterize the researcher's productivity. It's a very heterogeneous level. There were two groups of researchers: those who reached the top in their careers and those who started their careers as scientists. This group has a much smaller representation in relation to the management of funding agencies in their regions; they work in PGPs and have already served as postgraduate coordinators but all are well acquainted with the indicators widely used today to measure research development.

Question 2 was sent through Google tools in August 2020 and treated with content analysis. It is composed of open-ended questions with the objective of seeking alignment between the public notice and the demands of society pointing out which of the items listed should be included in the evaluations of research developments as shown in Table 2.

The list of 60 indicators was consequently reduced to 30 after the application of question 1 and level 2. Researchers had the opportunity to express their opinions about possible adjustments to the indicators.

3.1.4. Step 4: Application of the Q3

From the analysis of the results of step 3 which encompassed 30 indicators, a set of 34 indicators was chosen resulting in Q3. Therefore, the composition of the list of 34 indicators considered at the beginning of the survey was reduced to 20 indicators through a content analysis carried out by experts.

In this phase of the research, the sample consisted of 22 professors who work at a category 1 productivity level at levels A, B, C and D that is recognized on a comparative basis by their peers. It is a very heterogeneous group composed of researchers who have reached the top of their careers and work in research management at their institutions or funding agencies and have already served as postgraduate coordinators. We were all familiar with the indicators widely used today to measure research development.

This sample group was classified according to the areas of science knowledge which in Brazil is a grouping of eight areas of knowledge (Exact and Earth Sciences; Biological Sciences; Engineering; Health Sciences; Agricultural Sciences; Applied Social Sciences; Human Sciences; Linguistics, Letters and Arts) and in a macro way they can be grouped into three major schools, Life; Humanities; and Exact and of the earth.

As a data collection instrument, the questionnaire applied in September 2020 through a Google tool was composed of closed-ended questions with the objective of seeking alignment between the public notice and the demands of society pointing out which of the items listed should be included.

Table 2.
List of the 30 identified indicators.

No	Indicator
1	The number of ongoing research whose objectives and products are directly linked to society's priorities from the perspective of technology.
2	The number of ongoing research with objectives and products directly linked to society's priorities from the perspective of regional demands.
3	Percentage of ideas generated in collaboration with customers.
4	Search with multi-country themes.
5	Number of resources executed in previous projects (%).
6	Number of qualified demands for projects by area of knowledge.
7	Number of multifunctional equipment in operation.
8	Number of international teams.
9	Number of teams trained in multi-user equipment.
10	Number of non-conformities of contractors for the project fulfilling all contracting stages.
11	Number of innovations compatible with current attitudes and work/Personal routine.

No	Indicator
12	Number of R&D assets and strategies.
13	Number of equipment and tools or technology availability.
14	Number of ideas generated externally.
15	Number of innovations carried out.
16	Number of unconventional means used.
17	Number of new environments.
18	Number of agile processes teamwork.
19	Number of theses and dissertations.
20	Number of returns on investment with innovations.
21	Number of published articles.
22	Annual cost of tools.
23	Number of actions for the dissemination of knowledge.
24	Number of alliances in R&D.
25	Number of knowledge and technology transfer activities with a research institution or higher education institutions.
26	Number of individuals or groups influenced.
27	Number of international partnerships and agreements.
28	Number of internationalized PGPs.
29	Percentage of approved values that were not executed versus total cost.
30	Proportion of products with patent registration.

3.1.5. Step 5: Application of the Delphi Fuzzy Technique

According to step 4, the application of the Delphi Fuzzy technique allowed the prioritization of variables related to the quantity of 34 items.

This technique consists of presenting a consensus among professors with consultations lasting up to four rounds. However, the traditional Delphi method has low convergence and high execution costs. Overcoming these disadvantages, the integration and association of Fuzzy logic make the new methodology called the Delphi Fuzzy method present in just one round of research [96].

In the data generated by the different levels of expert participation, it is possible to increase the accuracy of the results and reduce the uncertainties of expert opinions to explore the efficiency of reinforcement allowing group decision-making with an approach that favours a rapid convergence in the forecast and then helps managers to decide faster [97].

As an appropriate technique for research, since public notices common to different areas of knowledge are considered in this study, it can lead to different perceptions about the importance of indicators depending on each area, since Fuzzy allows for fluctuation rather than absolute precision.

The Fuzzy Delphi analysis allows the prioritization of indicators and the calculation of the set allows identifying the most important ones within the Fuzzy pointing out the relevance not only by ranking but also by the lack of certainty and precision.

4. Consolidation of Results

Table 1 presents the indicators considered responsible for inducing a research policy based on the results of the questionnaires.

Data are kept in four categories with the following nomenclatures: induction, contracting, monitoring and result. With Q3 defined, the distribution was no longer unequal and by listening to three levels of important researchers which is rare and usually restricted to category or level 1, the open-ended questions answered by the level 2 researchers aimed to capture the perception of the researchers. Participants talked about the practical contribution of the indicators guide in a practical way, the systematicity of the elaboration of public notices and the alignment with possible public policies that would justify the expansion and contraction from one stage to the next.

The results obtained with the application of each questionnaire are presented in Table 3 using Table 2 as a reference.

Table 3.
Results of questionnaires on items evaluated in each grouping.

Questionnaire	Groupings			
	Induction	**Contracting**	**Monitoring**	**Result**
Q1	It showed an approximate reduction of 43% of the items which were initially 7 and changed to 3.	It presented an approximate reduction of 13% of the items that were initially 15 and went to 2 with a 100% agreement rate.	It presented an approximate reduction of 17% of the items which were initially 23 and went to 4 with a 100% agreement rate.	It presented an approximate reduction of 20% of the items which were initially 15 and went to 3 with a 100% agreement rate.
Q2	It showed an increase	It showed an increase	It showed an increase	It showed an increase

Questionnaire	Groupings			
	Induction	**Contracting**	**Monitoring**	**Result**
	from 3 to 4 items representing a 25% increase in the level of agreement when compared to Q1. Compared to the initial phase in which this grouping had 7 items during Q2 the indicators raised in the literature werepresent resulting in a 58% reduction in the 100% level of agreement.	from 2 to 6 items representing a 300% increase in the level of agreement when compared with Q1. Compared to the initial phase in which this grouping had 15 items, Q2 resulted in a reduction of 40% at the level of 100% agreement.	from 4 to 11 items, representing an increase of 275% in the level of agreement when compared to Q1. Compared to the initial phase in which this group had 23 items, Q2 resulted in a reduction of 48% at the level of 100% agreement.	from 3 to 9 items, representing a 200% increase in the level of agreement when compared to Q1. Compared to the initial phase in which this group had 15 items, Q2 resulted in a reduction of 48% at the level of 60% agreement.
Q3	It presented an increase from 4 to 5 items representing an increase of 20% in the level of agreement when compared to Q2 and in relation to Q1 we have an increase of 75%. In continuous action, comparing the result of Q3 with the initial quantity of items, it was reduced to 28%.	It presented a drop from 6 to 5 items representing a 17% reduction in agreement level. When compared to Q2 while in relation to Q1 we have a 150% increase in the level of 100% agreement. In continuous action, comparing the result of Q3 with the initial quantity of items, a reduction of 66% was observed.	It presented a drop from 11 to 5 items, representing a 67% reduction in the level of agreement when compared with Q2, while in relation to Q1 we have a 25% increase in the level of 100% agreement. In continuous action, comparing the result of Q3 with the initial quantity of items,a reduction of 67% was observed.	It presented a drop from 9 to 5 items, representing an increase of 44% in the level of agreement when compared with Q2, while in relation to Q1 we have an increase of 67% in the level of 100% agreement. In continuous action, comparing the result of Q3 with the initial quantity of items, a reduction of 67% was observed.

This section presents and analyzes the results referring to stages 4 and 5 resulting from the Q3, since the results of the Q1 and Q2 served to refine and verify the adherence to the literature. Empirically, submitted to different audiences of researchers which led to an initial reduction from 60 to 30 indicators and subsequently in a new round, a new reduction from 30 to 20 indicators which served to guide the construction of Q3. This was the starting point for discussing and evaluating the results in more detail identifying the indicators chosen and those eliminated among others. Results of Q3 were treated in this research through the observation of commonality, the variables have a source of variation in common, favoring the appearance of adhesion in the three questionnaires, originating with the questionnaire with 34 items that was the object of the application of the Fuzzy method. The number of indicators used must be considered for the performance evaluation. The methodology based on the approach of specialists, proposes a management system that guides the distribution of research support resources with the answers validated with the use of the Fuzzy Delphi method to identify the critical factors, indicators and sub-indicators present in the management of these resources. To facilitate the use of the questions, a Fuzzy code was agreed upon that corresponds to the number of the applied question as shown in Table 4.

Table 4.
Fuzzy codes used.

Fuzzy code	No. in the questionnaire	Applied question	Groupings
I_1	1.1	The project presents a theme aligned with public strategies and policies.	Induction
I_2	1.2	There is compatibility between the area of knowledge (NCSTD) and the project theme.	Induction
I_3	1.3	There must be adherence of the previous scientific productions of the participating professors to the theme of the project.	Induction
I_4	1.4	Verify ongoing or completed research whose objectives or products align with the theme of the project in question.	Induction
I_5	1.5	Indicate the number of studies in progress and complete them whose objectives or products are directly linked to society's priorities.	Induction

Fuzzy code	No. in the questionnaire	Applied question	Groupings
I_6	1.6	Indicate the percentage of projects with innovative ideas approved for the proposed theme.	Induction
I_7	1.7	Indicate the number and specificities of research developed in an international network.	Induction
I_8	2.1	Equally contemplate the areas of knowledge using qualified demand as a criterion.	Contraction
I_9	2.2	Indicate the number of international teams of researchers at different levels (From SI to associated researchers) that already use multi-user equipment with their own resources (Already obtained in other calls for proposals).	Contraction
I_10	2.3	Indicate the number of coordinators in the project with training in methods and tools for managing a team of researchers.	Contraction
I_11	2.4	Identify the number of contracting steps not completed due to nonconformities in previous projects.	Contraction
I_12	2.5	Demonstrate the relationship between the project and the current scientific topic.	Contraction
I_13	2.6	Demonstrate adequacy between the number of researchers on the project and the execution schedule.	Contraction
I_14	2.7	Demonstrate the number of multifunctional equipment being used by users from other institutions.	Contraction
I_15	2.8	Indicate the amount and proportion of funding from public source for research in relation to other funding sources in a given period of time.	Contraction
I_16	2.9	Indicate the percentage of resources executed in previous projects.	Contraction
I_17	3.1	List scientific research development practices (Daily work practices) compatible with possible limitations in the work or Personnel routine. (For example, restrictions on face-to-face activities due to the COVID-19 pandemic).	Monitoring
I_18	3.2	Ensure the necessary maintenance of the workforce employed in the execution of the project.	Monitoring
I_19	3.3	Ensuring efficiency in the execution of product processes in research development (Example: implementing lean production practices to reduce waste, follow-up and deadline monitoring practices, etc.).	Monitoring
I_20	3.4	Present indicators of partial monitoring of the return on the amount invested in the research.	Monitoring
I_21	3.5	Present indicators for monitoring disclosures of the research stages in new dissemination environments such as social networks and large-circulation newspapers.	Monitoring
I_22	3.6	Define and demonstrate an effectiveness index for the project.	Monitoring
I_23	3.7	List the number of equipment, tools and technologies available for use by the research network involved in the project.	Monitoring
I_24	3.8	Identify the number of research development proposed and not submitted to the ethics committee.	Monitoring
I_25	3.9	Identify intercurrences that demand resources not foreseen in the project.	Monitoring
I_26	4.1	Describe the project tools with the results achieved.	Result
I_27	4.2	Indicate the number and types of actions used to disseminate knowledge.	Result
I_28	4.3	Describe established research networks to the project.	Result
I_29	4.4	Describe knowledge and technology transfer activities.	Result
I_30	4.5	List the internationalized PGPs.	Result
I_31	4.6	List limitations found that may have prevented the development of products or processes foreseen in the project.	Result
I_32	4.7	Relate products generated with the participation of students and alumni (5 years post-link to the PGP).	Result
I_33	4.8	Indicate the percentage of values not executed versus the amount granted for the project.	Result
I_34	4.9	Relate the research products to patent registration.	Result

Consensus is achieved after four rounds of questions in which experts provide important information such as medians, means and deviations from previous rounds. The result is obtained when experts reform their opinions based on the average but the traditional Delphi method shows low convergence of expert opinions and a high cost of execution. Thus, the integration between the Delphi method and Fuzzy logic was proposed by Murray, et al. [98]. In the Fuzzy Delphi [39], with only one round of application of the questionnaire necessary for the opinion of the experts, it is already possible to identify the degrees of pertinence of the features correlated to represent the opinion of the experts.

Thus, it was possible to identify the group of variables that were the strongest [99]. For this, the 'α' limit was 0.50 which is adequate for the selection or rejection of a criterion. Based on the research and also from the experts' point of view, it may even be different [100, 101]. Table 5 shows the calculation memorial for identifying the influence of variables.

Table 5.
Identification of the influence of variables.

Groupings	Codes	a ij	b ij	c ij	Fuzzy index
Contraction	I_12	0.100	0.693	0.900	0.564
Contraction	I_13	0.100	0.613	0.900	0.538
Contraction	I_8	0.100	0.564	0.900	0.521
Contraction	I_10	0.100	0.492	0.900	0.497
Contraction	I_15	0.100	0.459	0.900	0.486
Contraction	I_11	0.100	0.456	0.900	0.485
Contraction	I_14	0.100	0.450	0.900	0.483
Contraction	I_9	0.100	0.437	0.900	0.479
Contraction	I_16	0.100	0.419	0.900	0.473
Induction	I_2	0.100	0.655	0.900	0.552
Induction	I_1	0.100	0.641	0.900	0.547
Induction	I_3	0.100	0.620	0.900	0.540
Induction	I_4	0.100	0.543	0.900	0.514
Induction	I_5	0.100	0.496	0.900	0.499
Induction	I_7	0.100	0.465	0.900	0.488
Induction	I_6	0.100	0.449	0.900	0.483
Monitoring	I_18	0.100	0.704	0.900	0.568
Monitoring	I_19	0.100	0.647	0.900	0.549
Monitoring	I_17	0.100	0.622	0.900	0.541
Monitoring	I_25	0.100	0.609	0.900	0.536
Monitoring	I_20	0.100	0.580	0.900	0.527
Monitoring	I_23	0.100	0.570	0.900	0.523
Monitoring	I_21	0.100	0.553	0.900	0.518
Monitoring	I_22	0.100	0.545	0.900	0.515
Monitoring	I_24	0.100	0.399	0.900	0.466
Results	I_27	0.100	0.690	0.900	0.563
Results	I_26	0.100	0.672	0.900	0.557
Results	I_31	0.100	0.670	0.900	0.557
Results	I_32	0.100	0.672	0.900	0.557
Results	I_28	0.100	0.650	0.900	0.550
Results	I_29	0.100	0.633	0.900	0.544
Results	I_33	0.100	0.571	0.900	0.524
Results	I_30	0.100	0.506	0.900	0.502
Results	I_34	0.100	0.452	0.900	0.484

The identification of data favoured the understanding of the applicability of the method but it was necessary to normalize the base. Table 5 showed conditions to distinguish within the constructs, the possibility of reducing the scope of the dimension to facilitate the analysis, and the unification of qualitative judgments by generating the same unit of measurement [102, 103]. The result could be separated into greater products and less than 0.50. The grouping of items in each of the constructs they compose favours the organization of data in a more detailed way to transform them into information that demonstrates their effects within the selected group.

The findings in Table 5 shown above were applied to the 34 indicators validated by experts using the Fuzzy Delphi method. All are relevant for evaluating projects or proposals [100, 101]. Normalization was the tool used to organize the data and contribute to the analysis and discussion [103].

The monitoring group stood out in item 18 addresses the maintenance and execution of the project. The proponent will be able to carry out the proposal that is approved. The expectations of society increasingly generate a craving for answers applied to everyday life which is not a simple practice. It is important to remember that basic research plays a key role in this context. Table 6 presents only the results of the frequencies of the variables validated by the Fuzzy Delphi.

Table 6.
Clean frequencies.

Intensity scale of likert					
Códigos	**1**	**2**	**3**	**4**	**5**
I_1	2.78%	2.78%	31.94%	23.61%	38.89%
I_2	0.00%	4.17%	27.78%	43.06%	25.00%
I_3	2.78%	4.17%	33.33%	27.78%	31.94%
I_4	5.56%	8.33%	36.11%	31.94%	18.06%
I_8	9.72%	8.33%	18.06%	22.22%	41.67%
I_12	4.17%	4.17%	9.72%	26.39%	55.56%
I_13	4.17%	9.72%	12.50%	44.44%	29.17%
I_17	1.39%	8.33%	25.00%	40.28%	25.00%
I_18	0.00%	4.17%	18.06%	37.50%	40.28%
I_19	0.00%	6.94%	27.78%	36.11%	29.17%
I_20	5.56%	0.00%	40.28%	31.94%	22.22%
I_21	6.94%	4.17%	36.11%	30.56%	22.22%
I_22	1.39%	11.11%	44.44%	34.72%	8.33%
I_23	4.17%	6.94%	36.11%	30.56%	22.22%
I_25	0.00%	8.33%	34.72%	37.50%	19.44%
I_26	0.00%	6.94%	19.44%	40.28%	33.33%
I_27	0.00%	5.56%	19.44%	36.11%	38.89%
I_28	1.39%	1.39%	33.33%	33.33%	30.56%
I_29	4.17%	1.39%	29.17%	29.17%	36.11%
I_30	11.11%	1.39%	44.44%	22.22%	20.83%
I_31	1.39%	6.94%	16.67%	36.11%	38.89%
I_32	2.78%	2.78%	18.06%	37.50%	38.89%
I_33	6.94%	5.56%	29.17%	27.78%	30.56%

Based on the data above, it is possible to analyse the results of the Fuzzy Delphi which have been highlighted as having little relevance I_30 and favouring the increase of invested resources and the internationalization of science thus generating the development of countries [15]. We have I_22 from the monitoring group gives importance to the definition of an index that partially presents the effectiveness of project performance [5].

Already with medium relevance I_20 from the monitoring group demonstrates that the focal point is to ensure efficiency in the execution of product processes in research and development by observing and implementing lean production practices [19]. With high relevance. I_13 from the contraction group demonstrates the evolution of project execution by adapting the number of researchers involved both in the project and in the network to the execution schedule and encouraging the training of manpower not limited to academia [26].

Item I_8 from the contraction group stood out as the item with the highest frequency reinforcing the extreme relevance and demonstrating the relationship between the project and the scientific relevance of the topic. Thus, the indicators used and the transversal themes of a given activity are observed [28].

5. Conclusion

The main purpose of this study was to point out a set of indicators that can guide the distribution of resources to promote research thereby enabling its development. The concept of approaching quality as an adjustment was adopted.

The objective was achieved through the grouping of the identified indicators after scrutinizing the responses of experts in which the identification and verification of the applicability of the proposed indicators took place. Thus. the comparison between the stages used the Fuzzy index to characterize the commonality of the applicability of these 34 indicators. Thus, the responding researchers contributed to the effects and practical implications of this research which were identified through some management indicators portraying the direction of the development of scientific research in Brazil.

Finally, the indicators proposed in this study have theoretical implications. It is possible to reduce the optional aspect and develop a systematic use of research management indicators that align all the institutions in this network that have the same purpose. Therefore, the indicators presented here can serve as a starting point to minimize possible discrepancies in the research development strategy to be used in any of these institutions despite the need for eventual adaptations that can be made for the particular context worldwide.

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