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The construction of a performance measurement system for self-evaluation of a graduate biotechnology program

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Abstract: The Literature on Performance Measurement Systems (PMS) is vast, however, little is found on the design stage of these for Higher Education. The purpose of this article is to present an SMD built for a Biotechnology Graduate Program (GP) to evaluate its performance. The Value Focused Thinking (VFT) approach was used to identify performance criteria. Mathematical modeling technique was used to identify the weights of these criteria through the Decision Support Method with Multiple Criteria: Analytic Network Process (ANP). Stakeholder decision compatibility was tested. Thirty-five performance indicators were built and grouped into eight fundamental objectives. The evaluation of the program identified that its strengths were Percentage of deadline fulfillment (by students) and Percentage of joint orientations between teachers and that managers should prioritize Percentage of patents or products students / teachers and Percentage teachers / students who participated as advisor / consultant.

Keywords: Graduate Programs. Performance evaluation. Performance Measurement Systems.

Introduction

Models of Performance Measurement Systems (PMSs) are addressed in the literature as an efficient way to obtain continuous improvement and enhance competitiveness of organisations in the market. However, designing a PMS is not an easy task, although there is no shortage of publications on performance measurement systems, there is a shortage of research elucidating how to build indicators and metrics (what and how to measure) that indicate precisely which activities contribute to performance using appropriate measurement theory [8].

The Coordination for the Improvement of Higher Education Personnel (CAPES – *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*) is the regulatory agency for Graduate Studies in Brazil and define criteria to assess Graduate Programs (GP) with the aim of continuously improving quality. However, the set of criteria adopted in the evaluation forms is not sufficient to capture the aspirations of all stakeholders for a GP. In addition, CAPES has recommended, from the 2017–2020 quadrennium onwards, that programs design and carry out their own Self-Assessment and Strategic Planning [3].

In the related literature, some authors, including Bressiani, Alt, and Massote (2001); Modell (2005); and Umashankar and Dutta (2007), argue that Higher Education Institutions are not accustomed to using PMSs to assist their management processes. In view of the importance of GP both for universities and for society at large, performance must be measured from various perspectives, to structure a management process that seeks continuous improvement. Hence, this paper hopes to address this gap.

The purpose of this article is to present a PMS built for a GP in Biotechnology to assess its performance, based on the perspectives of its stakeholders. The method for building the PMS includes: (1) Value Focused Thinking (VFT) – to identify the performance criteria with the stakeholders; (2) the Multicriteria Decision Method (MCDA): Analytic Network Process (ANP) – for mathematical modelling of criteria weights and for building scales; and (3), Compatibility ratios to check the proximity or distance of perspectives between decision makers.

In addition to the introduction, the work is divided into four other sections. The second section contains a literature review on the VFT approach and the ANP method in the construction of performance indicators and Biotechnology as a Graduate area. Section 3 explains the research method used to construct the PMS. Section 4 presents the PMS constructed and discusses the results found in the evaluation of the GP studied, and finally, section five provides the final conclusions and considerations.

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Theoretical reference

Performance Measurement Systems

This study adopts the concept of Neely, Adams, and Kennerley[32] that defines PMSs as a set of performance measures to quantify effectiveness and/or efficiency of past actions of an organization, aimed at management actions.

The literature reviews performed by Choong[5, 6,7 8] Yadav, Sushil, and Sagar[54]; and Valmorbida and Ensslin[51] about PMSs point to the need to customize performance measures according to organizational needs, contrasting frameworks such as the Balanced Scorecard or the Performance Prism. In general, although this aspect (PMS customization) is valued, companies still struggle with what they have to measure, the appropriate number of indicators, what to do with the measures found, and how to use them as a management tool and not just as measurements.

The methods for building PMSs presented in the literature seek to build SMP according to the needs of each company, but few present a step–by–step account of how the project took place, the planning and choice of indicators, and do not present details about the application, its difficulties and failures[35, 36]. According to Neely, Gregory, and Platts[33], the design phase of a PMS (selection of measurements and definition of metrics) is critical for success.

Value Focused Thinking and its support for construction of Performance Measurement Systems

According to Keeney[23], VFT is a method to assist the decision–making, which consists essentially of two activities: First identify what the decision maker wants and then figure out how to achieve it. VFT focuses on value and is recommended for problems involving complex applications with various alternatives, multiple objectives, and multiple stakeholders.

VFT has been used to build PMSs as shown in the Table 1; however, the works found do not focus on the Education sector. For more details on VFT, we recommend the readings of Keeney[16–19, 21, 23, 24] Keeney and Mcdaniels[16, 17]; Parnell et al.[37]; Keisler[22]; Keisler et al.[25]; Kenney, Bessette, and Arvai[15]; Marttunen, Lienert, and Belton [30] and Françozo; Belderrain[11].

Table 1– Value Focused Thinking (VFT) applications in Performance Measurement Systems (PMS) projects.

Author/ Year	Application
Barclay and Osei–Bryson (2010)	Performance criteria for Information Systems. VFT and Metric of objective question (Goal, Question Metric).
Chávez–Cortés and Maya (2010)	Sustainability indicators at local level and adequacy in the context of tourism development (Mexican community).
Kibira et al. (2018)	Environmental performance indicators for industrial processes.

Source: Authors.

The Analytic Network Process and its use in Performance Measurement Systems

ANP models a decision–making problem in network form, considering relations of dependence and/or feedback between: objectives, criteria, subcriteria, and alternatives[43]. In the construction of a PMS, major decisions require the employment of MCDA, either to assign weights to indicators (compare them) or to build scales (metrics) according to the subjective preferences of decision makers[38]. Table 2 shows a summary of MCDA AHP (Analytic Hierarchy Process) and ANP in PMS projects. No combination of VFT and ANP for PMS construction was found in the research literature.

Table 2 – Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) applications in Performance Measurement System (PMS) Projects (From 2013).

Author/ Year	Application
Ferretti and Pomarico (2013)	Employed the ANP and the Ordered Weighted Average (OWA) approach to compose a Multicriteria–Spatial Decision Support System; uses a value tree, does not detail VFT.
Song et al. (2013)	Use the AHP to assess client requirements in initial industrial product development.
Horenbeek and Pintelon (2014)	Employed PMS for maintenance
Van de Kaa et al. (2014)	Use AHP–fuzzy in standard battle technology decision making.
Guimarães and Salomon (2015)	Evaluated the priorities of the reverse logistics indicators in a small footwear industry in the State of Ceará, Brazil.
Liang (2015)	Measured the performance of interorganizational information systems in the supply chain of Thai IT industries (Balanced Scorecard + AHP fuzzy).
Yaraghi et al. (2015)	Compared the performance of the AHP with Monte Carlo at different levels of uncertainty.
Nisel and Özdemir (2016)	Used the AHP and ANP in sports–related decisions.
Kucukaltan, Irani and Aktas (2016)	Used the PMS for the logistics sector in Turkey, combining the Balanced Scorecard and the ANP.
Zong and Wang (2017)	Employed University Scientific Research Capacity Assessment (D–AHP)
Ho and Ma (2018)	Reviewed literature on approaches and applications: 2nd place Performance measurement – AHP.

Source: Authors.

The AHP is a special feature of ANP method. In AHP the hypothesis of interdependence and/or feedback among the decision-making elements is relaxed. Most of the works presented in Table 2 assume independence between performance criteria and, therefore, use the AHP. For more details on AHP/ANP, Saaty[39-46]; Salomon and Montevechi[47] are recommended.

Research method

The literature review that supported this study was performed in scientifically databases (Scielo, SpringerLink, Emerald insight, Science Direct, JSTOR, Web of Science, Scopus, and Google Scholar). The keywords used were performance measurement system, performance indicator, design, value focused thinking, analytic network process, and compatibility index.

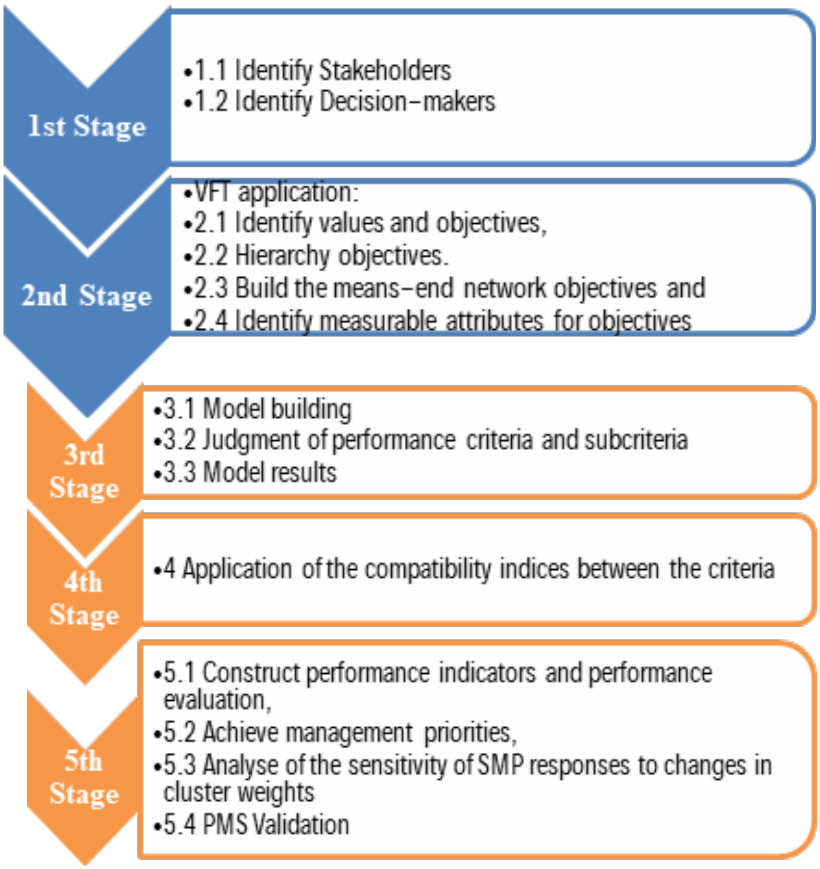
Figure 1 illustrates the research method used to construct and evaluate the analysed, which combines VFT (constructivist approach) with MCDA Analytic Network Process (rationalistic approach).

The subject of analysis was a Graduate Program in Biotechnology (GPB) of a Higher Education Institution (HEI) in the interior of the State of São Paulo, Brazil. In the constructivist phase, the first stage of the proposed method was subdivided into two sub-steps. The first entailed identification of stakeholders, and the second, identification of the decision makers involved with the construction of the PMS.

In the first stage, step 1.1, the stakeholders involved in the construction phase of the method were divided into groups: Organizations, that constitute the market needs of the programme; the HEI, represented by its members and with a major interest in improving the performance of the programme; the Community, symbolizing the return for the work conducted by GP; and CAPES, representing the government, in this case, through the Biotechnology area document and contained in the desires of the coordination and professors.

The representatives of the group 'Organizations', a professor with a professional background in a Biotechnology company and a businessman in the Biotechnology area with no relationship with the IES were interviewed. The 'IES' group for better comprehensiveness of the PMS was subdivided into coordination, faculty, student, and board representative. The 'Community' group, was represented by a person from the general society linked to the academic environment, working in a Graduation Program. For the construction of the PMS, the group composed of the coordinator, professors, and a student of the programme was defined as the main decision makers to involve in the decision-making processes and specific liaison with the programme – step 1.2 of the first stage. The criteria for selection and classification of stakeholders were based on the work of Ackermann and Eden (2011)[1].

Figure 1– Method for building Performance Measurement Systems for a Graduate Program.



Source: Authors.

The second stage of the proposed method was to apply the following four steps: 1) Identify objectives, 2) Hierarchize objectives, 3) Build means–end network objectives, and 4) Identify measurable attributes for the objectives. To this end, nine interviews were conducted with related stakeholders. These interviews lasted an average of 30 minutes and were validated by the interviewees after the recording was transcribed by the facilitator following the steps of VFT.

The guiding questions asked throughout the interviews were: What do you consider important to be measured/evaluated in a GP? What measures should a PMS cover for the GP? The questionnaire from Keeney[17] was also employed to stimulate identification of the objectives, for the construction of a PMS for the Graduate Program in Biotechnology.

The WITI (Why Is This Important?) test was applied, with the statements identified in step 1 (one by one). An individual hierarchy of objectives was structured for each interviewee. Following this hierarchization, the facilitator produced the hierarchy of objectives gathered from the nine interviews conducted to determine the fundamental objectives found. At this stage, the strategic objective of the group was identified.

Then, the network of objectives was elaborated, containing the strategic objective, the fundamental objectives, and their means. This was done by analysing the interviews and obtaining information from the decision makers, who also validated it. Depending on the structured network, the list of measurable attributes was also drawn up, by appealing to those involved according to the fundamental objectives established. These represent the performance criteria pointed out by the decision makers and CAPES (following the requirements of the area document) for this Biotechnology GP.

In the rationalist phase, Stage 3 – step 3.1, the multicriteria model was built with the aid of Super Decisions® software. Relationships of dependency and feedback between performance criteria were extracted from the objectives network and legitimized with decision makers participating in this phase.

Meetings were held with decision makers to verify judgements of relative importance between clusters, between PMS performance criteria and sub criteria, by peer review (step 3.2). The consistency of the trial matrices was also assessed.

In step 3.3 – model results, the establishment of the weights provided a strategic direction to the GP by enabling better prioritization of performance criteria. This step was made by group decision, carried out through the technique of Aggregation of Individual Priorities (AIP) geometric mean, according to Forman and Peniwati [10].

In the fourth stage, the compatibility rates S (Saaty), V (Valério), and G (Garuti) were applied to verify the proximity or distance between the opinions of the decision makers involved in the construction of the PMS. The compatibility indices were applied on the judgements in the clusters (set of fundamental objectives) and the performance criteria of the model. For details on the index calculations see Saaty[46]; Salomon[48]; and Garuti[12].

The fifth stage – step 5.1 – occurred in a preliminary meeting with one of the decision makers. It established levels for each performance criteria, accompanied by descriptors. Subsequently, another collective meeting was held with 3 of the 6 decision makers to sanction these levels and descriptors. The AHP method was then applied for relative comparison between the levels and to achieve the priority vector and consequently, the Function Value (FV).

The GP was evaluated for each performance indicator built, identifying the level of impact that best represented the Programme's performance. The GP global was obtained additively, multiplying the function value corresponding to each indicator by its weight (obtained in the third step). In step 5.2, the management priorities were defined, considering the potential that each indicator would contribute to increase the overall performance of the GP.

The sensitivity analysis was performed to check how sensitive the PMS is to a possible individual increase in weight of each cluster (step 5.3). Finally, in step 5.4, the validation of the PMS by the decision makers was based on the analysis of the representativeness of the results against the reality of the GP.

Results and discussion

The first and second stages of the constructivist phase produced the network of objectives presented in Figure 2. The network covers all the strategic and fundamental, objectives along with the mean of the GP, from the perspectives of its stakeholders.

The strategic objective of GP is 'To meet the needs of those involved in GP'. A fundamental objective and means to achieve it, from the perspective of the stakeholders, is exemplified in Figure 2: to offer the student quality training, the student must have knowledge, which can be assessed by means of the courses taken and in the offer of quality courses.

Table 3 shows the priorities (weights ordering) from each decision maker for the clusters (set of fundamental objectives) resulting from the steps of stage 3. Note that decision makers had different priorities in relation to clusters and that all had inconsistencies below 0.1 in their judgments (recommended for the AHP/ANP method). The decision makers on the program board were professors 1, 2, 3, 4, and 6 (which includes the coordinator) and 5 student representatives.

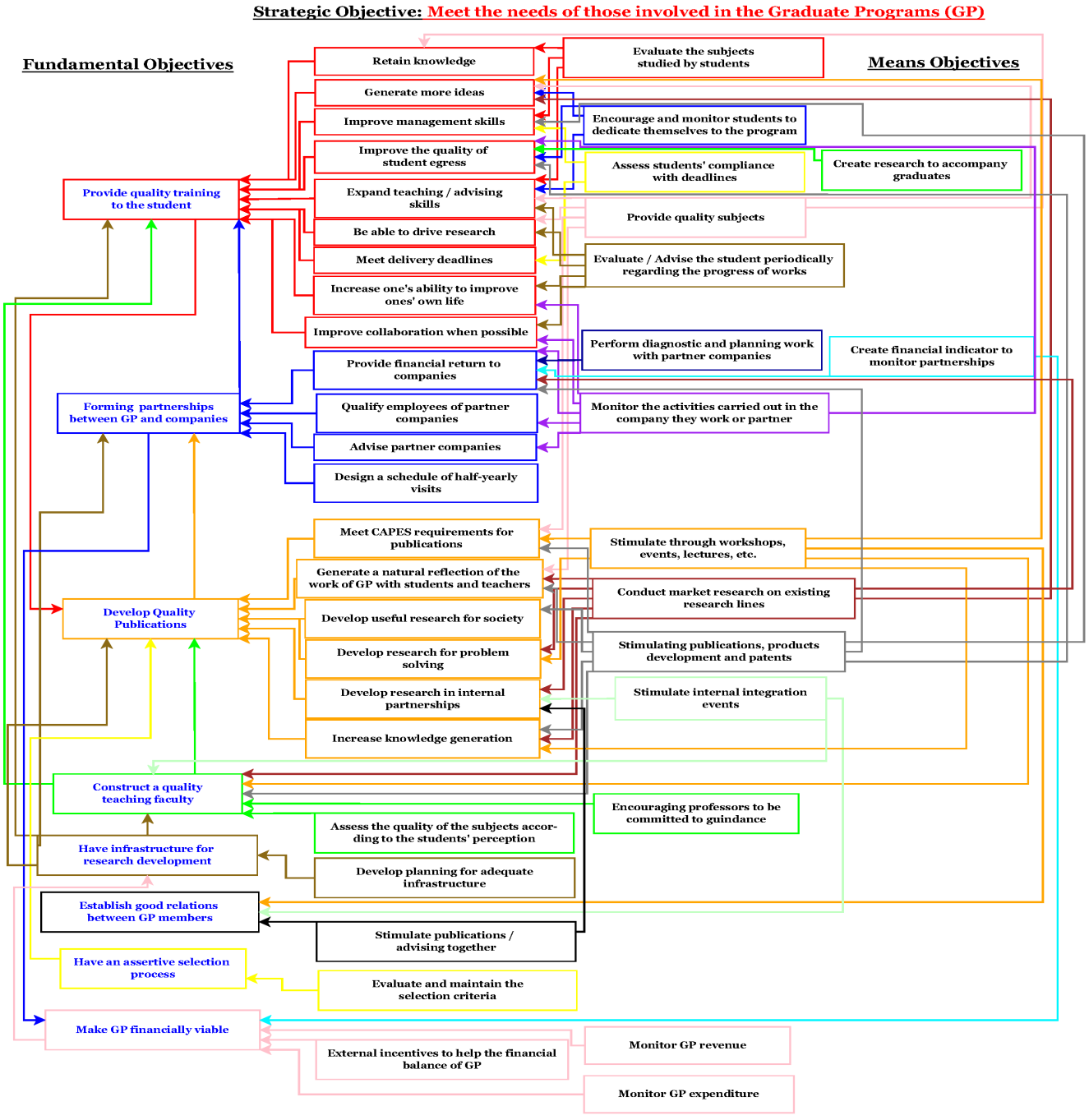
Considering the standardised geometric average, the three most important clusters were: 18.19%, to offer quality training to the student; 17.60%, to constitute a quality teaching staff; and 15.88%, to develop quality publications (totalling 51.68%). The professors naturally prioritize aspects related to the training of students and

faculty rather than the question of a good relationship between those involved, for example. Providing quality training to students is essential to the program according to the values presented in the interviews and proven numerically, such training needs a quality faculty that enables/supports this. Developing publications is inherent to the academic environment and carries with it the weight of CAPES as a regulating body.

The infrastructure cluster for the development of research was perceived with different weights among the professors themselves, which can be due to their specific needs for the lines of research developed. For some, the infrastructure was more important, and because it was a relatively new program. The formation of partnerships with companies was something valued by several of those involved and by the area of Biotechnology in general, highlighted in the area document by CAPES and necessary even as a support for the economic viability of the program. For decision–maker two, forming partnerships with companies was more significant than for the others. Economic viability is essential for the continuity of the program and had different weights among decision makers.

Table 4 presents the priorities of the performance criteria (top 10 in the ranking), considering the views of each of the decision makers interviewed. The first three

Figure 2 – Means–end network objectives.



Source: Authors.

positions, according to the normalized geometric average, were revenues/expenses with 9.10%, percentage of projects with external funding with 8.05%, and teaching publications in the quadrennium with 6.38%.

In Table 4, different rankings are noted for each decision maker. The revenue/expenditure rate indicator (AN) was the first in the ranking for decision–makers 1, 4, 5, and 6, highlighting the concern about the financial balance of the program. The second in the list, the percentage of projects with external subsidies (PA), which also denoted such concern, appeared in second place for decision–makers 2, 4, 5, and 6. Decision maker 4 marked the same order as the weighted geometric average for the first three indicators of the ranking, but not for the other indicators. The other decision makers alternated such initial positions or contemplate only one or two of the indicators among the first three.

Although, in the first positions, items were found in exchanged positions, the reasons that may lead to such different perspectives was complex, and such questioning to compare the answers obtained between them was not carried out, as this was not the objective of the work. However, the coordination, professors, and students had different and complementary perspectives and values within the GP, since each have different approaches to CAPES and IES. The application of the compatibility indices can contribute to this analysis.

In step 4, the following compatibility indices were applied: 'S' of Saaty [46], 'V' of Salomon[48], and 'G' of Garuti[12]. The indices were applied to check the distance from the weights assigned by decision makers to the performance criteria and those of the clusters in the model (set of objectives contained in the means–end network objectives). Both situations found incompatibility between decision makers, considering S and V, and little compatibility taking into account G. In other words, decision makers did not present a consensus on the relative importance of fundamental objectives and performance criteria.

The following is the construction of the performance indicators based on the performance criteria (step 5.1 of step 5). Table 3 exemplifies the construction of performance–indicator A, referring to the fulfilment of deadlines by students (qualification and defence), presenting the levels and their descriptors. For each level from 0 to 5 of indicator A, a value resulting from the decision makers' judgments on the levels, their respective value function, the target set for this indicator in the current quadrennium, and the result of the GP between the years 2017 and 2018 were associated.

The GP showed a 92% compliance rate for 2017 and 2018. Therefore, indicator A (Table 5) was classified in level 5. By multiplying the PV value for level 5 by the weight of indicator A (Table 6) – 100%*2.33%, the percentage of performance of indicator A (2.33%) in the GP performance was obtained. Carrying out the same procedure with the other criteria, in an additive way, the performance obtained for the PMS of the GP was 61.39%.

Table 3 – Priorities by clusters/decision makers.

Clusters/Decision makers	1	2	3	4	5	6	Geo. Mean	Geo. Mean Norm.
Offer quality training to the student	29.22%	15.48%	19.32%	10.33%	17.53%	14.02%	16.77%	18.19%
Establish a quality teaching staff	21.18%	22.44%	20.39%	8.38%	14.70%	15.26%	16.22%	17.60%
Develop Quality Publications	13.15%	10.93%	16.25%	21.08%	17.02%	11.71%	14.63%	15.88%
Possess infrastructure for research development	4.67%	11.20%	13.86%	14.42%	16.10%	16.14%	11.81%	12.82%
Form partnerships between GP and companies	7.83%	16.08%	10.63%	7.67%	13.24%	7.97%	10.13%	11.00%
Make GP economically viable	10.18%	6.97%	4.19%	15.22%	15.17%	6.80%	8.81%	9.56%
Have an assertive selection process	5.07%	13.88%	11.24%	9.35%	4.71%	6.05%	7.71%	8.37%
Establish a good relationship among those involved in GP	8.68%	3.01%	4.12%	13.55%	1.54%	22.06%	6.06%	6.58%
Total	100%	100%	100%	100%	100%	100%	92%	100%
Inconsistency	0.03	0.08	0.09	0.09	0.08	0.08	0.07	

Source: Authors.

Table 4 – Priorities by indicator.

Cod.	Indicator	1	2	3	4	5	6	Geo. Mean	Geo. Mean Norm.
AN	Rate of income/expenses (per year)	9.29%	5.66%	3.59%	14.42%	12.39%	8.86%	8.17%	9.10%
AF	Percentage of professors involved in external promotion (depending on the number of professors)	3.20%	7.96%	7.91%	8.23%	9.86%	8.78%	7.23%	8.05%
S	Percentage of publications (A1 – B4) professors (depending on the number of professors)	4.83%	3.95%	6.70%	7.16%	6.50%	5.96%	5.73%	6.38%
T	Percentage of patents/teaching products (depending on the number of professors)	3.32%	4.21%	6.19%	7.16%	7.16%	5.96%	5.46%	6.07%
L	Percentage of professors/students who participated in events with companies (according to the total number of professors and students)	2.57%	8.43%	4.47%	4.23%	3.90%	4.69%	4.42%	4.92%
K	Percentage of professors who made visits to Biotechnology companies (according to the total number of professors)	4.57%	4.63%	4.63%	2.38%	6.92%	1.31%	3.58%	3.99%
N	Average of projects with companies (per year)	2.78%	7.54%	4.04%	2.58%	4.22%	2.21%	3.56%	3.96%
AM	Percentage of starting/graduating students (depending on the number of students)	3.09%	5.63%	4.81%	4.08%	2.56%	2.08%	3.49%	3.89%
H	Percentage of graduates (in relation to those expected)	7.97%	2.60%	3.06%	1.11%	4.28%	4.17%	3.28%	3.65%
O	Percentage of publications (A1 – B4) students/professors (depending on the number of students)	2.73%	3.10%	3.48%	4.95%	3.01%	2.19%	3.14%	3.50%

Source: Authors.

Table 5 – Example of Levels. Vectors, FV, descriptors, results, and target for indicator A.

A Levels	Vector	FV (Vector Norm.)	Goal	Result	Descriptors
0	0	0%			Percentage of fulfilment of deadlines below 50% (total number of students)
1	0.11	33%			Percentage of compliance with deadlines lower than 51 – 60
2	0.14	44%			Percentage of compliance with deadlines is between 61 – 70 %.
3	0.19	57%			Percentage of compliance with deadlines is between 71 – 80
4	0.24	76%			Percentage of compliance with deadlines is between 81 – 90%.
5	0.32	100%	x	x	Percentage of compliance with deadlines is between 91 – 100 %.

Source: Authors.

Table 6 shows the percentage of performance for the indicators and their overall performance. The indicators with the highest percentage of performance (in view of the weight assigned) as a function of the levels recorded were Percentage of publications (A1 – B4) by professors (as a function of the number of professors), Percentage of professors involved in external promotion (as a function of the number of professors), and Income/expense rate (by year). The lowest performers are Percentage of student/professor books/chapters (as a function of the number of students), Percentage of awarded professors (as a function of the number of professors), and Average of integration projects with High School (per year)

Table 6 – Performance of indicators and general.

Ind.	Weight (Mean Geom. Norm.)	FV corresp. Level	% Performance Indicator	Indicator
S	6.38%	100%	6.38%	Percentage of publications (A1 – B4) by professors (depending on the number of professors)
AF	8.05%	57%	4.62%	Percentage of professors involved in external promotion (depending on the number of professors)
AN	9.10%	44%	3.96%	Rate of income/expenses (per year)
J	3.44%	100%	3.44%	Percentage of students who are advisors/co-advisors (according to the total number of students)
K	3.99%	76%	3.02%	Percentage of professors who made visits to Biotechnology companies (according to the total number of professors)
N	3.96%	76%	3.00%	Average of projects with companies (per year)
AM	3.89%	76%	2.95%	Percentage of starting/graduating students (depending on the number of students)
L	4.92%	57%	2.83%	Percentage starting/graduating students (depending on the number of students)
H	3.65%	76%	2.77%	Percentage of professors/students who participated in events with companies (according to the total number of professors and students)
T	6.07%	44%	2.64%	Percentage of graduates (in relation to those expected)
A	2.33%	100%	2.33%	Percentage of patents/teaching products (depending on the number of professors)
O	3.50%	57%	2.01%	Percentage of fulfilment of deadlines (according to the total number of students)
AL	2.75%	57%	1.58%	Percentage of publications (A1 – B4) students/professors (depending on the number of students)
G	2.71%	57%	1.56%	Average startings student per year
E	1.37%	100%	1.37%	Percentage of students who participated in external events (depending on the total number of students)
V	1.28%	100%	1.28%	Percentage of mentions (A and B) (according to the total number of students)
AK	1.68%	76%	1.28%	Percentage of professors integrated with the graduation (depending on the number of professors)
AE	2.67%	44%	1.16%	Percentage of satisfaction among GP professors (depending on the number of professors)
Y	2.00%	57%	1.15%	Number of scientific bases with access by the programme
P	3.43%	33%	1.13%	Percentage of professors with research fellowships (depending on the number of professors)
AI	1.13%	100%	1.13%	Percentage of patents/ student/professor products (depending on the number of students)
X	1.69%	65%	1.09%	Percentage of joint guidelines between faculty (projects with internal co-orientation per year)
U	1.76%	57%	1.01%	Average number of students per advisor (depending on the number of professors)
M	3.00%	33%	0.99%	Percentage of teaching books/chapters (depending on the number of professors)
AC	2.09%	44%	0.91%	Percentage of professors/students who participated as advisor/consultant (depending on the total number of professors and students)
Z	1.31%	65%	0.84%	Percentage of professors/students involved in internationalization projects (depending on the number of students and professors)
I	1.85%	44%	0.81%	Average numbers of subjects taught per professor (depending on the number of professors in the quadrennium)
AH	1.04%	76%	0.79%	Percentage of students awarded (as a function of total number of students)
AB	2.12%	33%	0.70%	Percentage of joint publications (A1 – B4) among professors (depending on the number of professors)
AG	0.91%	76%	0.69%	Percentage of professors/ students involved in extension/social insertion projects (depending on the number of students and professors)
AJ	0.62%	100%	0.62%	Percentage of professors/ students who participated in internal events (depending on the number of students and professors)
W	0.98%	57%	0.56%	Average of those who participate on committees (faculty/per year)
AD	0.88%	57%	0.51%	Average of integration projects with High School (per year)
Q	0.85%	33%	0.28%	Percentage of professors awarded (depending on the number of professors)
AA	2.60%	Not implemented		Percentage of student/professor books/chapters (depending on the number of students)
Total			61.39%	Percentage of teaching evaluation per student (depending on the number of students)

Source: Authors.

The top 10 positions of the GP management priorities are presented in Table 7 (step 5.2). Given the institutional characteristics, the concern with economic viability was significant and highlighted with the need to seek external incentives for research development. Partnerships with companies were also valued to assist in the financial health of the program, while taking cutting–edge research and knowledge into the companies. The evolution of GP in this direction could also allow the expansion of the infrastructure, which was valued and necessary.

The importance of publications and patents, already emphasized by the regulatory agency (CAPES), was also reflected in the management priorities (to make applied research efficient and capable of helping in the return of something more palpable to society), along with the need to bring the program closer to companies with visits and events that could facilitate partnerships and projects. The other indicators, although with lower priorities, should be monitored to ensure their collaboration in the composition of the PMS.

The PMS sensitivity analysis was performed, extrapolating the weights of each cluster individually, to check for any variation in the PMS performance (step 5.3). Changes in overall performance through cluster disruption are not considered to have a major impact. PMS was validated by decision makers, who judged it capable of portraying the reality of the GP for an adequate management process from the perspective of stakeholders, including CAPES. In addition, they reiterated their concern not to create an excessive number of metrics, particularly in view of the recent initiation of the programme.

Table 7 – Management priorities.

Ind.	Weight (Mean Geom. Norm.)	Levels	Management priorities	Description of Indicator
AN	9.10%	44%	5.14%	Rate of income/expenses (per year)
T	6.07%	44%	3.43%	Percentage of patents/teaching products (depending on the number of professors)
AF	8.05%	57%	3.43%	Percentage of professors involved in external promotion (depending on the number of professors)
P	3.43%	33%	2.30%	Percentage of patents/ student/professor products (depending on the number of students)
L	4.92%	57%	2.10%	Percentage of professors/students who participated in events with companies (according to the total number of professors and students)
M	3.00%	33%	2.01%	Percentage of professors/students who participated as advisor/ consultant (depending on the total number of professors and students)
AE	2.67%	44%	1.51%	Number of scientific databases that the programme has access to
O	3.50%	57%	1.49%	Percentage of publications (A1 – B4) students/professors (depending on the number of students)
AB	2.12%	33%	1.42%	Percentage of professors/students involved in extension/social insertion projects (depending on the number of students and professors)
AC	2.09%	44%	1.18%	Percentage of professors/students involved in internationalization projects (depending on the number of students and professors)

Source: Authors.

Conclusions

Thus, the geWneral objective of presenting a PMS built for a Biotechnology Graduate Program for self–assessment, integrating VFT with ANP, was achieved. As this was a recent program, the concern and appreciation of the planning aspects for growing development began in 2017 with the start of the planning and management project, which was in line with the new CAPES proposal from 2018. This concern shows that the program already recognized the need to structure its actions and plan itself before it was even required to in the evaluation process and not only to fulfil a proforma.

The PMS built incorporated the CAPES evaluation criteria and other valued by stakeholders. A point that called the attention of the Program Coordinator for immediate actions was the need for greater alignment and consensus among decision makers, which as diagnosed by the compatibility rates. On the other hand, a certain degree of divergence between opinions is valuable for a GP that is composed of stakeholders with different points of view, captured by the group decision (geometric mean).

PMS enabled monitoring the performance of the program throughout the four–year period, tracing actions that reflected results within the evaluation period. The specific criteria pointed out in the PMS helped in the overall result of the program and could indirectly generate positive impact on the CAPES criteria. Nevertheless, the coordination of the programme must be attentive to the performance criteria of CAPES (evaluation form) and their respective weights, as these change frequently.

However, through this research, we hope to collaborate with other GP or organizations that aim to build their custom PMS. This study presents the limitation of approaching a specific GP with individual characteristics observed at the time. Therefore, future studies should use the same research method for longitudinal comparisons in the same GP or even in other programs with distinct characteristics, in any area of CAPES to verify its applicability and effectiveness.

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