SUPPORTING THE DESIGN OF A PERFORMANCE MEASUREMENT SYSTEM WITH THE ANALYTIC NETWORK PROCESS

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ABSTRACT

The development process for a Performance Measurement System (PMS) can be split into four phases: (1) design; (2) planning and construction; (3) implementation, and; (4) operation and updating. The design phase focuses on the choice of performance indicators and is crucial to the success both of the PMS and the organization. This paper deals with the design phase for a PMS based on the Performance Prism using the Analytic Network Process (ANP) for modeling and ranking of the performance indicators. The application of the ANP as support for the PMS design was executed in the higher education sector with a view to the management of an undergraduate course in Production Engineering. The model and its results assured the representation of the various stakeholders´ objectives – in a significant and balanced manner – through 58 performance indicators distributed in four clusters: satisfaction, processes, capabilities and contribution.

Keywords: Performance Measurement System, The Performance Prism, ANP, Undergraduate Course

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1. Introduction

According to Fernandes (2004), organizational Performance Measurement Systems (PMS) have been used for more than fifty years, when the Tableau de Board came about in France. Currently, the Balanced Scorecard (BSC) from Kaplan and Norton (1990) is the most commonly used PMS in corporations and its creators have been the most referenced in the literature over the last two decades – Akkermans and Oorschot, 2005). Following Kaplan and Norton in the ranking of references in performance measurement are the proposers of The Performance Prism (Neely et al., 2002).

There are different approaches to the subdivision of the construction process into phases. The construction process for a PMS (BSC, The Performance Prism, or other) can be subdivided into three large phases (Bourne et al., 2000): design (construction), implementation and use of the performance measurements. Neely et al. (2002) proposed another subdivision for the process in four phases: design, plan & build, implement & operate and refresh (update).

The first, design, focuses on the choice of measurements and their metrics. The second, plan & build, plans the construction of the PMS (type of system, form of data access, data distribution configurations and manipulation, etc.), in addition to communicating its goals to the organization. The third, implement & operate, is concerned with the operation of the PMS (use of data for management). Finally, the fourth phase, refresh, revises the PMS and refines it.

In any of the two classifications, the design phase is crucial to the success of the PMS and of the organization – unfeasible strategies and visions and badly-planned performance indicators (PI) are the leading factors causing the failure of PMSs (Bourne et al., 2002). Neglecting this stage can result in the construction of a set of inappropriate measurements and metrics and lead to more serious consequences for an organization. According to Neely et al. (2002), organizations usually choose measurements that are easily obtained – with the focus on alternatives instead of studying appropriate measurements for the fundamental goals — value-focused thinking (Keeney, 1992).

According to Suwignjo et al. (2000), organizations do not dedicate time to structuring their performance measurements and understanding their interconnections in a logical manner. This could be decisive in the success of a performance measurement system because: (1) measurements must relate to the organization's strategy; (2) performance measurements vary from organization to organization, and; (3) performance measurements are dynamic (changing with time).

Bourne et al. (2002) and Smith (2005) corroborate the paragraphs above, stating that between 40% and 60% of large companies in the USA tried to implement the BSC at the end of the last century, and 70% failed, mainly due to:

- The wrong decision about what the measure. Many companies identified their performance criteria through diverse techniques (such as Brainstorming) without critical analysis of what really is important. In failing to identify a causal relationship between the performance indicators, it is not possible to establish a strategic map and, therefore, the measurements make no sense and are unfocused.
- Failing during implementation for diverse reasons, chief among them: internal difficulties, such as boycotts by people who feel threatened, inadequate infrastructure (especially in information technology, which demands heavy investment), and a loss of focus (mainly due to the implementation time that takes from 18 to 24 months on average).

The previous discussion highlights the critical importance of the design or construction phase. For this reason, this article focuses on the use of the Analytic Network Process (ANP) as a support method for the design phase of a PMS. To this end, a multi-criteria decision model will be conceived of in the form of a network, based on the framework for The Performance Prism in order to ordinate the performance indicators identified as important by the stakeholders on an undergraduate course in Production Engineering. Experimental performance evaluation will be used to validate the model. The article is structured in the following way: section 2 introduces The Performance Prism concepts; section 3 describes the ANP steps; section 4 introduces the justification for choosing the application in the education sector; section 5 introduces the model and discusses the results achieved; finally, section 6 introduces the paper conclusion.

2. The Performance Prism model

In the transition from the 20th to the 21st century, The Performance Prism model came about as a more flexible proposal in regard to the BSC, capable of being applied to any kind of organization/business. The result of various workshops on performance measurement run by researchers at Andersen Consulting and the British Universities of Cranfield and Cambridge, the new model is based on three premises:

(1) organizations must not center their efforts on satisfying only the expectations and needs of their shareholders and clients, but rather on all the stakeholders involved;

(2) an organization's strategies, processes and capabilities must be well-integrated and aligned with the aim of delivering value to its stakeholders, and;

(3) organizations and their stakeholders must understand their reciprocal relationships – stakeholders must contribute to organizations in order get value out of them.

Such premises can be represented in the five faces of a prism, as in Figure 1.

Handy (2002) defines The Performance Prism (Figure 2) as a model that helps identify the critical components of the strategies, processes and capabilities that need to be developed – from a managerial and performance control standpoint – as prerequisites for the satisfaction of stakeholders' needs and expectations, as well as those of the organization itself. The analogy is to a prism, which, in refracting white light, illustrates the complexity of an apparently simple phenomenon (the same happens when thinking about an organization from the multifaceted standpoint of performance and management).

The main difference between The Performance Prism and the BSC is the premise that, in the former, the strategies are not defined, but must be constructed by the identification of stakeholders' needs and expectations. This affirmation is corroborated by Handy (2002), who points out the main advantage of The Performance Prism in regard to the BSC: through application of the model in an organization, following the five perspectives in Figure 2, the elements that must be approached by the managers become evident.

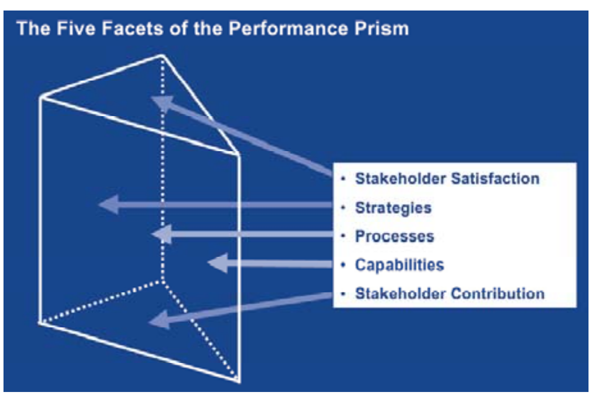

Figure 1. The five facets of the Performance Prism (Source: Neely, 2005).

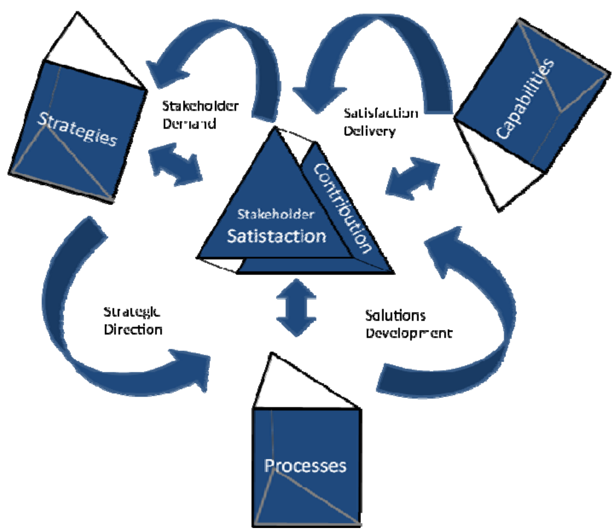

Figure 2. The Performance Prism model (Source: Handy, 2002).

2.1 The first face of the prism: Stakeholders

The first face of the prism aims to reflect on who the fundamental stakeholders in the organization are (investors, employees, consumers, intermediaries, suppliers, regulators, and the community) and what their needs and expectations are. According to Handy (2002), the concept "derive its measurements from strategy" is an error committed by nine out of ten citations related to the theme of performance measurement. Performance measurements must help the managers to move in the direction desired and the strategy represents only one among many routes to achieving these goals, and may therefore be wrong. Hence, instead of identifying the strategies of an organization, its stakeholders and their needs and expectations must be defined so that consistent strategies can be decided on.

An organization's strategy must transmit its goals and a plan to achieve them. Any and every action plan seeks to create value for its multiple stakeholders. So, a Performance Measurement System must begin from the perspective of all the stakeholders involved (Neely et al., 2002).

2.2 The second face of the prism: Contribution by Stakeholders

The second face of the prism aims to understand what the organization needs and wants from its stakeholders, for example: capital and credit from investors, loyalty and profitability from its clients, ideas and competencies from employees, quality materials and services from suppliers, and so on. This perspective is based on the premise that the organization needs contributions from its stakeholders to better play its role, just as they want to have their needs and expectations satisfied by it. For Handy (2002), organizations need loyal and profitable consumers, good suppliers, loyal and satisfied employees, to in return deliver valuable products and services to clients, pay promptly for supplies and reward their employees, respectively.

2.3 The third face of the prism: Strategies

Based on the previous faces, the third face of the prism seeks to reflect on which of the organization's strategies it must conceive of to satisfy the stakeholders. In other words, having defined the main stakeholders, their needs and expectations, and their contributions to the organization, strategies that will be adopted so that the organization can satisfy them must be defined. In this perspective, measurements must be established, the roles of which are: (1) to identify whether the strategies defined are being implemented; (2) to make communication of the strategy within the organization clear; (3) to encourage and incentivize the implementation of the strategies, and (4) to identify whether the strategies are working as planned.

Different authors have stated that, within an organization, people perform their functions better when they are evaluated by measurements. Handy, in Neely et al. (2002), says that when measurements are coherent with strategies, human behavior consistent with the strategies is achieved.

According to Neely et al. (2002), 90% of managers fail in implementing their strategies, because: (1) they assume hypotheses about the organization's performance drivers – if such hypotheses are not true, the goals will not be achieved; (2) they do not develop "capabilities" for the internal processes and/or they plan processes that are not designed to execute the strategies in practice. In this regard, the authors corroborate Kaplan and Norton (1992), ratifying that correct measurement of indicators is crucial to the development of capabilities and processes.

2.4 The fourth face of the prism: Processes

Once the strategies have been defined, the fourth face of the prism aims to identify which processes the organization needs to perfect to put the strategies into practice.

A process should be understood as a set of operations, stages, and events, which are necessary to the execution of a certain job. Within an organization it must be described where, when, and how the work will be done. Conceptually, these are easier to understand through representation of the system: inputs-actions-outputs-results. According to the authors of The Performance Prism, the entire process needs macro and micro measurements in order to provide an overview and identify critical details, such as the existence of bottlenecks. The whole process, then, must have someone in charge of identifying what performance measurements and metrics must be taken and by whom.

Such aspects can be classified, in turn, as measurements of efficiency and measurements of effectiveness. In general, measurements of efficiency are more closely related to process inputs and actions, and measurements of effectiveness to outputs and results. Measurements of inefficiency and variability are also important performance indicators, such as: defects, waiting time, time without adding value, overproduction, unnecessary movements, excessive stock, space wasting, pollution generated, oversizing, excessive complexity, etc. A compilation of various performance criteria common to a wide range of industrial processes can be found in the appendix of Neely et al. (2002) and in the article by Neely et al. (2005).

2.5 The fifth face of the prism – Capabilities

Finally, the fifth face of the prism seeks to reflect on what capabilities need to be developed to conduct such processes.

Behind an efficient and effective process there must be capabilities. Handy (2002) defines organizational capabilities as those formed by competent people, practices, technology and infrastructure capable of creating value for the stakeholders through distinct processes and operations. According to the authors of The Performance Prism, even the well-known capabilities of an organization – those that support the differentiated processes – must be constantly measured to guarantee their sustainability.

This section succinctly presented The Performance Prism, a framework for organizational performance measurement that is based on performance indicators according to the various stakeholders. For additional information on the subject, reading of the authors referred to herein is recommended.

3. The Analytic Network Process

The section introduces the ANP and its operation steps.

The Analytic Network Process (ANP) is a multi-criteria decision-making support method from the American School, originating in Graph Theory, which allows the modeling of a decision-making problem in the form of a network, in order to achieve priorities as regards its elements (criteria and alternatives) (Saaty, 2005).

In the context of the ANP, a network can be defined as a set of clusters, each one with its nodes, which can present dependency relations between each other (intra- and inter-clusters) in any direction (including feedback). If the elements of a certain network only present dependency relations in one single direction there is a hierarchical structure. In other words, a hierarchical or tree structure may be understood as a particular network case (Silva et. al., 2009). Figure 3 illustrates the representation of a decision-making problem in network form. In Figure 3, the clusters are represented by an ellipse, and the nodes belonging to a cluster are represented by full circles. The arrows indicate the relations of influence (dependency) between the elements.

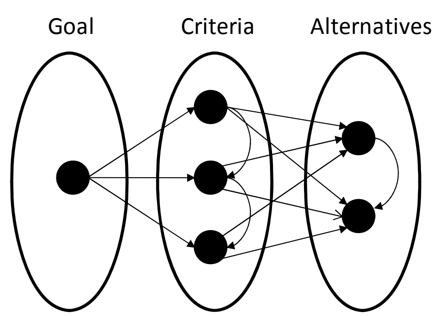

Figure 3. Network structure

Saaty (2005) classifies the nodes in a cluster as: (1) source component: that which exercises an influence on the other elements and is not influenced; (2) intermediary component: that which exercises an influence and is influenced by other elements, and (3) absorbing component: that which is only influenced by others. All three types of nodes are included in the example of a network structure portrayed in Figure 3.

In modeling a decision-making problem in a network, the hypothesis of independence between its elements (criteria and/or alternatives), necessary for the use of the Analytic Hierarchy Process (AHP) by Saaty (1980) – one of the widest-used methods in dealing with multi-criteria problems – is left aside. According to Saaty (2005), the main advantage of the ANP over the AHP is the possibility of working with problems whose criteria, sub-criteria and/or alternatives have interdependencies, which is very common in practice. Hence, the results tend to be more effective than for the AHP as a cost to efficiency – greater analytical effort as the number of pairwise comparisons increases between the elements (Paula and Salomon, 2008).

Silva et al. (2009) present three stages for the application of the ANP to a decision-making problem: 1) Formulation of the problem, 2) Judgments, and 3) Algebraic development. The procedures contained in these steps are presented in brief in Figure 4.

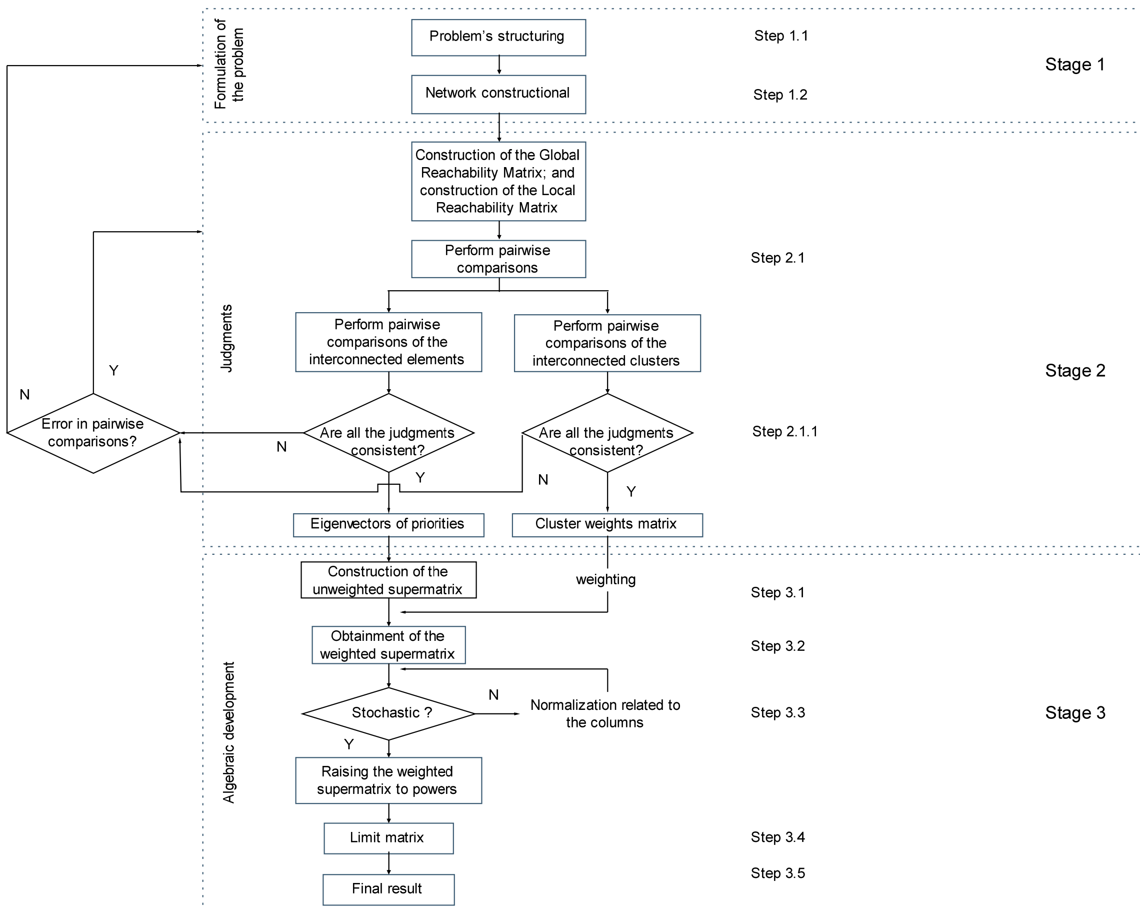

Figure 4. Stages for the application of the ANP to a decision-making problem (Source: Silva et al., 2009).

Stage 1 models the decision-making problem in two steps: the structuring of the problem and the construction of the network.

Step 1.1: In structuring of the problem, the objective of the decision-making context is defined, the clusters, elements and alternatives for decision-making.

Step 1.2: The construction of the network indicates the dependency relations between the elements of the clusters. According to Silva et al. (2009), the dependency relations are described in the matrixes of global and local reach, both of which are binary. The first indicates whether there are dependency relations (1. Relation or 0. no relation) between intra- or inter-clusters (any elements). The second describes the relation of dependency for each element of the network with the rest (1 or 0) elements.

Stage 2 can be summed up by the key word judgment. According to Silva et al. (2009) ,it is executed in one step and a verification sub-step.

Step 2.1: Pairwise comparisons. For all the connections established in Step 1.2, pairwise comparisons must be made according to Saaty's Fundamental Scale (1980), Chart 1. According to Silva et al. (2009), two kinds of comparison are made in the ANP: (1) between two or more elements when they influence another element in conjunction, and; (2) between two or more clusters (whenever there is at least one relation of dependency between any of its elements).

Chart 1. Saaty's Fundamental Scale (Source: Saaty, 1980).

Intensity of importance	Definition	Description
1	Equal importance	The two elements contribute equally to the goals
2	Intermediate value	
3	Moderate importance	Experience and judgment favors one element in relation to the other
4	Intermediate value	
5	Great importance	Experience and judgment strongly favors one element in relation to the other
6	Intermediate value	
7	Very great importance	One element is very strongly favored in relation to the other
8	Intermediate value	
9	Absolute importance	One element is absolutely prioritized in relation to the other

Figure 5 illustrates the use of Saaty's fundamental scale (chart 2) for pairwise comparison between two elements (X and Y) – cluster or node – in a network.

importance of X in regard to Y								X=Y	importance of Y in regard to X							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Figure 5. Illustration of Saaty's fundamental scale to compare two elements (Source: Silva et al., 2009).

The judgments made in comparisons (1) and (2) described above are computed in decision matrixes of order *n*, reciprocal and positive (where *n* is the number of elements compared). For each decision matrix A, the eigenvector and maximum eigenvalue are calculated (λ_{max}) which express the priority value (W) of the elements compared.

According to Gomes (2004), W e λ_{max} can be obtained, respectively, by (1) and (4) or (5).

$$W(A_i) = \sum_{j=1}^{m} W_i(A_j)/n \quad i = 1,\ldots,n\,, \tag{1}$$

Where:

$$W_i(A_j) = \frac{a_{ij}}{\sum_{i-1}^{m} a_{ij}} \qquad j = 1,\ldots,n \tag{2}$$

Such that:

$$\sum_{i=1}^{n} W_i(A_j) = 1 \quad j = 1,\ldots,n \tag{3}$$

$$Aw = \lambda_{max} \times w \tag{4}$$

Or

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{[AW]_i}{w_i} \tag{5}$$

Another way to get the priority vector is by calculating the normalized geometric average for each line of matrix A (Saaty, 2001). Silva et al. (2009) also present the theoretical foundation of the numerical power method to get W and λ_{max}, used by Saaty (2005). This method is relatively simpler for matrixes of large dimensions and seeks convergence for the eigenvalue and eigenvector through the iteration of vectors (Oliveira and Belderrain, 2008).

As the number of comparisons to be made in the ANP depends on the number of judgment matrixes between related nodes and between clusters that present inter-related elements, Saaty proposes the use of *SuperDecisions* software to make comparisons and the respective algebraic calculations in Stage 3. Equation (6) presents the number of comparisons necessary for the N judgment matrixes n_i a decision-making problem, where n_i is the order of the i-th matrix.

$$\sum_{i=1}^{N}\frac{n_i.(n_i-1)}{2} \tag{6}$$

Step 2.1.1 verifies the consistency of the comparison judgments made in 2.1. The decision matrix A is said to be consistent when all the value judgments are perfect, which means to say that aij x ajk = aik, for any i, j, k (Gomes, 2004). In other words, the eigenvector for A (λ_{max}) must be the closest to n.

Nevertheless, Saaty (1980) admits a certain degree of inconsistency in human judgments, above all in quadratic matrixes with n>3, through the indicator IC defined in (7):

$$IC = \frac{(\lambda_{max} - n)}{(n-1)} \tag{7}$$

Hence, he proposes the calculation Consistency Ratio (CR), obtained by (8), where IR (Index Random) are randomly tabled values in function of n, presented in chart 2. According to Gomes (2004), when n=2, CR must be zero; when n=3, CR must be less than 0.05; when n=4, CR must be less than 0.09 and; for n>4 CR must be less than or equal to 0.10.

$$IC = \frac{IC}{IR} \tag{8}$$

Saaty (1994) observes that the inconsistency indicator must be used to alert the decision maker to the need for a possible revision of their judgments. In other words, the rectification of judgments is not compulsory.

Chart 2. IR values for squared matrixes of order *n*, according to the Oak Ridge National Laboratory, USA (Source: Gomes, 2004).

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
IR	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Stage 3, according to Silva et al. (2009), comprises the construction of the supermatrices and getting results. The authors subdivide it into 5 steps:

Step 3.1: Construction of the supermatrix without weight W (generically represented in Figure 6). In W, the network clusters are defined by Ch (h=1, 2, ..., N) and the respective nodes by hnn, in the following form: $e_{h1}, e_{h2}, \ldots, e_{hn_N}$. The components Whh of the supermatrix represent the matrixes obtained by aggregating the eigenvectors obtained in the pairwised comparisons between the elements through step 2.1 (Silva et al., 2009).

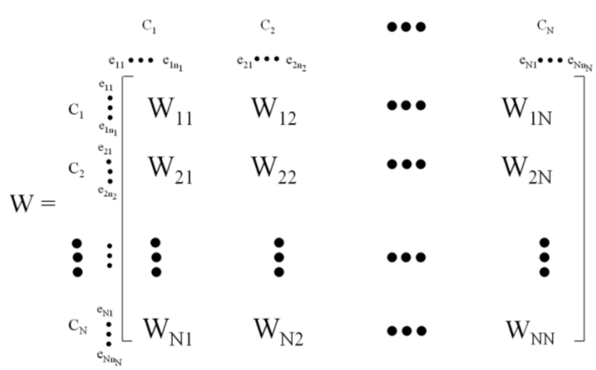

Figure 6. Standard structure of a supermatrix (Source: Saaty, 2005).

Step 3.2: Obtaining the weighted supermatrix through the multiplication of each matrix Whh by the corresponding weight of the cluster Ch.

Step 3.3: Verification of the weighted supermatrix. According to Saaty (2005), the weighted supermatrix obtained in Step 3.2 must be stochastic in regard to the columns. Otherwise, it must be normalized by the sum in regard to the columns.

Step 3.4: Calculation of the limit matrix through the power method described by Oliveira and Belderrain (2008). The limit matrix must also be stochastic in regard to the columns.

Step 3.5: Obtaining the results for ranking of the alternatives and criteria, according to the limit matrix obtained in Step 3.4.

For a better illustration of the ANP method, reading of Saaty (2005), Figueira et al. (2005), Saaty and Vargas (2006) and Silva et al. (2009) is recommended. For an understanding of the functioning of the *SuperDecisions* software, reading of Saaty (2003) is recommended

4. Application in higher education

This section briefly explains why a PMS should be constructed for educational institutions, more specifically, for undergraduate courses.

In Brazil, most educational institutions still work without a control and management system using indicator measurement (Bressiani et al.,2001). The managers of Higher Educational Institutes (HEI) and programs, for the most part, do not have a management system that includes performance indicators for their business units (courses) with the level of detail and scope necessary for effective management.

Course and program coordinators are generally aware of the performance indicators used by the Brazilian Ministry of Education (MEC) – government – for course accreditation processes, but often do not have access to other important indicators such as the financial impact of their courses and the satisfaction of those benefited directly and indirectly by the service provided. Many private HEI managers have financial control through indicators that often do not describe the true cost/benefit relations of the programs/courses in their departments/institutions.

A review of the literature shows the increase over time of work proposing the use of the PMS as a strategic management system for HEIs. Nevertheless, most of them suggest performance indicators for the institutions, but none deals with the application of the BSC in its full conception, according to the proposal by Kaplan and Norton (1992).

Higher Educational Institutions may have dozens of separate business units, focused on diverse areas of knowledge with their own goals, targets and operational strategies. Their corporate strategies and missions, however, tend to be generic. Porter (1998) suggests that competition in a given sector is at the level of business units and not between corporations. It makes sense, then, that PMSs be molded to the business units, as their strategies must support the corporation's strategy.

4.1 Evaluation by Ministry of Education (MEC)

Currently, Brazilian higher education is evaluated by two agents: one internal to the HEI itself, called the Self-Evaluation Commission, whose main instrument is institutional self-evaluation; the other is carried out by external agencies linked to the Ministry of Education (MEC), which carry out inspections: registration and re-registration of institutions, authorization, accreditation and renewal of accreditation for courses, and examining student performance. These agents and their instruments comprise SINAES – the National Higher Education Evaluation System – created by Law n° 10,861 (2004).

The three main instruments used by SINAES are:

- Institutional evaluation that aims identify the profile, vocation and operation of the HEI, through its activities, courses, programs, projects and sectors, respecting the diversity and specifications of the different academic organizations;
- Evaluation of the undergraduate courses, with a view to conceptualizing the teaching conditions offered through three main categories: didactic-pedagogical organization, the academic and technical-administrative staff, and the physical installations;
- Evaluation of student performance on undergraduate courses, via the National Student Performance Examination (ENADE), to verify student performance in terms of general and specific knowledge acquired, besides skills and competencies required of the career chosen.

However, what is noted in practice is that the mechanisms of evaluation created by MEC are not being carried out as planned by SINAES. The very expansion of higher education in the face of the limited capacity of the Ministry to evaluate the universe of higher courses has become one of the major stumbling blocks in the system. The focus in evaluation now on diagnosing the quality of higher education is centered on ENADE and its indicators. According to the concepts obtained from students on a course that was assessed by this exam, MEC calculates a Preliminary Course Concept (CPC), which can dispense it from a renewal of accreditation process (CPC ≥ 3) (Normative Ordinance n. 4, 2008).

For Macedo et al. (2005), even if the full range of SINAES evaluation were fully implemented, it would not be enough to contemplate the size and heterogeneity of current higher education. In the scope of evaluation, other authors have suggested that an effective project to reform higher education must conceive of an evaluation system that can handle the different educational segments and institutions that comprise the educational system. In other words, it must be able to identify the strengths and weaknesses of each HEI in order to be able to improve them. This makes it necessary for the instruments of evaluation to be able to describe the trajectory followed by the institution and, mainly, compliance with its mission, through careful measurement of pertinent performance indicators.

Piratelli et al. (2009) present the current Evaluation Instrument that supports the government accreditation processes for undergraduate courses and some of their potential deficiencies. The results of evaluation process simulations have identified that potential injustices could occur when using the instrument without the subjective intervention of an evaluation commission. The authors particularly show that it is easily possible to approve a course that is failing to comply with the demands of the labor market and pedagogically poorly structured because it has a good physical structure and good people. They also show that a course committed to pedagogical and professional aspects may not have a minimum concept of accreditation because of some deficiencies in the way it hires academic staff and promotes them.

In addition, from the Balanced Scorecard or The Performance Prism standpoint, MEC's diagnostic and evaluation instruments focus on internal process and learning/growth indicators, and ignore performance from the point of view of the other stakeholders – and mainly for the direct and indirect clients, who chiefly benefit from their processes and products.

The arguments presented in this section justify the application of The Performance Prism in higher education, more specifically for the management of university courses.

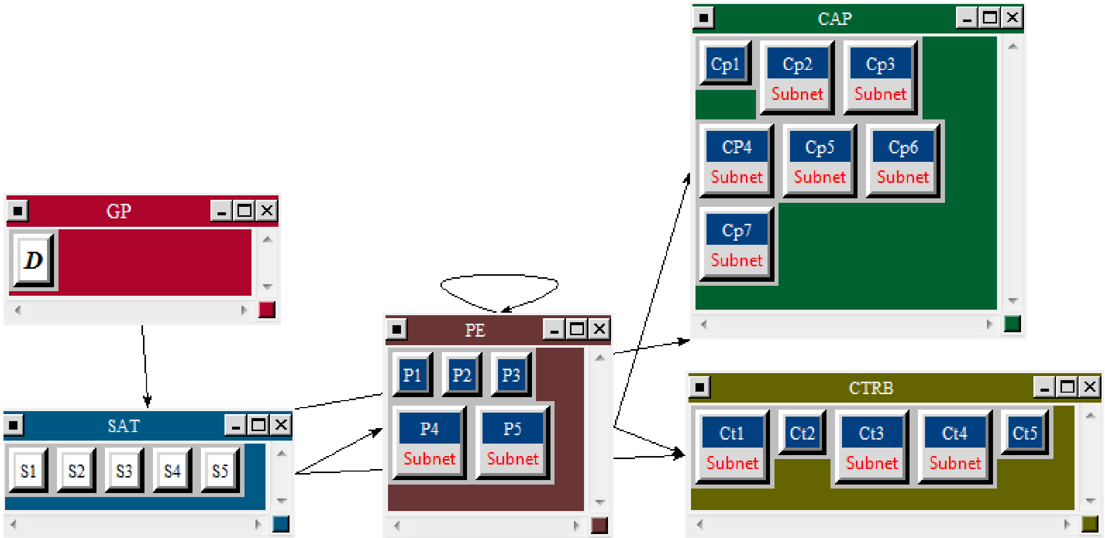

Figure 7. The PMS modeled with ANP in the *SuperDecisions* software.

5. Modeling of The Performance Prism in the ANP

To introduce the model and its results, this section follows the same stages described in section 3. The results are subdivided in sections 5.1 (model and results), 5.2 (evaluation) and 5.3 (model sensitivity analysis).

5. The model and its results

Stage 1: Formulation of the problem.

Step 1.1: The objective of the problem is to order the performance indicators (PI) for an undergraduate course in Production Engineering. The PI were identified as relevant by its stakeholders (students, academic staff, educational institute (manager), organizations, and society). The ranking will serve to evaluate the course performance from the standpoint of the various stakeholders, allowing better strategic management (focusing on critical points).

Step 1.2: The PMS was modeled on 4 of the 5 faces of the prism: satisfaction, value delivery processes, capabilities and stakeholder contributions. Each face of the prism is represented by a cluster in the ANP. So the clusters are Satisfaction, Processes, Capabilities and Contribution. The course performance is measured through satisfaction indicators for the stakeholders: students, academic staff, educational institution, society and organizations. Satisfaction indicators for each stakeholder, in turn, depend on the nodes belonging to each of the other clusters. As in section 2, the face “strategy” is not measurable, and so is not incorporated in the model. The decision-makers (collegiate board) understand that strategic direction can only be conceived after knowing the importance of each indicator from the stakeholders’ standpoint. Figure 7 presents the PMS model. Chart 3 has the key for the clusters and nodes in the PMS network.

Chart 3: Model key

Code	Indicator or cluster name	Code	Indicator or cluster name
Ab1	laboratories basic scope	Cu3	activities content integration
Ab2	laboratories specific scope	Cu4	teaching multi-methodology
Ab3	professional training laboratories scope	D	global performance
Bb1	collection update (library)	Dc1	focused complementary activities
Bb2	number of copies (library)	Dc2	guideline percentages

Code	Indicator or cluster name	Code	Indicator or cluster name
C1	economic competencies to engineering	Dc3	students intern supervision
C2	general competencies to engineering	En1	assisting pupils
C3	human competencies to engineering	En2	technical visits
C4	socio-political competencies to engineering	Eq1	laboratories basic equipment
C5	technical competencies to engineering	Eq2	laboratories specific equipment
CAP	cluster: Capabilities	Eq3	laboratories professional equipment
Cd1	teaching didactics	Fi1	classroom climate
Cd2	teaching experience	Fi2	classroom space
Cd3	professional experience (teacher)	Fi3	classroom furniture
Cd4	degree (teacher)	GP	cluster: Global Performance
Co1	collegiate board performance	I	cluster: main indicator for each subnet
Co2	structuring core faculty performance	IE1	library
Co3	time to coordinate	IE1	cluster: Library
Cp1	level of entering students	IE2	laboratories
Cp2	secretarial	IE2AB	cluster: Laboratories : Scope
CP2	cluster: Secretarial	IE2EQ	cluster: Laboratories : Equipment/Material
Cp3	working infrastructure	IE3	classrooms
CP3	cluster: working infrastructure	IE3FI	cluster: Classrooms – physical aspects
Cp4	coordination	IE3RD	cluster: Classrooms – didactic resources
CP4	cluster: Coordination	IF1	percentage of occupation
Cp5	capacity of academic staff	IF2	percentage revenue /revenue potential
CP5	cluster: Capacity of academic staff	IO1	ENADE concept
Cp6	teaching infrastructure	IT1	scientific bases
CP6	cluster: Teaching infrastructure	IT2	work rooms
Cp7	pedagogical policy project	P1	publications
CP7co	cluster: project consistency	P2	service provision (to society)
CP7cu	cluster: Curriculum indicators	P3	social projects
CP7dc	cluster: compliance by DCs	P4	solving organizations problems
Cs1	curriculum-goal	P4	cluster: Resolution of problems
Cs2	curriculum-intended egress profile	P5	competencies to engineering
Ct1	contribution academic staff	P5	cluster: Competencies
CT1EN	cluster: teaching commitment	PE	cluster: Processes
CT1RE	cluster: rule compliance	Rd1	internet access
Ct2	employability	Rd2	multimedia (availability)
Ct3	contribution HEI-staff	Re1	staff punctuality
CT3	cluster: Contribution HEI-staff	Re2	staff deadlines
Ct4	contribution students and society	Rp1	quality of interns
CT4FI	cluster: Financial	Rp2	research
CT4IO	cluster: Others (ENADE)	Rp3	monographies applied
Ct5	contribution HEI –students (scholarships P-E)	S1	students (satisfaction)
Cti1	research incentive	S2	academic staff (satisfaction)
Cti2	working hours	S3	HEI (satisfaction)
Cti3	career plan	S4	organizations (satisfaction)
Cti4	remuneration	S5	society (satisfaction)

Code	Indicator or cluster name	Code	Indicator or cluster name
CTRB	cluster: Contribution	Sa1	number of terminals
Cu1	professional attributions	Sa2	employee qualification
Cu2	regional focus	SAT	cluster: Satisfaction

The dependency relations between the elements of the network in Figure 7 are presented in the global reach matrixes (charts 4 and 6) and in the local reach matrixes (charts 5 and 7).

Stage 2: Judgment matrixes and verification of consistencies

Step 2.1: The judgment matrixes were filled in, mostly, by members of the collegiate board (5 academic staff and 2 students). Each group of stakeholders judged, in a consensual manner, the pertinent indicators and clusters. The indicators referring to the HEI stakeholders (director board) and organizations were judged by members external to the collegiate board in identical questionnaires shown in Figure 5. In these cases the geometrical average was used to get the priority vectors (Saaty and Peniwati, 2007). The judgments of the indicators for the satisfaction cluster were made in a consensual manner by all members of the collegiate board, resulting in the priority vector in Table 1.

Chart 4. Global reach matrix.

	GP	SAT	PE	CAP	CTRB
GP	0	1	0	0	0
SAT	0	0	1	1	1
PE	0	0	1	1	1
CAP	0	0	0	0	0
CTRB	0	1	0	0	0

Chart 5. Main network local reach matrix.

		CAP								CTRB				GP	PE					SAT				
		Cp1	Cp2	Cp3	Cp4	Cp5	Cp6	Cp7	Ct1	Ct2	Ct3	Ct4	Ct5	D	P1	P2	P3	P4	P5	S1	S2	S3	S4	S5
CAP	Cp1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cp2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cp3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cp4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cp5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cp6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cp7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CTRB	Ct1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Ct2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Ct3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ct4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Ct5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
PE	P1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
	P2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	P3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	P4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	P5	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SAT	S1	1	1	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

	S3	0	0	0	1	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0
	S4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
	S5	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0

Chart 6. Subnet global reach matrices.

	I	P4
I	0	1
P4	0	0

	I	P5
I	0	1
P5	0	0

	I	CP2
I	0	1
CP2	0	0

	I	CP3
I	0	1
CP3	0	0

	I	CP4
I	0	1
CP4	0	0

	I	CP5
I	0	1
CP5	0	0

	I	CP6
I	0	1
CP6	0	0

	I	Ct3
I	0	1
Ct3	0	0

	I	IE1
I	0	1
IE1	0	0

Chart 6. Subnet global reach matrices (continuance)

	I	CT4IF	CT4IO
I	0	1	1
CT4IF	0	1	0
CT4IO	0	0	0

	I	CT1EN	CT1RE
I	0	1	1
CT1EN	0	0	0
CT1RE	0	0	0

	I	IE2AB	IE2EQ
I	0	1	1
IE2AB	0	0	0
IE2EQ	0	0	0

	I	CP7co	CP7cu	CP7dc
I	0	1	1	1
CP7co	0	0	0	0
CP7cu	0	0	0	0
CP7dc	0	0	0	0

	I	IE3FI	IEFRD
I	0	1	1
IE3FI	0	0	0
IEFRD	0	0	0

Chart 7. Subnet local reach matrices.

Subnet P4		I	P4		
		P4	Rp1	Rp2	Rp3
I	P4	0	1	1	1
P4	Rp1	0	0	0	0
	Rp2	0	0	0	0
	Rp3	0	0	0	0

Subnet P5		I	P5				
		P5	C1	C2	C3	C4	C5
I	P5	0	1	1	1	1	1
P5	C1	0	0	0	0	0	0
	C2	0	0	0	0	0	0
	C3	0	0	0	0	0	0
	C4	0	0	0	0	0	0
	C5	0	0	0	0	0	0

Subnet CP2		CP2		I
		S1	S2	Cp2
CP2	S1	0	0	0
	S2	0	0	0
I	Cp2	1	1	0

Subnet CP3		CP3		I
		It1	It2	Cp3
CP3	It1	0	0	0
	It2	0	0	0
I	Cp3	1	1	0

Subnet CP4		CP4			I
		Co1	Co2	Co3	Cp4
CP4	Co1	0	0	0	0
	Co2	0	0	0	0
	Co3	0	0	0	0
I	Cp4	1	1	1	0

Subnet CP5		CP5				I
		Cd1	Cd2	Cd3	Cd4	Cp5
CP5	Cd1	0	1	0	0	0
	Cd2	0	0	0	0	0
	Cd3	0	0	0	0	0
	Cd4	0	0	0	0	0
I	Cp5	1	1	1	1	0

Subnet CP6		CP6			I
		IE1	IE2	IE3	Cp6
CP6	IE1	0	0	0	0
	IE2	0	0	0	0
	IE3	0	0	0	0
I	Cp6	1	1	1	0

Subnet CP7		CP7	CP7co		CP7cu				CP7dc		
		Cp7	Cs1	Cs2	Cu1	Cu2	Cu3	Cu4	Dc1	Dc2	Dc3
CP7	Cp7	0	1	1	1	1	1	1	1	1	1
CP7co	Cs1	0	0	0	0	0	0	0	0	0	0
	Cs2	0	0	0	0	0	0	0	0	0	0
CP7cu	Cu1	0	0	0	0	0	0	0	0	0	0
	Cu2	0	0	0	0	0	0	0	0	0	0
	Cu3	0	0	0	0	0	0	0	0	0	0
	Cu4	0	0	0	0	0	0	0	0	0	0
CP7dc	Dc1	0	0	0	0	0	0	0	0	0	0
	Dc2	0	0	0	0	0	0	0	0	0	0
	Dc3	0	0	0	0	0	0	0	0	0	0

Subnet Ct1		CT1EN		CT1RE		I
		En1	En2	Re1	Re2	Ct1
CT1EN	En1	0	0	0	0	0
	En2	0	0	0	0	0
CT1RE	Re1	0	0	0	0	0
	Re2	0	0	0	0	0
I	Ct1	1	1	1	1	0

Subnet IE1		I	IE1	
		IE1	Bb1	Bb2
I	IE1	0	1	1
IE1	Bb1	0	0	0
	Bb2	0	0	0

Subnet IE2		I	IE2AB			IE2EQ		
		IE2	Ab1	Ab2	Ab3	Eq1	Eq2	Eq3
I	IE2	0	1	1	1	1	1	1
IE2AB	Ab1	0	0	0	0	0	0	0
	Ab2	0	0	0	0	0	0	0
	Ab3	0	0	0	0	0	0	0
IE2EQ	Eq1	0	0	0	0	0	0	0
	Eq2	0	0	0	0	0	0	0
	Eq3	0	0	0	0	0	0	0

Subnet IE3		I	IE3FI			IE3RD	
		IE3	Fi1	Fi2	Fi3	Rd1	Rd2
I	IE3	0	1	1	1	1	1
IE3FI	Fi1	0	0	0	0	0	0
	Fi2	0	0	0	0	0	0
	Fi3	0	0	0	0	0	0
IE3RD	Rd1	0	0	0	0	0	0
	Rd2	0	0	0	0	0	0

Subnet Ct3		CT3				I
		Cti1	Cti2	Cti3	Cti4	Ct3
CT3	Cti1	0	0	0	0	0
	Cti2	0	0	0	0	0
	Cti3	0	0	0	0	0
	Cti4	0	0	0	0	0
I	Ct3	1	1	1	1	0

Subnet Ct4		CT4IF		CT4IO	I
		IF1	IF2	IO1	Ct4
CT4IF	IF1	0	0	0	0
	IF2	1	0	0	0
CT4IO	IO1	0	0	0	0
I	Ct4	1	1	1	0

Table 1. Priority vector for the elements of the satisfaction cluster (stakeholders).

Stakeholder	Priority	*Stakeholder*	Priority
S1	23.81%	S4	19.05%
S2	19.05%	S5	19.05%
S3	19.05%		

Step 2.2. The consistency of the judgments was guaranteed in a satisfactory manner in all the comparison matrixes.

Stage 3 corresponds to the construction of the supermatrices and obtaining results from the model. Steps 3.1 to 3.4 have been omitted for reasons of space.

Step 3.5: Results. The results for the model (weight of indicators in the evaluation) are in Table 2.

Table 2. Weight of indicators in the evaluation of course performance.

Indicators	Weight in evaluation	Indicators	Weight in evaluation	Indicators	Weight in evaluation	Indicators	Weight in evaluation
Cd1	3.58%	Eq2	2.15%	C4	1.44%	Sa1	1.08%
Cd2	3.58%	Eq3	2.15%	C5	1.44%	Ab1	1.07%
P2	3.31%	P1	2.01%	IT1	1.39%	Fi1	1.06%
Ab2	3.22%	Cu1	1.98%	Rp2	1.38%	Fi3	1.06%
Ab3	3.22%	Cu2	1.98%	Sa2	1.33%	Bb1	1.03%
P3	3.14%	Cu3	1.98%	IF1	1.31%	IT2	1.00%
Co2	2.92%	Cu4	1.98%	IO1	1.31%	Dc1	0.99%
Co3	2.92%	Rp3	1.70%	Cp1	1.27%	Dc2	0.99%
Cd3	2.79%	Cd4	1.64%	Bb2	1.25%	Dc3	0.99%
Fi2	2.66%	Ct5	1.61%	Cti4	1.25%	Rd1	0.98%
Rp1	2.37%	Ct2	1.52%	Cti2	1.25%	Eq1	0.72%
Cs1	2.34%	Co1	1.46%	Cti3	1.25%	Re2	0.58%
Cs2	2.34%	C1	1.44%	En2	1.16%	IF2	0.44%
En1	2.31%	C2	1.44%	Re1	1.16%	Cti1	0.42%
Rd2	2.21%	C3	1.44%				

5.2 Evaluation of Course Performance

Through the ranking of indicator priorities obtained (Table 2), it was possible to measure course performance individually, as well as globally. For each indicator the course collegiate board described five levels of impact. For each descriptor, a function value was constructed, varying between 0 and 100 points with a corresponding one for each level of impact. Course evaluation was done by the collegiate board. Table 3 presents the satisfaction percentage for each stakeholder (performance). The global course indicator was 58.62%.

Figure 8 details the performance indicators pertinent to each *stakeholder*, illustrating chromatically what must be prioritized by the manager: red-orange: worst performance (urgent action required); yellow-green: average performance (attention: improvement is required) and; green-Dark green: good performance – no action required, keep monitoring).

S1

Indicadores	%
Cd1	50.00%
Cd2	100.00%
Ab2	75.00%
Ab3	65.00%
Cd3	95.00%
Fi2	0.00%
En1	35.00%
Rd2	55.00%
Eq2	90.00%
Eq3	20.00%
Cd4	100.00%
Ct2	70.00%
Sa2	50.00%
Cp1	25.00%
Bb2	50.00%
En2	60.00%
Re1	60.00%
Sa1	0.00%
Ab1	50.00%
Fi1	50.00%
Fi3	70.00%
Bb1	25.00%
Rd1	0.00%
Eq1	55.00%
Re2	85.00%
	57.10%

S2

Indicadores	%
Fi2	0.00%
Rd2	55.00%
IT1	50.00%
Sa2	50.00%
Cti4	100.00%
Cti2	50.00%
Cti3	25.00%
Fi1	50.00%
IT2	30.00%
Rd1	0.00%
Cti1	25.00%
	38.48%

S3

Indicadores	%
P2	0.00%
P3	37.50%
Co2	80.00%
Co3	100.00%
P1	100.00%
Ct5	0.00%
Co1	80.00%
IF1	50.00%
IO1	50.00%
IF2	60.00%
	54.74%

S4

Indicador	%
Rp1	20.00%
Cs1	100.00%
Cs2	100.00%
Cu1	75.00%
Cu2	75.00%
Cu3	10.00%
Cu4	30.00%
Rp3	100.00%
C1	75.00%
C2	80.00%
C3	90.00%
C4	90.00%
C5	80.00%
Rp2	0.00%
Dc1	50.00%
Dc2	100.00%
Dc3	50.00%
	65.81%

S5

Indicador	%
Cd1	50.00%
Cd2	100.00%
P2	0.00%
Ab2	75.00%
Ab3	65.00%
P3	37.50%
Cd3	95.00%
Fi2	0.00%
Cs1	100.00%
Cs2	100.00%
Rd2	55.00%
Eq2	90.00%
Eq3	20.00%
Cu1	75.00%
Cu2	75.00%
Cu3	10.00%
Cu4	30.00%
Cd4	100.00%
Ct5	0.00%
C1	75.00%
C2	80.00%
C3	90.00%
C4	90.00%
C5	80.00%
Bb2	50.00%
Ab1	50.00%
Fi3	70.00%
Bb1	25.00%
Dc1	50.00%
Dc2	100.00%
Dc3	50.00%
Rd1	0.00%
Eq1	55.00%
	59.07%

Figure 8. The PMS: its indicators and evaluation of the course for management.

Table 3. Course performance by satisfaction of the stakeholders.

Final Performance	%
S1	57.10
S2	38.48
S3	54.74
S4	65.81
S5	59.07
D	58.62

Table 4. Course performance by stakeholder satisfaction (with equal weights).

Final Performance	%
S1	57.89
S2	41.25
S3	54.88
S4	64.58
S5	58.99
D	58.50

5.3 Analysis of the model's sensitivity

As each judgment was made consensually by the stakeholder groups, analysis of the model's sensitivity was carried out by varying the priority vector in Table 1. Considering all the stakeholders to have equal importance in judging the indicators, there were no significant changes in the evaluation of the course (despite small variations in the priority vectors). Table 4 presents the satisfaction percentage for each stakeholder (performance) for this configuration. Table 5 presents the new ranking of the indicators. The new global performance indicator was 58.50%.

Two other sensitivity analyses were carried out: (1) considering internal stakeholders to be twice as important as the external ones, and (2) considering the external stakeholders to be twice as important as the internal ones. The results of the model are in Tables 6 and 7, respectively.

Table 5. Weights for performance indicators when all the stakeholders have equal weights.

Indicators	Weight in evaluation	Indicators	Weight in evaluation	Indicators	Weight in evaluation	Indicators	Weight in evaluation
Cd1	3.49%	Rp3	2.08%	Cd4	1.60%	Dc2	1.01%
Cd2	3.49%	Cu1	2.02%	Cp1	1.52%	Dc3	1.01%
Rp1	2.91%	Cu2	2.02%	Co1	1.45%	Sa1	0.98%
Co2	2.89%	Cu3	2.02%	IT2	1.42%	En2	0.90%
Co3	2.89%	Cu4	2.02%	C1	1.39%	Re1	0.90%
P2	2.80%	IT1	1.97%	C2	1.39%	Ab1	0.90%
Ct5	2.80%	Rd2	1.85%	C3	1.39%	Fi1	0.89%
P1	2.76%	Ct2	1.81%	C4	1.39%	Fi3	0.89%
Cd3	2.72%	En1	1.81%	C5	1.39%	Bb1	0.86%
Ab2	2.70%	Eq2	1.80%	IF1	1.29%	Rd1	0.82%
Ab3	2.70%	Eq3	1.80%	IO1	1.29%	Eq1	0.60%
P3	2.64%	Cti4	1.76%	Sa2	1.20%	Cti1	0.59%
Cs1	2.39%	Cti2	1.76%	Bb2	1.05%	Re2	0.45%
Cs2	2.39%	Cti3	1.76%	Dc1	1.01%	IF2	0.43%
Fi2	2.23%	Rp2	1.70%				

Table 6. Course performance by stakeholder satisfaction (1).

Final Performance	%
S1	54.88
S2	39.55
S3	56.58
S4	64.49
S5	54.67
D	56.68

Table 7. Course performance by stakeholder satisfaction (2).

Final Performance	%
S1	60.52
S2	37.94
S3	51.89
S4	66.59
S5	62.63
D	61.13

Through sensitivity analysis, no significant changes were observed in the course evaluation results.

6. Conclusion

The design phase, in focusing on the choice of measurements and their metrics, is crucial to the success of the PMS and the organization. This article approached the design phase for a PMS bases on The Performance Prism using the Analytic Network Process (ANP) for modeling and ranking of the performance indicators. Application of the ANP as support for the PMS design was carried out in the higher education sector to aid management for an undergraduate Production Engineering course. The model and its results assured the representation of diverse stakeholders "voices" – in a significant and balanced manner – through 58 performance indicators distributed in 4 clusters: satisfaction, processes, capabilities and contribution.

The results of the model – ranking of the indicators and measurement of performance – were useful for the course's collegiate board to be able to reflect on issues that were lacking in information and to discuss action plans make improvements. The group was satisfied with the representative nature and robustness of the model, as sensitivity analysis did not significantly impact the performance evaluation results. It can be stated that the model is legitimate in accurately reflecting strengths and weaknesses of the course. Confidence in the model was guaranteed not only by the participation of diverse stakeholders (structuring of indicators and judgments), but also because the collegiate board was willing to construct value descriptors and functions for each performance indicator which were useful in operating a subjective evaluation by the group.

Although this model does not stipulate the MEC stakeholder (government), many performance indicators include this agent's interest. The next step in this work will be to guarantee, through Monte Carlo simulation, that if the course performance is rated as good by the PMS constructed, the government stakeholder (MEC) will be satisfied (with a score sufficient for accreditation).

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