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Multi-Criteria Decision Making and the validation of indicators for process prioritization in BPM

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Abstract. Business Process Management (BPM) is a management tool supporting business processes through methods, techniques, and software that design, represent, control and analyze processes involving people, organizations, applications, documents and other sources of information. This paper aims to apply MCDM, specifically the Analytic Hierarchy Process (AHP), to the validation of indicators for process prioritization during the planning phase of a BPM cycle. This article contributes by highlighting the need for testing and validating PPIs and verifying their adherence to the reality of organizations. In a specific test, it was possible to verify that a good definition avoids conceptual errors when choosing an indicator. The advantage of a prioritization method, such as the AHP, over arbitrary choices when prioritizing critical processes through the application of BPM, was also observed.

Keywords: Business Process Management, Process indicator, AHP, BPM, KPI.

1 Introduction

Business Process Management (BPM) is an administration discipline that integrates an organization's strategies and objectives with customer expectations and needs, by focusing on end-to-end processes. BPM encompasses strategies, objectives, culture, organizational structures, roles, policies, methods and technologies to analyze, design, implement, manage performance, transform and establish process governance (ABPM 2013).

To improve the operational efficiency of an organization with BPM, all processes must be clearly defined and, if possible, organized and formalized, so that everyone involved understands their roles or duties.

Process management emerges as a dominant organizational method for the 21st century, where functional structures are abandoned or modified in favor of a matrix approach (Hammer and Champy 1994). BPM is a management tool that supports business processes through methods, techniques, and software that design, represent, control and analyze processes involving people, organizations, applications, documents and other sources of information (Van Der Aalst Hofstede and Weske 2003).

According to Baldam, Valle and Rosenfeld (2014), BPM helps organizations to identify the importance of their processes and to obtain competitive advantages through process evaluation indicators, such as execution time and performance improvements. The authors further illustrate that the use of Digital Information and Communication Technologies facilitates the identification of structures within a BPM cycle, namely: plan the BPM; analyze, model and optimize processes; implement; and monitor processes and their performance (Baldam, Valle and Rozenfeld 2014).

There are several types of BPM cycles mentioned in the literature. For example, the Association of Business Process Management Professionals (ABPMP 2013) agreed on a standard BPM cycle model, considering the common body of knowledge established by academics, professionals, and stakeholders, as can be seen in Figure 1.

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In the planning phase of the BPM cycle of Baldam, Valle and Rosenfeld (2014), two main elements, closely related to the Multi-criteria Decision Support Methods approach, were observed: the selection of critical processes, and the prioritization of activities. These two elements form the basis of BPM planning, since the complexity, range and demand of business processes in organizations require methods, rather than random intuition, to ensure that managers make better decisions.

In this context, the present article aims to apply MCDM, specifically the AHP, to the validation of indicators for prioritizing the planning phase processes of a BPM cycle, using the Super Decisions software (Shirali and Nematpour 2019, Solar et al. 2018, Tiwari and Tiwari 2018).

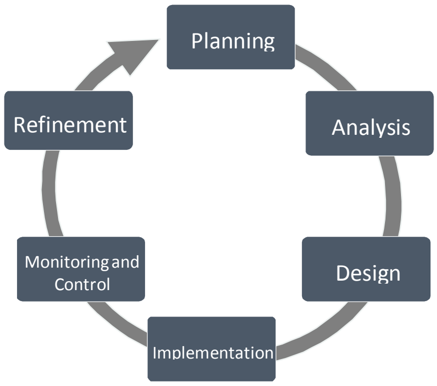

Fig. 1. BPM Cycle (ABPMP 2013).

2 Theoretical Background

2.1 Analytic hierarchy process (AHP)

The multi-criteria approach to decision making or Multi-Criteria Decision Making (MCDM), aimed at the hierarchy and prioritization of critical processes associated with BPM, has been gaining relevance in the scientific community (Saaty 1990, Cho and Lee 2011, Sampaio et al. 2018).

The methods of support for multi-criteria decision making are drawn from two schools, the American and the French. Among the various methods of the American tradition, AHP stands out as the most well-known and utilized, due to its ease of application (Baldam, Valle and Rozenfeld 2014). MCDM can be classified into three major groups: selection, where the objective is to select one of the solution options (alternatives); ordering, which aims to create a ranking of solution options (the case to be applied in this work); and classification, which classifies solutions into predetermined groups (Diaby and Goeree 2014).

The nature of multi-criteria problems is added to those of the prioritization processes, since they involve significant tradeoffs, requiring the allocation of weights for each criterion, as is the case with the AHP. Indeed, among the various existing multi-criteria methods, AHP is considered one of the most studied and applied, in terms of its complexity and subjectivity (Process Management, Risk Management, Quality Management Systems, among others) (Becker and Braunschweig, 2004).

The AHP was developed by Prof. Thomas Saaty in the late 1970s to solve complex multi-criteria decision-making problems (Shimizu 2006). The Decision Support Systems Glossary (Power 2014) defines AHP as ñAn approach to decision making that involves structuring multiple-choice criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternativesò.

The AHP is an important tool in the decision-making process, as it enables the involvement of both quantitative and qualitative aspects during its modeling (Vaidyac and Kumar 2006). The method also allows comparisons between pairs of elements, through levels of criteria and alternatives, to define the relative importance of one element over the other within each level (Saaty 1991).

The implementation of the AHP method consists of the following steps (Gomes, Gonzalez-Araya and Carignano 2004): (a) define the objectives; (b) define the alternatives; (c) define the criteria relevant to the problem; (d) assess the relative importance of each criterion; (e) evaluate the alternatives against the criteria; and (f) determine the overall assessment of each alternative. In short, the hierarchical structure of an AHP comprises a goal (or objective), criteria and alternatives, as shown in Figure 2.

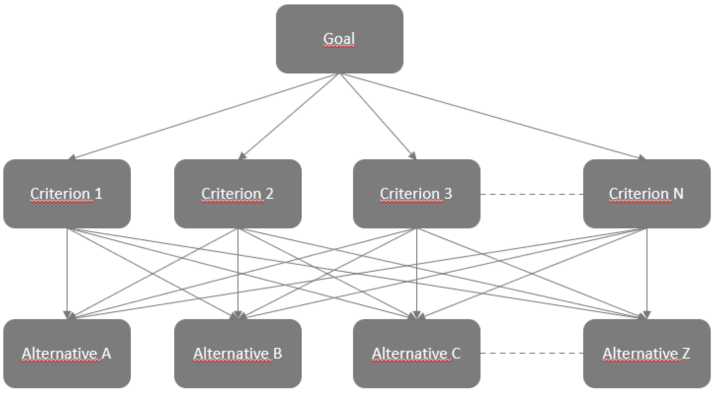

Fig. 2. Hierarchical Structure of the AHP (Costa 2006).

Saaty (2008) establishes the application of AHP in 4 stages:

1. Definition of the problem: in this step, the objective of the problem is defined and the criteria and sub-criteria to be evaluated are identified, based on the context of the problem and the convictions and beliefs of the decision-maker;

2. Structuring the decision hierarchy: in this step, the hierarchical structure is built according to an order of priority, where the final objective of a decision problem is at the top, followed by the main criteria of this problem. Below this level are the sub-criteria for each criterion, possibly with more than one level of sub-criteria;

3. Construction of the decision matrices: in this stage, the comparison matrices are built pair by pair according to experience and judgment. For this purpose, a scale from 1 to 9, called the Saaty Fundamental Scale (Saaty 2001), as shown in Table 1, is used.

4. Final synthesis: in this step, the priorities obtained in the pairwise comparisons are used to weigh the alternatives and, thus, obtain the result.

Table 1. Saaty's basic scale of relative importance (Saaty 2001).

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another.
5	Essential or strong importance	Experience and judgment strongly favor one activity over another.
7	Demonstrated importance	Activity is strongly favored, and its dominance demonstrated in practice.
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed.

Salomon (2002) summarizes the application of the AHP in a more didactic manner, as follows: (i) structuring the model, (ii) making judgments and (iii) synthesizing the results. Table 2 shows the set of equations that comprises the AHP method.

Table 2. Synthesis of AHP equations (adapted from Mendes Erthal Júnior and Hosken 2013).

Order	Equations number	Equations	Description
1	Eq. 1	$\begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & a_{2,3} & \cdots & a_{2,n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{m,1} & a_{m,2} & a_{m,3} & \cdots & a_{m,n} \end{bmatrix}$	Formation of matrices of decision or judgment. Expresses the number of times an alternative dominates or is dominated by others
2	Eq. 2	$Wi = \left(\prod_{j=1}^{n} Wij\right)^{1/n}$	Eigenvector calculation (Wi). It consists of ordering the priorities or hierarchies of the characteristics studied.
3	Eq. 3	$T = \left\lvert \frac{W1}{\sum Wi}; \frac{W2}{\sum Wi}; \frac{W3}{\sum Wi} \right\rvert$	Calculation of self-vector standardization enables comparison between criteria and alternatives
4	Eq. 4	$\lambda máx = T \times W$	Index that lists the criteria of the consistency matrix and the criteria weights
5	Eq. 5	$IC = \frac{\lambda máx. - n}{(n-1)}$	Consistency index allows evaluating the degree of inconsistency of the paired judgment matrix
6	Eq. 6	$RC = \frac{IC}{CA}$	The consistency ratio allows you to evaluate the inconsistency due to the order of the judgment matrix (if the value is greater than 0.10, then review the model and, or, the judgments).

2.2 Key Performance Indicators (KPIs) and Process Performance Indicators (PPIs)

An institution's strategic and/or operational objectives dictate its goals. They must be clear, measurable and visible to interested parties. Performance is the success or efficiency of an organization. There are two types of performance: the overall performance, that concerns the entire institution; and the process performance, which concerns a particular process within the institution. Measuring and monitoring these objectives is crucial for institutions (Stanojkovií and Cvetkovií 2018). The monitoring of the progress of a given objective can be measured by these indicators, directly or indirectly. Indicators can be quantitative or qualitative and are used to estimate progress towards a given goal. The process of monitoring and measuring performance indicators is carried out over time, that is, during determined intervals, and the results serve as a basis for improving the process or the business itself (Stanojkovií and Cvetkovií 2018).

For Sujová, Marcineková, and Simanová (2019) proposing appropriate indicators is one of the most difficult tasks of process measurement. Considering the differences between production indicators and non-productive processes, indicators could be categorized, based on various factors. The most important individual performance measures are divided into four categories: Quality, Time, Flexibility, and Costs.

There are three types of process performance measures: (1) Key results indicators (KRIs) measure the results of many actions and focus on a long time period. (2) Key performance indicators (KPIs) are the most critical for the current and future success of an enterprise. (3) Performance indicators (PIs) lie between KPIs and KRIs and are shown in the scorecard with KPIs (Parmenter 2007).

A PPI is a kind of key performance indicator (KPI) that focuses exclusively on the indicators defined for business processes. It is therefore suitable for integrating the management of PPIs throughout the life cycle of business processes, from planning to evaluation (del-Río-Ortega et al. 2019).

ABPMP (2013) relates the importance of defining PPIs for companies that have limited experience in this type of measurement, the care necessary to ensure that indicators are part of an evolutionary program, and the fact that their use and value determine longevity.

3 Application and Analysis

For the application of a PPI selection model, an administrative sector of a Public Higher Education Institution was chosen. This sector has already worked with modeled processes and, as a result, it was possible to make real measurements of the indicators. The following steps were proposed: (1) Meeting, to survey possible indicators, and to request that an initial "intuitive" ordering of processes by degree of criticality be drawn up, according to the indicators proposed. (2) Use of the AHP with the Super Decision Software for ordering processes and comparing the results with the intuitive ordering as a way to evaluate PPIs. (3) Evaluation and Adjustment Proposals for the Indicators. The processes that made up the sample are shown in Table 3.

Table 3. Selected processes.

REFERENCE	PROCESSES
P1	Control of printed disclosures
P2	Print media releases, wall maintenance
P3	Issuance of University Extension Certificates and Extracurricular Courses
P4	Academic Incomings Exchange
P5	Academic Outgoings Exchange
P6	FAPESP accountability
P7	Reservations for special classrooms and auditoriums
P8	Review and preventive maintenance in classrooms
P9	Submission of Research Projects

3.1 Meeting: initial ordering

Employees in technical or management positions who work directly with the group of mapped processes were selected. Based on the parameters for the definition of PPIs present in the literature, employees defined the indicators they considered most important given the possibility of monitoring the processes, as well as their ranking, i.e., process prioritization. The current budget restrictions led to the suggestion of indicators. Aiming to quantifying the work generated in each process, four process performance indicators were initially proposed: (1) Number of activities or sub-processes; (2) Total process execution time; (3) Number of Actors; (4) Frequency of the processes. Regarding the ordering proposed by the employee group, a increasing order of criticality was defined for the processes as follows: P5; P6; P8; P4; P3; P9; P1; P2; P7.

3.2 *AHP Application*

Once the indicators had been defined, the employee group was asked to attribute an importance weighting to each of the indicators, keeping in mind the objective of prioritizing a reduction in workload for each process. After obtaining the criteria weighting, together with the judgment matrix consolidation (Figure 3), and the AHP structuring (Figure 4), the hierarchy of processes was obtained, as given in Table 4.

In the hierarchy validation carried out during a meeting with the employees involved in the analysis, the result was questioned, since the P7 and P8 processes that would be given intervention priority, were in reality, well computerized or notarized and demanded little overall time and workload, although they occurred at a much higher frequency than the other processes.

1	Participant 1			
	1	2	3	4
1	1	5	1/4	1/6
2	1/5	1	1/8	1/8
3	4	8	1	1
4	6	8	1	1

2	Participant 2			
	1	2	3	4
1	1	4	1/5	1/6
2	1/4	1	1/7	1/7
3	5	7	1	1
4	6	7	1	1

3	Participant 3			
	1	2	3	4
1	1	6	1/3	1/6
2	1/6	1	1/9	1/9
3	3	9	1	1
4	6	9	1	1

C	Consolidated			
	1	2	3	4
1		4,93	0,26	0,17
2	0,2		0,13	0,13
3	3,91	7,96		1
4	6	7,96	1	

Fig. 3. Matrices of judgment and of the consolidated result.

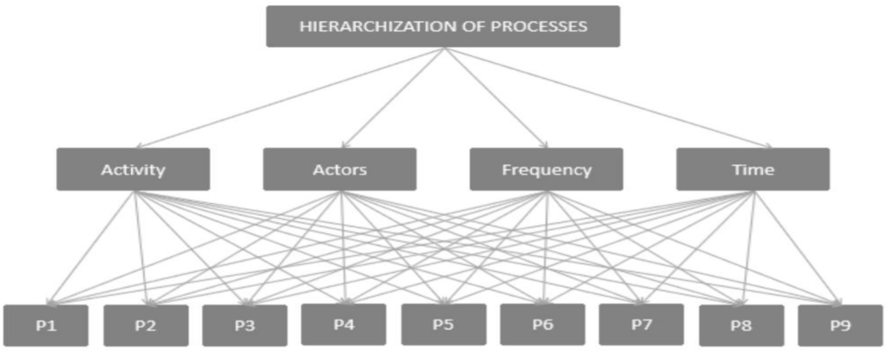

Fig 4. Proposed Hierarchical Structure.

Table 4. Ordering of processes (from more to less critical).

Preference Order (criticality)	Empirical Ordination	AHP Ordination
1	P4	**P8**
2	P6	**P7**
3	P8	**P5**
4	P5	**P4**
5	P3	**P9**
6	P9	**P6**
7	P1	**P3**
8	P2	**P1**
9	**P7**	**P2**

When the model was analyzed, it was found that the use of the Frequency indicators when not directly associated to process time indicators meant the processes that do not demand time, but occur more often, took priority over the slower processes of lower frequency.

3.3 Evaluation and Proposals for Adjustment of Indicators

Because of the discrepancy presented, it was found that the importance given to the Frequency in judgment indicator favored Process 7 which, although very important, is already fully automated and without much possibility for improvement, but its occurrence at a frequency far above the others created a distortion. However, during the evaluation meeting, it was considered that the simple exclusion of this indicator could harm other processes, and the prioritization model would not take into account the real workload, which would be a priority for managers. In this way, it was proposed to combine the indicators, Total Process Time X Frequency of a cycle.

This way, the Workload indicator was created. With the new AHP matrix considering only 3 indicators and a new value judgment, a result that was more in line with that initially proposed by the employee group was obtained (Table 5).

Table 5. Comparison between rankings.

Process	Empirical Ordination	AHP Ordination (4 PPIs)	Deviation concerning the reference position	AHP Ordination (3 PPIs)	Deviation concerning the reference position
P1	7°	8°	-1	8°	-1
P2	8°	9°	-1	9°	-1
P3	5°	7°	-2	5°	0
P4	4°	4°	0	3°	1
P5	1°	3°	-2	2°	-1
P6	2°	6°	-4	6°	-4
P7	9°	2°	7	7°	2
P8	3°	1°	2	1°	2
P9	6°	5°	1	4°	2

The new ordering with 3 PPIs still presented some significant deviations (see fourth and fifth columns of Table 5) from what was proposed in the first meeting (Empirical Ordination), although being much smaller than that of the first cycle with 4 indicators (see second and third columns of Table 5).

In a reassessment meeting, the employee group understood that the last set of PPIs presented were more adherent to reality and considered the deviations as a result of the difficulty of making decisions without a measurement and ordering method.

The employee group from the sector studied agreed that the proposed ordering was better than what had been arbitrarily defined and that with the numerical analysis with the AHP it was possible to define, not only which processes are more critical, but also to define the PPI goals for each cycle.

Previously, the choice of which processes should be remodeled and improved were made without measurement, that is arbitrarily and intuitively. With the proposal described here, it was possible to quantify them.

4 Final Considerations

This article contributes by highlighting the need for testing and validating PPIs and verifying their adherence to the reality of organizations. In a specific test, it was possible to verify that a good definition avoids conceptual errors in the choice of an Indicator. It was also possible to observe the advantage of a prioritization method, such as the AHP, in relation to arbitrary choices when deciding which process is more critical to prioritize through the application of BPM.

The results and conclusions presented here come from only one case, so generalization is not possible. The authors recommend that other cases should be investigated.

Also, future works might research the introduction of qualitative PPIs, as the indicators proposed in the present study were restricted to those that could already be measured in the processes modeled.

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