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Flexible benchmarking: a new reference model

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Abstract

Purpose – The purpose of this paper is to describe and propose a new way to do benchmarking. It describes an explanatory case study whereby data are collected through an internet benchmarking system with multi-criteria performance.

Design/methodology/approach – The research methodology was to conduct a literature review on international journals about evolution, typology and trends of benchmarking. Through a third year case study of Internet Benchmarking and Monitoring System of Productive Arrangements System the authors describe and propose a flexible benchmarking model.

Findings – The paper provides empirical insights about a new model of flexible benchmarking taking into account different demands, whereby partners' data are collected and processed according to their needs.

Research limitations/implications – For monitoring and trending analysis more data and time is needed. These three-year applications show that it takes a long time to build a database that can be meaningful for benchmarking and monitoring purposes management. It also requires management maturity, performance system and finally procedures to invite companies to collect and input online data.

Practical implications – The paper describes a flexible benchmarking, detailing its features in the form of a case study. The gap analysis shows the individual and collective gaps and requirements. Examples of practical use and reports generated "online" are presented.

Originality/value – The paper presents a new potential for the use of benchmarking tools. It is expected to contribute to the academic area, describing ways to achieve greater potential in the use of benchmarking tools, proposing a new way to do benchmarking.

Keywords Monitoring, Model, Flexible benchmarking, Productive arrangement

Paper type Case study

1. Introduction

In recent decades, globalization has highlighted the inability of companies to aggregate all the skills necessary for their survival. As a result, corporate interrelationships are not only seen as trade relations but opportunities to add value and complementarities. Thus, there is a rapid growth in relationships as collaborative networks, supply chains, clusters, industrial agglomerations, among others studied with intensity in academic literature (Lehtinen and Ahola, 2010) and referred to in this work of productive arrangements (PAs).

Johnson (2008) notes that benchmarking surveys have been made with a focus on intra-relationships, instead of business interrelationships and business networks. Simatupang (2001) states that there is a positive correlation between collaboration and performance ratios and encourages collaborative efforts among the participants in a supply chain to improve its operating results.

Huang and Wang define benchmarking as a reference point where they can perform measurements and comparisons of every kind and nature. Benchmarking can be a tool to ensure that participating members are continually improving, in

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other words implementing best practices. This tool stimulates mutual learning and bringing benefits to its participants.

Wong (2008) notes a new trend of research on benchmarking, from intra-relationships toward interrelationships with a holistic approach. In this case, a strategic and collaborative relationship among participants is necessary so that benchmarking activities can succeed and achieve meaningful results.

Routledge (2001) adds that it is likely that the success of benchmarking in recent years is due to the fact that it is a motivational process which happens in an environment that allows the exchange of knowledge. According to the same author, benchmarking helps to improve several business activities, such as learning and managerial processes.

Bogetoft and Nielsen (2005) states that the current potential of this tool has not been fully explored and it may be more useful if it is more flexible. There are restrictions on the use of the tool and accessibility to results that users often do not accept or would like to change, depending on each company's goals and due dates. The author concludes that flexibility both in the actual benchmarking process and in its reports should be relevant to the design of any benchmarking.

It is observed that benchmarking can evolve further, becoming a more dynamic tool, becoming more comprehensive and more flexible, which will potentially provide better results for its users.

This paper describes the methodology of a computerized large scale benchmarking tool that innovates by its flexibility and by its approach on inter-organizational relationships. It discusses the use of information and communication technology (ICT) to facilitate the flexible collection, data processing and distribution of reports and results of benchmarking.

The objective is to describe a new type of flexible benchmarking, detailing its features in the form of a case study of a Internet Benchmarking and Monitoring System of Productive Arrangements (SIMAP), which in its third year of use has more than 300 registered companies. Through this analysis, is expected to contribute to the academic area, describing ways to achieve greater potential in the use of benchmarking tools, proposing a new generation of this tool.

The research methodology was to conduct a literature review on international journals about evolution, typology and trend of benchmarking. Keywords such as "flexibility" and "benchmarking" were researched in different scientific research portals like "Science Direct" and "Web of Science." Priority was given to articles related proposition models, typologies and trends in benchmarking.

This paper is structured in five sections, including this introduction. The second section presents a framework on the evolution of benchmarking considering its application in collaborative systems, and the third describes the benchmarking tool SIMAP, emphasizing its flexibility in the classic steps of a benchmarking process. The fourth section presents the characteristics and features that suggest flexible benchmarking. Finally, the conclusions of this work are discussed.

2. Development of benchmarking

Comparisons occur among products, processes and business functions. The types of benchmarking can be defined by "what to benchmarking" and whom to benchmarking against" (Bhutta and Huq, 1999). With the evolution of benchmarking supported by ICT, it is proposed to complement and extend the previous statement both in the scope of comparison (what) as well as the application (whom) increasing flexibility in the use

of a benchmarking tool. First, we emphasize the importance of benchmarking as a collaborative tool, followed by its evolution.

2.1 Collaborative benchmarking and existing methods

The collaboration in the supply chain enables companies to achieve better performance, but requires efforts from all the members. They seek new ideas and best practices through benchmarking (Simatupang, 2001). The process of comparing best practices among companies provides insights for a company to improve its performance, stimulating and motivating the learning in the process of improvement (Simatupang, 2001).

Benchmarking has been used to exchange experiences and information among companies of different organizational nature. In research conducted by Johnson (2008), using benchmarking on 150 companies, it is concluded that the effective exchange of information improves learning in the supply chain.

Clusters are comprised by businesses and organizations interrelated and geographically close to each other that are connected by their similarities and complementarities. However, the advantage of the external economy depends on relationships more than the spatial approximation (Porter, 1998). Carbonara *et al.* (2002) describes industrial districts as small and medium enterprises located geographically close, specializing in one or more phases of a process that is integrated into a complex network of interrelationships. The most important factor of the success of this production model is the process of corporate network. The same author has identified different supply chain networks involved in different value adding processes in the industrial districts.

Industrial clusters such as industrial districts and local clusters have the concept of geographic concentration and intensive inter-organizational relationships. This idea leads agencies of public and private development to create and implement policies to increase competitiveness and support regional development. In this case, benchmarking can support the decision process of policy implementation through a collective process of gathering and processing data with territorial approach. This approach, regarding SIMAP, is tied to the methodology described in Section 3.

Bhutta and Huq (1999) note that there are several methods of benchmarking in the literature, whereby cases of companies using from four to 33 steps can be found. Camp (1989) and, later on, Bhutta and Huq (1999) used the method of PDCA (Plan, Do, Control, Act) to characterize the main stages of this process, such as: Plan: planning of the goal and type of benchmarking; Do: gathering and processing of data; Check: comparisons and gap analysis; Act: actions for improvement. Bhutta and Huq (1999) analyzed several cases and identified its five basic components in the form of a wheel (Figure 1) as: plan the study; form the benchmarking team; identify partners; collect and analyze information and adapt and improve.

2.2 Evolution and types of benchmarking

The performance evaluation and comparison of internal operations of a company with the best practices of other became popular since the 1980s, when significant performance improvements of products were obtained by Hewlett-Packard and Xerox through benchmarking studies (Camp, 1989). The methodology for comparing features and functions of a product with the competitors has been used to enhance its performance. First, however, benchmarking had been used informally, as is the classic

Source: Bhutta and Huq (1999)

Figure 1.
The SIMAP benchmarking wheel

case of the "principle of the supermarket" observed by Taichi Ohno, in 1958, in the USA, and built on the just in time system of the Japanese automotive industry (Ahmed and Rafiq, 1998). Since then, many types of benchmarking were identified by several authors, such as Camp (1989), Watson (1993) and Ahmed and Rafiq (1998).

The interest for benchmarking remains today with more challenging and innovative developments aided by ICT. Table I describes the main types of benchmarking found in the research. The types are found in consensus in the literature but differ classification criteria. It is noted that the comparisons have evolved, thus making the benchmarking object wider (what) and with larger scope (whom). The scope ranges from an internal business to external and global (e.g. economic blocks). The scope ranges from process, product, procedures, technologies, practices, competitors, among other possible.

The types of benchmarking follow a trend characterizing new generations formulated and are also found in consensus in the literature. Watson (1993) and Ahmed and Rafiq (1998) identified the development of benchmarking in five generations that were complemented by Kyrö (2003), highlighting the benchmarking of competence (bench learning) and networks, as shown in Figure 2. A new generation does not eliminate or replace the previous one, but complements the range or variety of possible combinations of the tool.

The first generation "reverse engineering" has the focus on the features and functionality of competing products. The second generation compares the performance of competing companies, identifying the best practice. The third generation (1982-1988) "process" has an even more comprehensive, focussing on process and systems knowledge and also outside the industry (Ahmed and Rafiq, 1998). The fourth generation (1990) sought the learning of successful strategies from external partners complemented by the fifth generation with global geographic coverage, enabling comparison and learning from competence (Ahmed and Rafiq, 1998). The sixth generation of benchmarking proposes changes in the ability to face new challenges. The ability to learn with others and develop skills to implement the continuous learning process. Learn in a broader geographic scope may include business units, clusters, networks and economic blocks. The goal always is to compare with the best and learn from them.

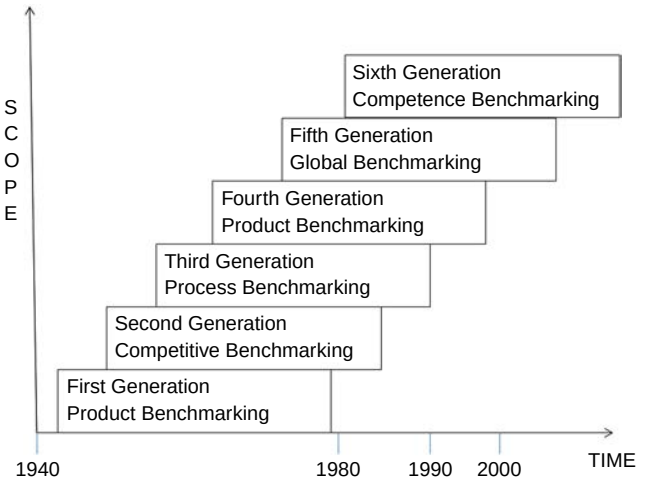
Classification criteria	Types	Object of comparison	References
Method	Informal	Unstructured	GBN (2010)
	Formal can be	Systematic and conscious	
	Best practices	Tools	
	Performance	Performance level	
Partner	Internal	Departments and internal units	Huang and Wang
	Competitive	Best competitor	Kyrö (2003)
	Functional	Technologies/processes in industry and other organizations	
	General sector	Different sectors and companies	
		Same sectors	
General	Internal and external	Intra- and interorganizational	GBN (2010)
	Competitive	With the best activity or company	Andersen and Pettersen (1994)
	Strategic	Strategies and outcomes	
	Product or reverse engineering	Characteristics and performance of products	Ahmed and Rafiq (1998)
	General process	Different sectors and companies Processes and methods	Bhutta and Huq (1999)
	Performance strategic	Indicators and indices Types of strategies	
Activity	Process	Business processes	Andersen and Pettersen (1994)
	Competitive	Practices and performances	
	General	Practices and performances	
Activity	Functional	Functions and departments of several companies and sectors	Andersen and Pettersen (1994)
Geographic scope	Local, regional or national	Performance, Technology, Processes, Competence and Strategies	Kyrö (2003)
	International and global (economics block)		
Sector public or private	Private	Best service competitor	Kyrö (2003)
	Public	Best possible service	
	Public-private	Both	
Organizational structure	Unit	Units and departments	Kyrö (2003)
	Organization network	companies Collaborative networks	
Intra- and Inter-relationship	Individual	Business performance	Simatupang (2001)
	Collaborative	Collective performance	
	Cooperative	Sharing experiences	
Intelligence	Natural	Uni-and bidimensional	Lai *et al.*
	Artificial	Dynamic and multidimensional (DEA) and decision support	
Flexibility	Rigid	Predefined comparisons	Proposed in this paper
	Flexible	Simulations, comparisons and reports defined by multiple users	

Table I.
Benchmarking types

Source: Authors

Analyzing the generation and evolution of benchmarking, Kyrö (2003) proposes a new and more complete definition:

> Benchmarking refers to evaluating and improving an organisation's, its units' or a network's performance, technology, process, competence and/or strategy with chosen geographical scope by learning from or/and with its own unit, other organisation or a network that is



Source: Adapted from Kyrö (2003)

Figure 2.
Benchmarking generations

> identified as having best practices in its respective field as a competitor, as operating in the same industry, cluster or sector or in the larger context with chosen geographical scope (p. 222).

Lai *et al.* proposes a benchmarking supported by knowledge systems and artificial intelligence. This online data processing is performed by computational tools that support decision making, as an example, using the tool of data envelopment analysis (DEA). This tool uses the approach of linear processing and allows flexible use, comparing measures of output and input multicriteria and various scales. Thus, the benchmark tool becomes more versatile, and can be applied in various ways to meet the requirements of the improvement process for a greater number of organizations and challenges.

The last classification in Table I "flexibility" features a new reference type of benchmarking proposed by the authors in this paper, featuring a new way to use this tool. The "flexible benchmarking" is described in the next section through a case study exemplifying its features.

3. Benchmarking flexibility: the SIMAP case

In this section the characteristics that allow new comparisons and benchmarking typification are presented and exemplified.

3.1 SIMAP: context and application

The SIMAP computer system was designed for the purpose of diagnosing the following problem in Ceara (State of Brasil located in Northeast): "Why the supply from Ceara's companies to the leading company Lubnor-Petrobras, in Ceara, was only 6.4% in 2006?". In order to develop a possible dynamic and always current response, the local PA of oil and gas was mapped and the first phase of the system was developed. Through the online registration, any company can participate and analyze its performance compared with the average of the other, checking what are their performance gaps, i.e. requirements not met to supply the leading company.

To meet other projects' demand, the system was expanded by consolidating the development method represented by the adapted benchmarking wheel. The wheel, as seen previously, has been used in order to synthesize many kinds of benchmarking process. Figure 3 shows the model proposed by the SIMAP. The process starts with a (new) demand "what to compare," identifying goals, potential partners, type of benchmarking and flexibility (i.e. ability to respond to changing demand) necessary for the common use of benchmarking studies.

In the second stage a team that will drive and support the benchmarking process is formed. It determines the performance indicators and its metrics (criteria), programs the internet tool for collecting and processing data on the web and provides the system for their partners. They participate in collecting data electronically and conduct their studies and simulations from the data entered and information processed by themselves. By means of the reports available, individual or collective actions for improvement can be proposed.

Demand is always related to a PA and starts with the mapping, which consists in identifying the activities or process (links) and the interrelationships among existing companies considering the agents of a PA, both processing (primary) and the support (secondary). The method can be suitably modified to accommodate any number of criteria, links given the structure of the PA as industrial agglomerations, industrial network and clusters.

The support companies is always considered because it often represents the innovative solution to the competitiveness of the processing chain (Albertin, 2003). Its importance on regional development is highlighted in concepts of the Triple Helix (Etzkowitz and Zhou, 2006; Johnson, 2008), clusters (Porter, 1998) and Systemic Competitiveness (Messner, 1996; Altenburg *et al.*, 1998).

The approach used to perform the mapping of a PA consists of: literature review, preliminary visits to companies of the sector, discussions with representation entities and consulting experts. The information obtained generates an initial version of the mapping of the PA, which must be validated by experts or businessmen. With this validation, this new PA must be registered in the system.

Figure 3.
The SIMAP methodologies

It is observed that the inclusion of data in SIMAP occurs with the indication of the location, which can be territorial state, region or country, as represented in the axis "territory" in Figure 4. This figure illustrates the possible comparisons in SIMAP. The axis "activities" provides the benchmarking by activity (link) of a company compared to other links of the same or different PA. It is possible, for example, for a machining company to compare itself with the average performance of other states and countries, and with its direct competitors in the same PA (territory) or in the same country. It is possible to draw a value chain, a supply chain, cluster, or other types of PAs, and make restricted or unrestricted access comparisons.

The SIMAP does not make a distinction between leading and lagging regions in Brazil but makes the observation that while economic growth in regions is unbalanced, development can be inclusive. The flexible report makes comparisons between spatial areas as federal states. Therefore, increasing local interactions and reducing distances within a country and globally contributes to these virtuous circles and development.

The 46 criteria (C1, C2, …, C46), shown in Figure 4 were grouped by similarity on seven subsystems, as described in the Appendix. Each criteria has a growing performance metric adapted from Likert scale of five levels (0,25,50,75,100), featuring categorized qualitative data. These criteria represent performance and best practices. There is the possibility of "not applicable" when the same cannot be implemented in a particular company. The criteria and performance levels derive from the requirements established in the Malcom Bridge Award, as well as in the Toyota Production System, ISO/TS 16949 and ISO 9001.

3.2 ICT and database

The SIMAP programming is done using free software with flexible tools that allow adjustments on demand. This makes the system more attractive, since different PA and customization can be defined and entered into the system. We adopted the open source tool LimeSurvey whose goal is the creation and management of online surveys with the following features: multilanguage, user management, creation of tokens, initial

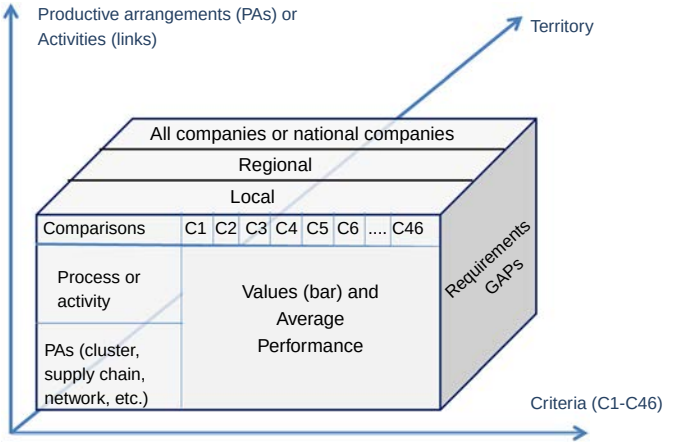


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Figure 4.
Possible comparisons on SIMAP

statistical analysis through easily export reports (LimeSurvey, 2009). The LimeSurvey is organized by questionnaires, focus groups, questions and answers. Within each of the levels and sublevels of administration, the following features are available (LimeSurvey, 2009):

(1) permission control, technical data visualization, database backup, labels management for questions and administration of questionnaires models;

(2) general data editing, completed questionnaire testing, generating printable version, excluding the questionnaire, excluding rules for the questionnaire, results exporting, changing the display order of the groups, managing the responses from each questionnaire, and managing access tokens to the questionnaire;

(3) change the order in which the questions appear within the group, removing a group, and change the basic data of a group; and

(4) edition of basic information about the question, removing question, duplicating an existing question, creating rules for the question, test the question.

The information collected in the on line survey is stored in a database, which is a structured collection of records allowing further consultations and reports. The Database System Manager (DBMS) is responsible for storing and querying data stored using it for a relational structure, where tables have links to each other. The DBMS used was MySQL (free software available under the GPL license). There is a specific table in this database where all survey responses are stored and centralized, facilitating recovery and data analysis. The other LimeSurvey table applications serve as the management resource of tokens, users, profiles, themes, graphics, besides the more specific attributes of each: group question and answer.

The information captured by the system must meet the relationship between the entities as described in Figure 5, which states that: the activities (links) are associated directly to PA, and the criteria directly linked to the associated subsystems management. Other deductions from this figure are: one PA has many links, one link can only be in one PA, one subsystem has many criteria, one criteria can only belong to a subsystem, one criteria or one link has many performance information (since there are several companies and several criteria) and one company has many performance information (since there are various links and various criteria).

The storage of information in the database the way it was modeled ensures that the system is resilient to events such as the creation or extinction of a PA, an activity, a subsystem or even a criterion. This flexibility gives survival to information already captured and the system administrator, or even the companies themselves, must update the records already made in the system, thus preventing the need for collecting any information again.

3.3 Flexibility of SIMAP

The SIMAP allows online benchmarking analysis indicating the need for improvements in the 46 performance criteria. This tool collects, processes and reports information in real time to any company in any benchmarking partner. The greater the number of registered companies the greater the possibilities of comparison and the more representative the database will be. The database can be continually updated by the companies, enabling individual and collective tracking of the PA.

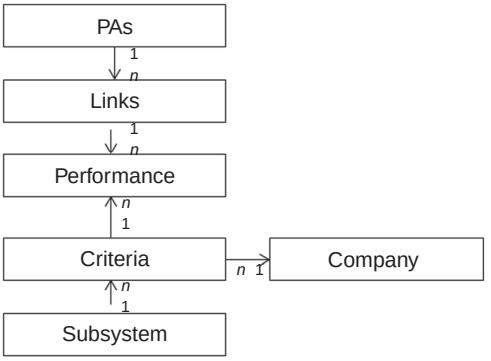

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Figure 5.
Entity diagram and relationship among system's main entities

The freedom to access SIMAP through the internet allows the partner firm to perform the following comparisons and simulations:

- positioning the company relative to the average performance of competitors and to the benchmarking company;
- performance of a company against the average of all companies in the same activity in the same PA, in the same local or country;
- comparative acting against other activity, PAs or location;
- performance of a firm against the average of all listed companies;
- performance of the benchmarking company against the average of all companies in the same activity, in the same AP, in the same state or country; and
- the gaps to supply a given focal (leading) company.

These information are highlighted in the form of four reports, using a graphics package called "Fusion Charts" of SIMAP. These are as follows.

(a) Bar and sequential reports

A company can analyse its performance against the average performance of others working in the same PA or in the same activity (link). On the proposed methodology, the company may register in more than one PA. The following information can be obtained online (Figure 6):

- individual performance in 46 criteria and their seven subsystems;
- average performance of companies registered in the same PA, or even in the same activity or in the same state (territory);
- individual and collective gaps analyses;
- simulation of competitive positioning in other PAs, regions or countries; and
- visualization of competitive positioning after some actions.

It is observed in Figure 6 the performance of a company (bar chart) and the mean comparison of performance in the GP01 to GP07 subsystems (see the Appendix) of all registered companies on the local automotive supply chain in State of Ceara. Similar reports can be generated online by activities (links) or in others PAs.

(b) DEA

This report processed "on line" allows to compare the performance of a company with other considering the PA, the territorial location or activity, as shown in Figure 7. On the *x* axis is shown the number of criteria applicable (maximum 46) and on the *y* axis is shown their average performance (0-100 percent).

The application of DEA with categorized qualitative data presented good results with the following changes:

- the Likert scale (0-25-50-75-100 percent) was replaced by the scale (1-2-3-4-5); and
- it was necessary to transform multidimensional inputs (criteria) in one-dimensional for better identification of the benchmarking company.

The DEA report allows the same simulations just as the report of bars and sequential. In the case of the example company, this can be compared with competitors in three APs as automotive supply chains, oil and gas and refractories. In these chains, it is possible to compare to direct competitors (same activity or process) or to the company average of all companies registered in a state (territory) or to the average of all registered companies.

(c) Flexible report with "restricted access"

The third report has multiple parameters that can be used to create flexible statistical reports. To build these reports, the analyst chooses what statistics is wanted (i.e. demand or question that will be analyzed), and that filter will be used. The filters act as aggregators of logical types "AND" and "OR." The first restricts the size of the sample, while those of type "OR" expand. Thus, by combining parameters, the analyst can perform other analyzes such as:

- comparisons between companies in different countries (or states), PAs or activity's;
- comparisons also considering the company size (small, medium and large); and
- comparisons considering only international capital firms and many other.

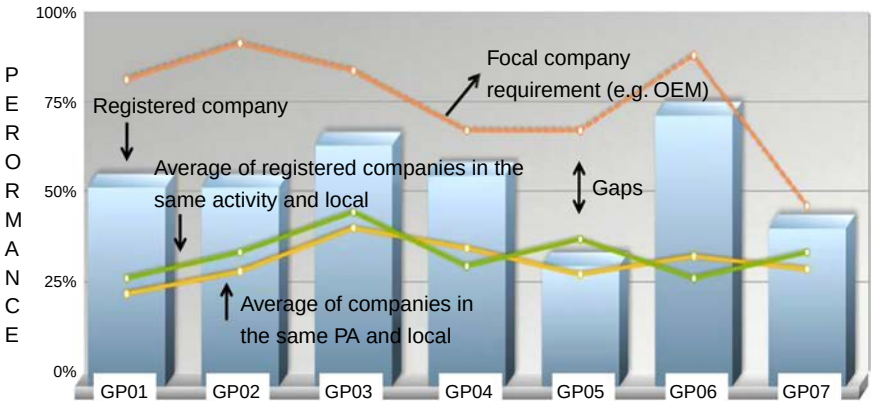

Figure 6.
Individual performance (bars) and the average performance (line) of Ceara automotive supply chain

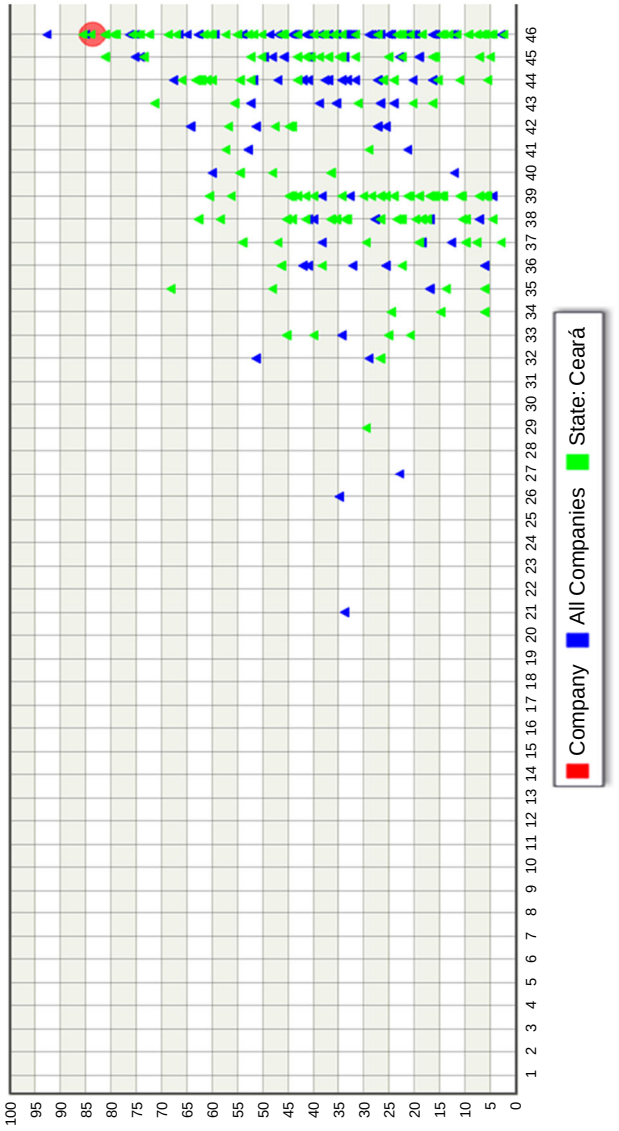

Figure 7.
Application of DEA

Figure 8 shows in a simplified fashion the main information present on the flexible report. These are:

- the special information are made by the number of countries across the globe *(P)*, the number of regions of Brazil (*R*), and number of states (*E*);
- the organization's information comprises the number of different classifications of size of company (*T*), amount of existing capital (*M*) and the number of options of market segment (*A*);
- information on how many PAs were mapped (*C*) and how many activities exist in each chain i (C_i).
- the performance according to the quantity of subsystems (*S*) and the number of applicable criteria for each subsystem j (S_j).

The combination of information from mutually exclusive group (groups of elements with empty intersection) through aggregation "AND" brings to null results. For example, in "Spatial Information" on the same search, it makes no sense for a company to be located in Brazil "and" in China.

First, it is analyzed the total combinations of filters at the flexible report, named *TotS*, when there is no aggregation (Equation (1)). In this case, the objective is to search for a single aspect individually:

$$TotS = C_P^1 + C_R^1 + C_E^1 + C_M^1 + C_A^1 + C_C^1 + \sum_{i=1}^{C}\left(C_{C_i}^1\right) + C_S^1 + \sum_{j=1}^{S}\left(C_{5\times S_j}^1\right) \quad (1)$$

To analyze the total filter combinations when there is aggregation of type "AND," called *TotAND* (Equation (6)), as discussed previously requires extra care when dealing with mutually exclusive sets. To better present this formula, it will be decomposed in terms of clusters of Figure 8: spatial information (Equation (2)), company information

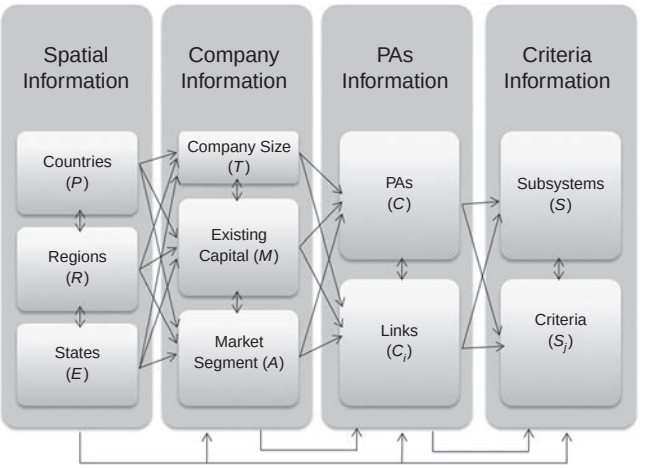

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Figure 8.
Combination of comparisons on SIMAP on flexible report for administrative area

(Equation (3)), PA information (Equation (4)) and criteria information (Equation (5)):

$$TotE1 = \left(C_P^1 + C_R^1 + C_E^1 + 1\right) \tag{2}$$

$$TotE2 = \left(C_T^1 + C_M^1 + C_A^1 + C_T^1 C_A^1 + C_M^1 C_A^1 + C_T^1 C_M^1 + C_T^1 C_M^1 C_A^1 + 1\right) \tag{3}$$

$$TotE3 = \sum_{i=1}^{c} \left(C_C^i\right) \times \prod_{i=1}^{c} \left(C_{C_i}^1 + C_{C_i}^2 + \ \ldots \ + C_{C_i}^{C_i}\right) \tag{4}$$

$$TotE4 = \prod_{j=1}^{s} \left(C_{5\times S_j}^1 + C_{5\times S_j}^2 + \ \ldots \ + C_{5\times S_j}^{5\times S_j}\right) \tag{5}$$

$$\begin{aligned} ToE = {} & (TotE1 \times TotE2) + (TotE1 \times TotE3) + (TotE1 \times TotE4) \\ & + (TotE2 \times TotE3) + (TotE2 \times TotE4) + (TotE3 \times TotE4) \\ & + (TotE1 \times TotE2 \times TotE3) + (TotE1 \times TotE2 \times TotE4) \\ & + (TotE1 \times TotE4 \times TotE3) + (TotE2 \times TotE4 \times TotE3) \\ & + (TotE1 \times TotE2 \times TotE4 \times TotE3) \end{aligned} \tag{6}$$

To analyze the total filter combinations when there is aggregation of type "OR," called *TotOR*, the number of possibilities increases even further because there is no elimination of mutually exclusive sets. To better present this formula, it will be decomposed in terms of clusters of D1 (Figure 9): countries (Equation (7)), states (Equation (8)), regions (Equation (9)), composition of capital (Equation (10)), size (Equation (11)), market segments (Equation (12)), PAs (Equation (13)), activities

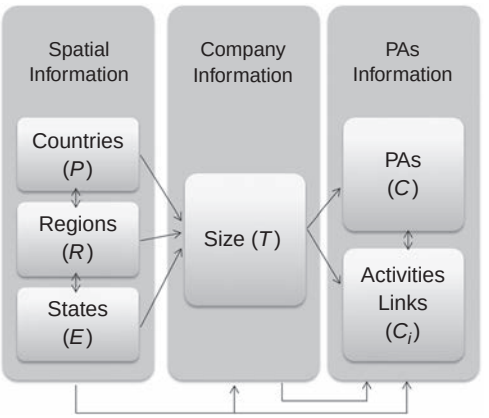

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Figure 9.
Possible comparisons on SIMAP using the flexible report open to companies

(Equation (14)), subsystems (Equation (15)) and criteria (Equation (16)):

$$TotOR1 = \sum_{k=1}^{P-1} C_P^k \tag{7}$$

$$TotOR2 = \sum_{m=1}^{E-1} C_E^m \tag{8}$$

$$TotOR3 = \sum_{o=1}^{R-1} C_R^o \tag{9}$$

$$TotOR4 = \sum_{n=1}^{M-1} C_M^n \tag{10}$$

$$TotOR5 = \sum_{l=1}^{T-1} C_T^l \tag{11}$$

$$TotOR6 = \sum_{p=1}^{A-1} C_A^p \tag{12}$$

$$TotOR7 = \sum_{q=1}^{C-1} C_C^q \tag{13}$$

$$TotOR8 = \sum_{r=1}^{S-1} C_S^r \tag{14}$$

For each PA i, the quantity of activities in this PA (C_i) generates the quantity of filters described by Equation (15):

$$TotOR_C = \sum_{i=1}^{C} \sum_{k=1}^{C_i-1} C_{C_i}^k \tag{15}$$

For each subsystem j, the quantity of criteria of this subsystem (S_j) generates the quantity of filters described by Equation (16):

$$TotOR_S = \sum_{j=1}^{S} \sum_{l=1}^{5\times_j-1} C_{5\times S_j}^l \tag{16}$$

Observing the quantities obtained in Equations (7-16) as a set of elements of a set Z (Equation (17)), each element of Z is known as Z_w, and $|Z| = 8+C+S$, it is possible to

perform combinations among the different elements of Z, generating a much larger number of filters called $TotOU$ (Equation (18)):

$$z = \{TotOU1,\ TotOU2,\ TotOU3,\ TotOU4,\ TotOU5,\ TotOU6,\ TotOU7,\ TotOU8,\ TotOU\_C,\ TotOU\_S\} \quad (17)$$

$$TotOU = \sum_{w=2}^{|Z|} C_{|Z|}^{w} \quad (18)$$

Given the current scenario of the SIMAP system, with the possibility of tracking 195 countries, five regions, 27 states, three possible sizes of companies, two types of composition of capital, three classes of markets, 16 supply chains, 323 distributed links in these chains, seven subsystems with 230 and levels of impact on these subsystems' criteria; it gives a very large number of filters. To simplify the dimensioning of the number of possible combinations from the flexible reports, we propose a limited scenario considering only: ten countries, no region, ten states, no size of business possible, no composition of capital, no class of market segment, ten chains, each chain with ten links. Also for this more restricted scenario, he filters from the 46 criteria is not considered. Table II presents the number of possible filters within the system for this more restricted scenario applicability.

Our experience with the use of flexible reports indicates that comparisons usually combine only two different types of information: i.e. small businesses in the automotive supply chain of state São Paulo and Ceará. In a new scenario, limiting the possibilities to only four countries, three Brazilian States, 16 PAs we would have the number of possible filters shown in Table III, representing a more current scenario.

In another example, you can find among the companies part of SIMAP, which ones are certified by ISO 9001 "AND" the ones located in the countries studied. The answer is presented in Table IV.

(d) Flexible reports open to companies (on line)

Type of filter to be applied	Quantity
No aggregation	130
Aggregation "AND"	Over 87×10^{33}
Aggregation "OR"	Over 3.51×10^{56}

Source: Authors

Table II. Benchmarking possibilities on wide scenario

Type of filter to be applied	Quantity
Analysis of a given size (small, medium or large) "AND" of certain state (SP, RJ, …)	$C_T^1 \times C_E^1 = 9$
Analysis of certain PA "AND" of a particular country	$C_C^1 \times C_E^1 = 16 \times 3 = 48$
Analysis of two certain AP (type "OR") "AND" a given state	$C_C^2 \times C_E^1 = 252$

Source: Authors

Table III. Examples of benchmarking analysis for current scenario

The fourth report of the flexible type "on line "with multiple parameters is used to create statistical reports combining information of the space, the PAs and the company, as shown in Figure 9. It also uses aggregators such as "AND" and "OR." Further analysis can be performed, such as:

- What is the performance of the PA in which the company operates, compared with other PAs in which the company has an interest in acting?
- What is the performance average of the subsystems on the machining chain "AND" that operates in the state of Ceará "AND" has small size (Figure 10)?
- What is the performance average of the subsystems on the automobile chain "AND" that operates in the Ceará "AND" has small size (Figure 10)?
- What is the performance average of the subsystems on the automobile chain "AND" that operates in the Rio Grande do Sul (RS) "AND" has small size (Figure 10)?
- What is the performance average of the subsystems on the machining chain "AND" that operates in the Ceará "AND" has large size (Figure 10)?

The difference between Figures 8 and 9 is that the second does not show individual data with company names maintaining the confidentiality of the data. The results are

Answer	Quantity	%
Brazil	20	90.91
Spain	1	4.55
USA	1	4.55

Source: Authors

Table IV.
Companies certified by on SIMAP

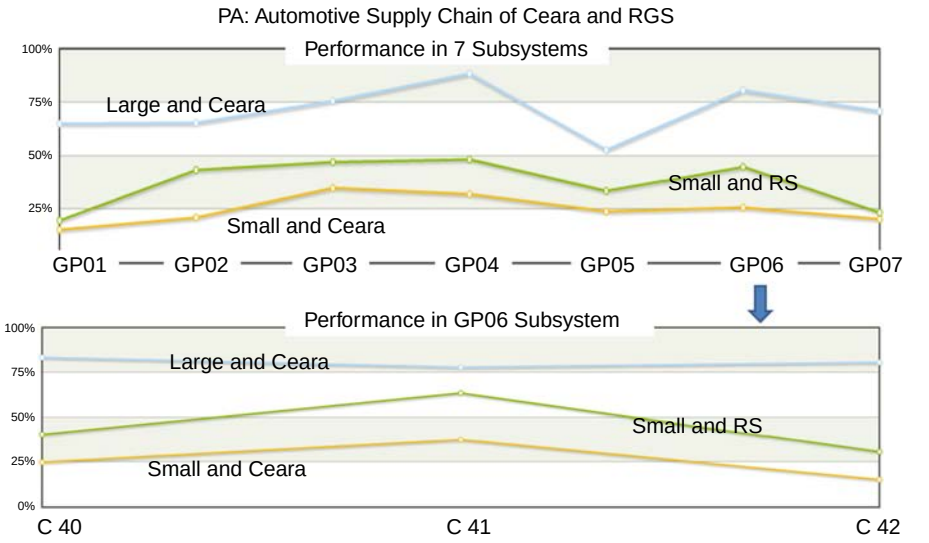

Figure 10.
Display of flexible comparisons available to companies

illustrated in Figure 10 by comparing the average performance of small businesses of automotive supply chain of RS (State of Brazil located in South) and Ceará.

The Figure 11 was extracted from the flexible report "and/or" and represents the average performance of seven subsystems of P&G companies from Ceara. In this study, companies were separated by size, as the "number of employees" (small 1-99; medium 100-499; large up to 500). It shows that small and medium sized companies have a performance around 25-50 percent and Petrobras requirements are from 50 to 75 percent.

4. Conclusion

The proposal for a new type of benchmarking aims to draw attention to the potential use of this new tool. Through a literature review, the types of existing benchmarking and its evolution were identified and classified as six generations. The continuous trend of increasing scope and comprehensiveness is noted. The benchmarking progresses from product to strategies and from internal processes to comparisons of PAs and economic blocks. A model of flexible benchmarking has been characterized and exemplified through a case study of SIMAP, which presented the following main features:

- it allows continuous use and provides access and data processing by partners;
- meets the different demands and may be programmable varying range and scope; and
- data processing and decision support tools allow varied reports and simulations.

The great differential presented by SIMAP is the flexibility to generate analysis for enterprise and dynamism in the collection and updating of data in the system. Another positive feature of the developed system is that it is developed on free software platforms, which reduces development costs.

SIMAP can be a tool for promoting local and regional competitiveness, innovation and growth, as well as for identifying best practice and sharing information about

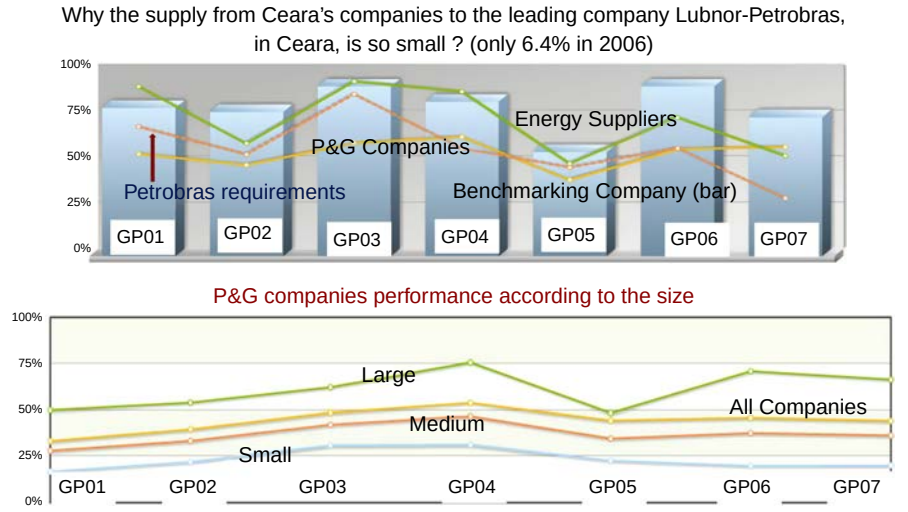

Figure 11. P&G companies performance in Ceara

Steps	Characteristics	Examples
Demand identification	Continuous and adaptable Allows change of range and scope	New research, new PA and activities
Programming	Flexible and customized tools	LimeSurvey
Data gathering	Benchmarking partners and others	Restriction of individual data from other companies
Partners	Online and continuous access	Figure 3
Data processing	Online Parametric and nonparametric data	Various types of reports Bars, average, percentage, DEA
Measurement system	Unidimensional, bidimensional and multidimensional Quantitative and qualitative variables	Electronic Survey Criteria
Reports	Allow comparisons and simulations Decision support	Flexible reports with conditional filters: and/or/na Parametric and nonparametric tools

Source: Authors

Table V. Characteristics of flexible benchmarking

improvement strategies. Online services will also allow academics and practitioners to interact on a larger scale than otherwise possible.

After reporting the case study, the goal is to synthesize the characteristics of flexible benchmarking (Table V) exemplified in SIMAP through the steps of "benchmarking wheel."

Throughout three years the SIMAP has evolved successfully meeting the demands of different projects with expansions of scope and range. This performance shall be deposited in the flexibility of its conception and use.

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(The Appendix follows overleaf.)

Appendix 1. Benchmarking Questionnaire

Hints for fulfilling: To be 100% is necessary before to be 75%, and to be 75% is necessary before to be 50%, and forward ...

Table AI.
Integrated Management System (GP01)

Integrated Management System (GP01)					
GP01	0	25	50	75	100
1. ISO 9001	Informal Procedures	Documented Procedures	Formal program deployment	Conducts internal audits	Certificated
2. ISO 14001					
3. 5S					
4. SA 8,000					
5. OSHAS 18,000					
Production Management (GP02)					
GP02	0	25	50	75	100
6. Setup time	Informal Procedures	Documented Procedures	Time < 60 min	Time < 40 min	< 10 (SMED)
7. Production Planning and Control (PPC)	Informal Procedures	Electronic sheets (Excel, Calc, etc.)	Software	MRP and ERP	MRP II
8. Capability studies	Informal Procedures	Instable process	Stable process	CEP	Cpk > 2
9. Quality costs	Unknown	Monitors	1-10% revenue	< 1% revenue	< 0,5 revenue
10. Process Control	Informal Parameters	Formal Parameters	Monitored parameters	Calibrated instruments	Capability studies
11. Part Per Million (PPM)	Unknown	Known	1-10%	< 1,000 PPM	< 500 PPM
12. Total Preventive Maintenance (TPM)	Corrective	Maintenance plan informal	Preventive	Predictive	TPM
13. Just in Time	Not use tools	One tool	Two tolls	Three tools	Many tools
14. Suppliers development	Informal Procedures	Formal Procedures	Monitors performance	Training programs	Establishing partnership
15. Average age of equipment	Unknown	More than 20 years	Between 10 and 20 years	Between 5 and 10 years	More than 5 years

(continued)

Product Management (GP03)

GP03	0	25	50	75	100
16. Use of technical norms	Unknown	Knows and use partly	Uses the main	Always use	Uses 100% and update
17. CAD – CAE – CIM	Unknown	Known	Uses CAS	Uses CAD e CAE	Uses CAD-CAE-CIM
18. Multifunctional groups	Doesn't perform	Uses informally	Documented procedure	Implemented	Always uses
19. Time to market (product and service lead time)	Doesn't control	Informal control	Monitor	Competitive	Is benchmark
20. Methodology for development of new products	Unknown	Informal	Documented	Continually improve	Concept uses of lessons learn
21. Suppliers and customers partnerships	Doesn't perform	Informal	Formal	Suppliers	Suppliers and clients

Strategic Management (GP04)

GP04	0	25	50	75	100
22. Strategic planning	Informal	Formal	Periodically monitors	Informs all	Define: Mission, vision and indicators (eg BSC)
23. Production strategies	Informal	Defined	Monitored	Informs	Tasks plan
24. Leadership style	Controller	Centered	Decentralized	Involvement	Environment for improvement
25. Benchmarking use	Doesn't perform	Benchmarking local	Benchmarking regional	Benchmarking national	Benchmarking international
26. Customers focus	Informal	Monitors dissatisfaction	Satisfaction survey	Monitors satisfaction	Customers very satisfied > 80%
27. Use of indicators	Informal	Financial	Quality	Process	PDCA – Targets set

(continued)

Table AI.

Table AI.

Logistic Management (GP05)

GP05	0	25	50	75	100
28. Stock control	Low control, WITHOUT using specific systems or spreadsheets	Documented control, ONLY the finished product, with the use of spreadsheets	Documented control of the finished product and intermediate stocks	Use of interdependent systems of control stocks	Stock Integrated management (integrated suppliers)
29. Stock rotativity	Low spin, without monitoring	Monitoring partial	Turnover of stocks of 1 to 12 times a year	Turnover of stocks of 12 to 24 times a year	Turnover of stocks more than 24 times a year
30. Logistics Services	Not considered important and has its own fleet	Uses only carrier outsourced	Uses transport contractors and other service	Use logistics operator with at least three functions	Uses the operator logistics as integrator (all channel)
31. Handling	Do not use machines	Use few machines, default kind, with much human interference (manual)	Uses standard machines and few specific machines, with much human intervention (manual)	Semi-automated system, with little human interference, customized tools for handling	Specialized machinery, use of fully automated systems and robotics
32. Unitization	Do not use any kind	Use pallets of any kind	Use specific pallet, shelves and others	Use specific pallets, also uses larger stents	Use of various types of stents, with standardization focused on the final transport
33. Material flow	Manual Visual control	Electronic Sheet and software	Use of bar code	RFID and GPS	Intelligent container
34. Information flow	Consultation over cell phone	Consultation over internet and email	EDI	Satellite tracking	Date basis integrated in the supply chain
35. Financial flow	informal	individual	Partial integrated	Sharing databases	Total integrated
36. Commerce transaction	Manual	Computer assister ordering	RC or VMI	ECR and CRM	Marketplace
37. Warehouse control	Manual Visual Control	Electronic Sheet and software	Use of bar code	Cell phone tracking or Picking voice or RFID	Warehouse Management System
38. Transportation system	Informal	Electronic Sheet and software	Milk-run	GPS, Routing software	Transportation Management System
39. Supply chain relationship	Arms length relationship	Partnership	Long period partnership	Supplier Relationship Management	Strategic partnership

(*continued*)

Human Resources Management (GP06)					
GP06	0	25	50	75	100
40. Trainings Program	Informal	Documented procedures	Monitors hours of training in year/ employee	< 20 hours	> 20 hours
41. Competence Program	Informal	Description of responsibility/ authority	Description of Competences	Program multifunctionality	Estimate of competences
42. Collaborative Program	Informal	Formal	More than one program	Several programs	Equity in results
Financial Management (GP07)					
GP07	0	25	50	75	100
43. ERP	Doesn't perform formally	Implemented	Perform partially	Final phase of implementation	Use for making decisions
44. Direct cost					
45. ABC Method					
46. Analyze of investment					

Table AI.

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