Measurement and evaluation of intangible assets of diagnosis and testing laboratories for electrical equipments

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Abstract. In the last decade, there has been an increasing interest in measuring and evaluating intangible assets, not only by private firms, but also by knowledge organizations such as universities, research centers, and testing laboratories. This paper aims to present a model for measuring and evaluating intangible assets developed for electrical equipment diagnosis and testing laboratories. For the proposal and selection of indicators and metrics that integrate the model, multicriteria decision support methods were embedded into the model, combined with fuzzy logic. The applicability of the model has been demonstrated through an empirical study in one electrical equipment diagnosis and testing laboratory that integrates the Laboratory Network of Eletrobras Enterprises (Relase) in Brazil. The results of this research can be replicated within Relase, which covers today a total of 98 laboratories, of which 16 are accredited for calibration services.

Keywords. Metrology; measurement of intangible assets; electrical equipment diagnosis and testing laboratories; multicriteria decision-making methods; fuzzy logic.

1. Introduction

Nowadays, the information provided by traditional financial statements is not able to disclose the value of intangible assets of an organization. Several models have been proposed and adopted by managers of organizations in various sectors. The interest in measuring and evaluating intangible assets can be observed not only by private firms, but also by knowledge organizations such as universities, research centers, and testing labs. By way of illustration, the following models may be cited: Skandia Navigator [1]; Intangible Asset Monitor [2]; Value-Added Intellectual Coefficient [3]; and Balanced scorecard, designed for converting intangible assets into tangible outcomes [4].

Focusing more specifically on the universe of Science and Technology Institutions (STIs), there is a growing number of articles published from 2000 to 2018 about the measurement and evaluation of intangible assets (or intellectual capital) of STIs in European countries, such as Austria, Spain, Italy, Romania, Poland, Greece, Lithuania and Latvia, and also in Taiwan, Colombia and Brazil [5-21].

Austria pioneered the adoption of a model for measuring and evaluating intellectual capital in one of its ICTs – The Austrian Research Centers Seibersdorf (ARCS) [5-6]. Due to the positive results of this initiative in the late 1990s and the recognition of the importance of STIs' annual intellectual capital reports in this country, since 2002 Austrian universities have been required by law to issue their intellectual capital statements annually [7;18].

Assuming that: (i) intangible assets are strategic to the overall performance and competitive positioning of organizations, so the measurement and evaluation of such assets are critical to their effective management and capitalization; (ii) the measurement and evaluation of intangible assets of the Laboratory Network of Eletrobras Enterprises (Relase) are considered to be of strategic relevance for the value created by these assets for the Eletrobras System companies and all their stakeholders; (iii) Relase's Laboratories may improve the measurement and evaluation of their intangible assets, aiming at their effective management and value creation for the interested parties in their operations; and (iv) there are gaps identified in the literature regarding the central theme of this research, namely models for measuring and evaluating intangible assets and intellectual capital addressed to diagnostic laboratories and testing of electrical equipment; the main questions addressed in this paper are:

i. How to measure and evaluate the intangible assets of electrical equipment testing laboratories aiming at demonstrating value creation for these institutions and their stakeholders?
ii. How to identify, propose, and validate indicators and metrics to integrate a monitoring and evaluation system of the intellectual capital of these laboratories?

The development of a conceptual model for measuring and evaluating intellectual capital that can be universally applied in different contexts is a very complex challenge. However, if it is addressed to a sector or an activity, it may be something feasible, as is the case of this research, which focused on diagnostic laboratories and electrical equipment testing. In addition, it is worth remembering that STIs are becoming increasingly aware of the importance of this process to demonstrate their performance, recognizing that effective management of their intellectual capital is an essential task for value creation for their stakeholders.

This article is structured in six sections. Following this introduction, Section 2 briefly reviews the approaches for measuring and evaluating intangible assets, with particular attention to STIs. Section 3 presents the adopted methodology. Section 4 introduces the conceptual model for defining and hierarchizing indicators and metrics, classified in eight dimensions, being three related to intellectual capital; and five associated with laboratories' outputs and impacts of their activities to stakeholders and society. Section 5 demonstrates the applicability of the model through an empirical study carried out in one of Relase's Laboratories. Finally, Section 6 synthesizes the concluding remarks and recommendations for the effective adoption of the proposed model by other Relase's Laboratories or similar organizations.

2. Theoretical background

The literature review and documentary analysis covering the period of 1998-2018 encompass the following themes: (i) measurement and evaluation of intangible assets in organizations; (ii) empirical studies on measuring and evaluating intangible assets in STIs; and (iii) application of fuzzy multicriteria decision methods in the research context.

2.1. Measurement and evaluation of intangible assets in organizations

In general, when organizations decide to measure and evaluate their intangible assets, they implement strategic initiatives aiming at the internal management of intangible assets, or external disclosure, such as the intellectual capital reports. The increasing interest in measuring and evaluating intangible assets, not only by private firms, but also by knowledge organizations, led to the development of methodological approaches reviewed in several works [22-25]. However, all methods described in these papers are based on the classification proposed by Sveiby [23], with four categories to classify such methods:

- Market Capitalization Methods: calculate the difference between an organization's market capitalization and its equity as the value of its intellectual capital or intangible assets [26-28];
- Return on Assets Methods: use the relationship between revenues and the values of tangible assets [3; 26; 28-31];

- Direct Intellectual Capital Methods: estimate the value of intangible assets by identifying their various components. Once these components are identified, they can be directly evaluated, either individually or as an aggregate coefficient [32-36]; and
- Scorecard Methods: the different components of intangible assets or intellectual capital are identified, and indicators and indices are generated and reported in scorecards [2; 4; 37-40].

2.2. Measurement and evaluation of intangible assets in STIs: models and empirical evidence

A considerable amount of literature has been published on measurement and evaluation of intangible assets in STIs from different countries since the pioneer ARCS Model was diffused in Europe [5-21]. These studies are mostly concerned with experiences by European countries; however, initiatives in emerging economies such as Taiwan, Brazil, and Colombia were also identified, as follows:

- ARCS Model (Austria) [5;6];
- Intellectual capital management for Austrian STIs (Austria) [6-8];
- Measuring the intellectual capital of a Polish university (Poland) [9];
- Intellectual capital management in Spanish universities (Spain) [10;19];
- Intellectual capital evaluation model for Romanian universities (Romania) [11];
- Intellectual capital management for European universities (Europe) [12;18;20];
- Intellectual capital reporting at UK universities (UK) [13];
- Intellectual capital evaluation model for a university in Taiwan (Taiwan) [14];
- Intellectual Capital Measurement System: Evidence from Italian Universities (Italy) [15];
- Intellectual capital evaluation model for Professional Master Programs (Brazil) [17];
- Intellectual capital and university performance in public universities (Colombia) [21].

2.3. Application of fuzzy multicriteria decision methods in the research context

Considering the specificities of STIs to measure relevant aspects related to their intangible assets management and also the results from the literature review on multicriteria decision methods, the following methods were combined aiming at selecting and ranking indicators addressed to measuring and evaluating intangible assets in these organizations, and particularly in diagnosis and testing laboratories for electrical equipments. They are: (i) fuzzy Analytical Hierarchy Process (AHP) for decision making processes under uncertainty [41]; and (ii) fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), that is based on the concept that the chosen alternative should have the shortest distance from the fuzzy positive ideal solution (FPIS) and the farthest from the fuzzy negative ideal solution (FNIS), used for group decision-making under fuzzy environment [42].

3. Methodology

The research methodology comprised: (i) a systematic search on articles published between 1998 and 2018 about the central research themes and selection of most relevant works; (ii) adaptation of a model for measuring and evaluating intangible assets for the context of diagnosis and testing laboratories, which has already been adopted by European STIs concerning elaboration of their intellectual capital reports; (iii) proposition and selection of indicators and metrics by using multicriteria decision support methods, combined with fuzzy logic; and (iv) demonstration of the applicability of the model through an empirical study carried out in one of the Relase’s Laboratories in Brazil.

4. Description of the developed model for measuring and evaluating intangible assets

To develop a conceptual model considering the specificities and assignments of a diagnosis and testing laboratory for electrical equipments, a set of assumptions was previously defined. These assumptions, in turn, should be aligned with the objectives of the future application in the context of Relase. Thus, it was established that the model should include the following attributes/characteristics:

- A holistic and multidimensional approach to the measurement and evaluation of the laboratory's intangible assets: aiming at identifying its strengths and weaknesses regarding the three components of intellectual capital, i.e., human, structural and relational capital;

- Alignment of intangible assets with the laboratory's strategic drivers: by recognizing the strategic importance of intellectual capital for its higher performance;
- Definition of the laboratory's knowledge objectives: allows to associate different elements of human, structural and relational capital with the achievement of knowledge objectives;
- Process-oriented approach: to enable managers to link the measurement and evaluation of intangible assets to the definition of goals associated with the non-financial performance of their activities and impacts to their stakeholders;
- Differentiation between process and outcome/impact indicators: providing short-, medium- and long-term perspectives in the management of the laboratory's intangible assets;
- Some degree of harmonization and standardization of indicators: important to ensure comparability between similar institutions;
- Flexibility in defining key processes: to enable managers to consider in the process modeling phase the specificities inherent to the laboratory's activities; and
- Institutional context assessment: assessing the context in which the laboratory is inserted facilitates the systemic management of intellectual capital, including the perception of the information needs of its stakeholders.

Based on the theoretical background that founded this work and considering the institutional profiles and external conditions for the operation and management of diagnosis and testing laboratories for electrical equipments, it was concluded that the ARCS model [5-7] complied with all the above assumptions and should, therefore, be adopted as a basis for the development of the model in focus. Figure 1 schematically represents the ARCS model, adapted to the context of diagnosis and testing laboratories for electrical equipments.

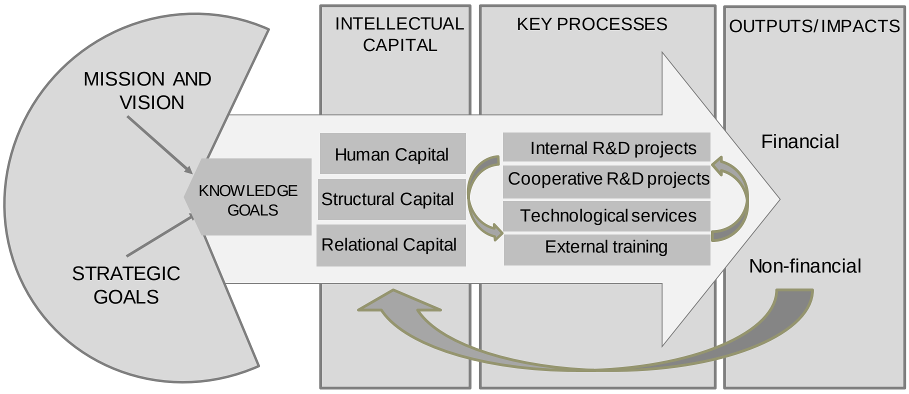

Figure 1: Components of the ARCS model for measuring and evaluating the intellectual capital of STIs, adapted to the context of diagnosis and testing laboratories for electrical equipments [6]

Figure 1 shows the basic components that should integrate a model for measuring and evaluating the intellectual capital of these laboratories, according to a logical chain, that begins with the definition of the strategic drivers of the Laboratory in focus, passing through the identification of its intangible assets with potential for value creation, and key process mapping, to finally measure and evaluate the results and impacts of its intangible assets considered strategic.

During the modeling phase, it was found that previous works on measurement and evaluation of intellectual capital of STIs did not refer to the use of multicriteria methods to select intellectual capital indicators and metrics. In order to fill this gap, the use of multicriteria decision support methods to validate intangible assets measurement and evaluation indicators were incorporated into the logical structure of the model represented in Fig.1. Thus, a multicriteria approach combining the fuzzy-AHP method [41] and the fuzzy-TOPSIS method [42] was proposed to integrate the conceptual model. As a result, the model for measuring and evaluating intangible assets in diagnostic laboratories and testing electrical equipment comprises seven steps, as shown in Figure 2.

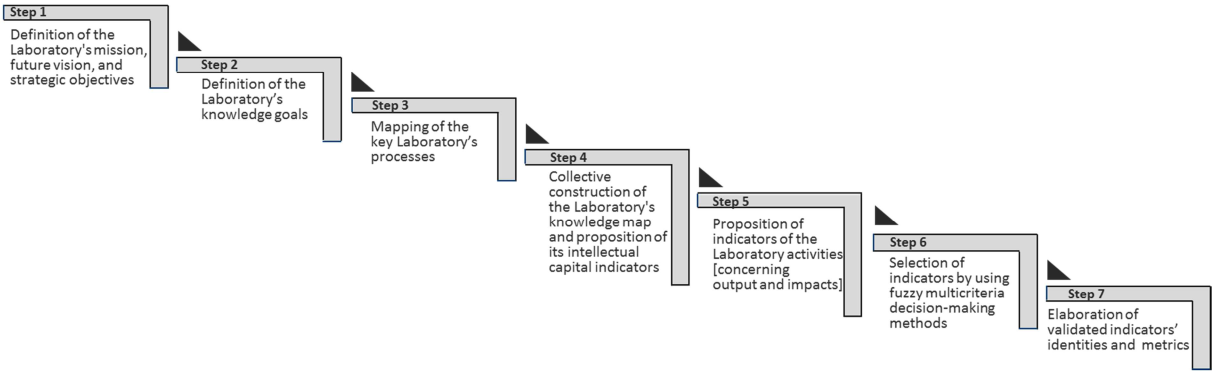

Figure 2: Model for measuring and evaluating intangible assets in diagnostic laboratories and testing electrical equipment

5. Demonstration of the applicability of the model: an empirical study in one of Relase's Laboratories in Brazil

During the period from March to September 2018, ten meetings were held, in which the proposed model was tailored to the Lab under analysis, and validated by its team. Due to space limitations, the results of the empirical study are partially presented in this section. Nevertheless, the detailed description of the conceptual model and all results of the empirical study are published in the first author's MSc. Dissertation, on which this paper was based [43].

Step 1 focused on the definition of the Lab's strategic drivers. Its results were specific to this Lab, so they will not be included here.

Step 2 yielded the following knowledge goals (KGs):

- To increase the degree of interdisciplinarity, recognized as an essential lab characteristic (KG1);
- To perform technological prospecting for staying at the vanguard position in the areas of monitoring, evaluation, and diagnosis of electrical equipments (KG2);
- To strength organizational competencies aiming at technical excellence in the areas of monitoring, evaluation, and diagnosis of electrical equipment (KG3);
- To disseminate knowledge through activities of external training and scientific and intellectual production in the areas of the Lab (KG4);
- To expand and intensify networking within the innovation system of the electrical sector in Brazil (KG5); and
- To increase international cooperation, through partnerships with similar institutions and participation in technical working groups in other countries (KG6).

Next, Step 3 defined the following four key processes, according to [44]: (i) Internal R&D projects; (ii) Cooperative R&D projects; (iii) Technological services; and (iv) External training. Each of the key processes was then mapped by defining inputs, activities, outputs, and key elements of intellectual capital associated with the activities.

As suggested by [45], Step 4 mapped the knowledge of the Lab through participative meetings and proposed a total of 47 intellectual capital indicators, divided into its three main components of intellectual capital: human capital (20 indicators); structural capital (11 indicators); and relational capital (16 indicators).

Step 5 focused on the output/impact indicators, divided into five dimensions, as follows: (i) knowledge enhancement (12 indicators); (ii) potential economic benefits (16 indicators); (iii) results and impacts to the electrical sector (12 indicators); (iv) results of cooperation with external entities (6 indicators); and social-environmental results (5 indicators). Thus, there were 98 proposed indicators that needed to be assessed and ranked, and this was the focus of Step 6. In this Step, the participants employed fuzzy multicriteria decision support methods. Two fuzzy multicriteria decision-making methods were adopted during this Step for selecting top indicators and metrics that should integrate the model. The fuzzy AHP method was used to define the criteria weights, and the fuzzy TOPSIS method for the final hierarchy of the degree of compliance of the indicators proposed to the decision criteria (by each model dimension).

Finally, Step 7 introduced a template for defining indicators' specifications in a standardized way, making explicit relationships between indicators and between them and the Lab's knowledge goals. Indicators' specifications include relevant information and metrics organized in a one-page form, as shown in [43].

6. Final remarks and recommendations

In this paper, an attempt was made to demonstrate the applicability of a conceptual model developed for measuring and evaluating intangible assets of diagnosis and testing laboratories for electrical equipments. During the period from March to September 2018, an empirical study carried out in one of Relase's Laboratories in Brazil validated the model in a real laboratory context. A set of 98 indicators could be objectively proposed, being 47 directly associated with intellectual capital, and 51 associated with outputs/impacts of its performance.

The empirical study results show a positive acceptance of the proposal in the Lab and can be understood as pieces of evidence of the conceptual model and tools' usefulness and feasibility. However, there still may be limitations with respect to the generality of the findings, such as: only one Lab was considered (pilot experience); the knowledge mapping did not include the use of the technology readiness scale (TRL) as planned by the authors, and proposed by [46]. Nevertheless, the material developed for this pilot experience is suitable for later implementation in the Lab itself and other Relase's Labs.

The conceptual model and the empirical results of this work may contribute to the current decision-making processes regarding intangible assets management in Relase's Labs, especially concerning the use of combined fuzzy multicriteria decision-making methods for selecting indicators and the collective construction of knowledge map of Labs. They can also enhance the methodological approaches adopted by European institutions, by the adoption of fuzzy multicriteria decision-making methods, and other tools that integrated the proposed model.

For the effective implementation of the model proposed in this work, the Laboratory managers should establish an action plan, with the initial focus on collecting base data on the highest scoring indicators. However, from a systemic perspective of the measurement and evaluation of intangible assets, those indicators with lower scores should also receive special attention regarding resource availability to enable their measurement in future and to increase the reliability of sources and their traceability over time.

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