School of Economics and Management
TECHNICAL UNIVERSITY OF LISBON

VALUATION AND OPTIMIZATION OF THE IMPACT OF INTELLECTUAL CAPITAL ON ORGANIZATIONAL PERFORMANCE

Feruccio Bilich
Universidade de Brasília - UnB – Brasil

Ricardo da Silva
University of Brasilia – UnB – Brasil

Abstract

Intellectual capital is the pre-eminent resource for creating economic wealth. Tangible assets such as property, plant and equipment continue to be important factors in the production of both goods and services. However, their relative importance has decreased over time as the importance of intangible, knowledge-based assets has increased in developing and maintaining a competitive advantage, value creation and competitiveness. This paper prescribes policies for optimizing intangible assets such as Intellectual Capital or, in other words, how and where the organization should invest, with minimum effort, in order to improve its market value and competitiveness in the technology-driven world.

Key words: Intellectual Capital, Knowledge-based Assets, and Value Creation.

INTRODUCTION

Intellectual capital is a term employed by knowledge-based companies that use Intangible Assets as resources to gain competitive advantages. The knowledge-based company employs specific products, patented processes, know how for production, and market knowledge to differentiate itself from its competitors.

In a general way, there are many words to describe intellectual Capital, such as: invention, technology, ideas, abilities, processes, or creativity. But, what mainly characterizes it is the interaction among the tacit and explicit knowledge

Correspondence Address: University of Brasilia – UnB, Campus Darcy Ribeiro, Prédio da Face, Asa Norte, CEP, 70910 Brasilia. E-mail: bilich@unb.br and ricardos@unb.br

that together with the culture of the company will position it in a sustainable way in the market.

Intellectual capital and knowledge management are topics of studies on intangible goods that have been of increasing interest to researchers, policy makers and managers, because the future of the latter professionals is directly related to the knowledge-based economy.

This paper presents and applies a model for evaluating intangible assets using a Multi-criteria Decision Aiding method. The intangible asset specifically analyzed was Intellectual Capital. This asset is an intangible that is increasingly gaining in value as a result of the changes brought about in knowledge management. Intellectual Capital can be divided into four categories: market assets, human assets, intellectual property assets, and methods and processes assets.

According to Arora and Gambardella (1992, 1994), in the past most innovations resulted from empiricist procedures; the outcome of each trial yielding knowledge that could not be readily extended to other contexts. While trial and-error may remain the primary engine of innovation, developments in many scientific disciplines - along with progress in computational capabilities and instrumentation - are encouraging a new approach to industrial research. Instead of relying purely on trial-and-error, an attempt is made to understand the principles governing the behavior of objects and structures. The result is that relevant information, whatever its source, can now be cast in frameworks and categories that are more universal. This greater universality makes it possible for the innovation process to be organized in new ways: firms can specialize and focus on producing new knowledge, and the locus of innovation may be spread across both producers and users. More generally, the use of general and abstract knowledge in innovation opens up the possibility for a division of labor in inventive activity.

Edvinson and Malone (1997:38) describe Intellectual Capital in a metaphor, comparing an organization to a tree. The visible part represents the company structure, the financial statements and other accounting and financial documents. The other part, which is to be found hidden below the surface although it belongs to the same organization, is made up of the more dynamic factors that support the organization. However, as a value aggregator, Intellectual Capital should principally be evaluated in high technology and service companies.

The current competitive environment for organizations exerts constant pressure on the valorization of intangible assets. This competitive scenario demands the evaluation and measurement of assets focusing principally on Intellectual Capital. In the evaluation and measurement of Intellectual Capital, the market must be taken into consideration, with its occasional financial instability, as well as its possible institutional turbulence.

The central purpose of this paper is to demonstrate the suitability of multi-criteria decision support methods as an operational strategy to evaluate, measure and optimize Intellectual Capital.

The review of multi-criteria methods and their applications led us to choose the ELECTRE (*Elimination and Choice Translating Reality*) family of methods, more specifically the multi-criteria method ELECTRE TRI (Yu and Roy, 1992:27).

Decision aiding using multi-criteria is the activity of one who uses explicit, but not necessarily completely formalized models, to obtain elements of answers to questions raised by an actor involved in a decision process.

The methodologies, models and techniques on which it is based and which are discussed below, usually have a different aim: to reason out the change prepared by a decision in such a way as to make it more consistent with the goals and systems of values of the one for whom or in whose name the decision-aid is to be performed. (Goicoechea, 1977).

Organizations increasingly depend on the ability to measure and optimize Intellectual Capital to create value-focused thinking. Keeney (2001:374) makes a case for using values as the primary driver for problem structuring and analysis, including the generation of alternatives, and he provides methods to aid in this process.

This value-focused thinking expands upon earlier work on multi-attribute utility and value models, and has been a major force in increasing the number and scope of multi-attribute applications, as well as the quantity and quality of alternatives generated in decision makers.

In the organizational processes, decision analysis has matured; increasing attention has been devoted to specifying procedures for successfully conducting and implementing decision analysis in organizations. Large-scale strategic decision analyses in particular that follow a well-defined process are typically used for managing the efforts of, and the interactions between carefully constructed teams composed of analysts, managers, and executives. Such a process is typically used first in structuring and analyzing the decision problem at hand and then in following through to manage and carry out recommended action plans and accompanying changes.

Intellectual Capital is not easily integrated in formal economic models and there are few examples of these models in economic theory. By contrast, R&D innovations are placed at the very center of analysis. It should be observed that analysis refers primarily to interactive processes where both parties are professional units, private or public organizations. It should also be observed that an economic perspective is rather abstract and gives rise to many interesting complications. One reason for this restriction on integrated Intellectual Capital is that valuation becomes a fuzzy concept when strategic organizations are involved. Another complication not reflected in the analysis is the nature of the assets. The

gist of the argument is best understood if we think of knowledge-based assets as a system made up of brand names, trade secrets, production processes, distribution channels, and work-related competencies. But, with some modifications, this view will also be valid for services and other intangibles.

Multi-criteria analyses of R&D project selection emphasize the benefits of stimulating researchers to develop better projects by improving communications (Ensslin, 2001). As a result, considerable additional guidance is now available concerning processes for successfully conducting and implementing major decision analysis projects within an organization.

The survival of organizations is characterized by uncertainties and by their valorization in the market. Consequently, it a great challenge to establish the criteria to be adopted in the decision-making process. Multi-criteria methods are recommended as they permit consideration of a diverse range of processes and the participation of various actors, including decision-making under situations of uncertainty, conflicts of interest and the elicitation of judgment values (Roy, 1992).

ANALYTICAL FRAMEWORK

For a long time, wealth was associated with the possession of physical assets, which was easy for accounting because they were expressed in a direct form on the balance sheets and in annual financial statements. However, in today's society wealth derives principally and increasingly from intangible intellectual assets. In other words, knowledge is becoming the most valuable production factor.

Knowledge is transforming the nature of production and thus work, jobs, the firm, the market, and every aspect of economic activity. Yet, knowledge is currently a poorly understood, thus undervalued economic resource. We need new sets of attributes through which to analyze the emerging knowledge economy. We also need new models to predict and plan future strategies, whether national, organizational or personal. The starting point for this process must be to understand the nature of knowledge, its role as an input to production, and its valuation and measurement.

A knowledge based organization is defined as one with a cumulative stock of information and skills that are derived from the use of information. To be a knowledgeable organization thus implies having capabilities or competencies that are likely to be valuable in the future as well as the present.

The knowledge capital of an organization is often referred to as its Intellectual Capital or intellectual assets. It can be identified in its workforce (human capital), its customers' demands and preferences (customer capital), and its sys-

tems, products, processes, and capabilities (structural capital) (Edvinson & Malone, 1997: 47). The value of the knowledge assets of an organization may thus significantly exceed the value of its tangible assets.

Advances in the information and communication technology infrastructure may contribute to a knowledge-based economy. The reduction in the cost of information facilitates the service of diffusing codified information, i.e. knowledge (Cohendet and Steinmuller, 2000: 195).

Knowledge itself remains the paramount resource and thus the key to economic progress. This is why we need to move beyond the limited concept of an information-based economy to the broader and more powerful concept of a knowledge-based economy, where a model for evaluating intangible assets can be applied.

In their analysis, Nonaka and Takeuchi (1995: 54) describe how knowledge creation in the company demands a series of repeated interactions between tacit and explicit knowledge, involving four possible permutations: Tacit to Explicit; Explicit to Explicit; Explicit to Tacit; and Tacit to Tacit. As organizations look for new ways to gain a competitive edge, they may be expected to switch the focus of their information initiatives towards improving the competitive scenario. This requires evaluation and measurement of assets, including and principally focusing on Intellectual Capital.

The major conclusion in the context of examining policy measures and institutional reforms to promote knowledge transfers between a knowledge-based economy and commercial R&D processes is that there are no economic forces that operate automatically to maintain dynamic efficiency in the interactions of these two organizations (Dasgupta and David, 1994).

Human intellectual capital is better suited to dealing with not only institutional turbulence but also market turbulence because it is more adaptive and creative at finding solutions that are appropriate to any problematic situation.

Strategic capacity planning involves an investment decision that must match resource capabilities to a long-term demand forecast. New technology creates new scope for introducing competition into many infrastructure sectors, such as telecommunications, distance cable network, cellular systems, etc. (Chase, 2001: 241)

The technological advances of the last two decades have determined that highly valued knowledge is that which can be applied systematically and objectively. In this way, the current "organization of knowledge" is one whose key resources are knowledge, both explicit and tacit, providing clearly observable competitive advantages that, in a general way, are truly valued in the organizations (Nonaka and Takeuchi, 1995: 45).

According to Balconi (2002), tacit skills that have been substituted by codified know-how and have become obsolete in the most modern manufacturing

processes are those relying on the perceptions of sensory organs or manual ability. In such a context Bellman's optimality principle (1957) becomes relevant.

According to Bellman's optimality principle, an optimal policy has the property that whatever the initial state and initial decision, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision. This is important for our analysis because knowledge is not related to the quantity of information; it is not enough to have it or manipulate it. It is making intelligent use of it that is indispensable.

In this way, if the managers/decision makers themselves are not attentive to changes, or if they refuse to abandon the ideas that brought success to the organizations in the past, they will be seen as the greatest obstacle in confronting the competition. Hence, the decision makers ought to adopt Bellman's principle whenever performing decisions over time.

For Sveiby (1997:39), knowledge is the art of creating value from the leverage of the intangible assets of an organization. Starting from this argument, Sveiby considers intangible assets to be represented by the following elements: external structure, internal structure and the competence of the employees. In synthesis, the author considers intangible assets basically to be composed of competence, relationships and information.

The more complex variant theme of the knowledge-based economy considers a situation where an R&D decision-maker knows *ex ante* that there are several technological attributes that need to be present if the techniques are to have desired economic attributes. (Nelson, 1982: 461).

For Roman (1970:130), normative forecasting represents a different approach; it is mission or goal-oriented as distinct from exploratory forecasting. Normative forecasting is an active or action-directed process.

A knowledge-based economy cannot be developed until the economic value of knowledge is better understood at all levels and evaluated. At present, knowledge acquisition (education, learning, skills formation) and knowledge development (research, innovation) are massively undervalued, both economic and socially.

Knowledge in all its manifestations increases in value. Consequently low knowledge-intensive goods and services and basic commodities will decrease in value. In one sense this is the hope of future. Knowledge will improve productivity and open market competition. Knowledge will force the organization to share that increase with the consumer by way of reduced prices. Consumer surplus will thus rise, which in turn will reduce prices for more goods and services. So the economy may be turned ever faster to competitive advantages.

Intellectual Capital is a term used to describe organizations of knowledge which use their intangible assets as resources to secure competitive advantages. They also use other intangible assets, such as specific techniques and products,

patented processes, know-how inherent to production and to the knowledge of the market, and their own competitive intelligence.

Generally speaking, there are many words to describe Intellectual Capital, such as: invention, technology, ideas, skills, processes, or creativity. However, what principally characterizes it is the interaction between tacit and explicit knowledge, which, together with the company culture, places it in a sustainable position in the market.

Increasingly, studies are showing that organizations' assets are more than the traditional domains of capital, physical assets (property), or workforce. These materials can easily be appropriated and/or substituted inside the competition process. This does not occur with intangible assets

Thus, there is much attention focused on Intellectual Capital, for in the environment of competitive business, ideas and innovations are currency, and information about markets and clients are increasingly valorized through greater investment in: 1) the development of a competent workforce which produces gains for the organization through their knowledge, capacity for action and creativity; 2) an internal structure which includes new concepts of management, information systems, technology, and use of networking, and serves as support to allow the human resources to develop; 3) an external structure which corresponds to the relations with the market and, principally, with clients and suppliers, in which a great investment is made in the organization's image; and 4) intellectual property which corresponds to the legal mechanism for the protection of the company's assets, such as patents, copyright, design, and brands, as well as trade secrets to maintain the competitive strategy.

RESEARCH METHODOLOGY

Multi-criteria methods are generally used to compare alternatives when countless objectives exist. As an instrument to aid decision makers, they provide more explicit, rational and efficient choices.

Multi-criteria methods

- enable a better organization of the information and of each participant's role in the several stages of the decision-making process;
- make the conflicts among objectives explicit and they quantify the degree of existing commitment among them;
- treat each objective in its unit of more appropriate measurement, without the distortion introduced by the simple conversion into monetary units as in an economical financial analysis.

Multi-criteria methods are the only procedure that can deal with multi dimensions or attributes or criteria. Therefore it is the only appropriate methodology to deal with intellectual capital, which is a multi dimensional entity.

The methodology employed in carrying out this research used the following steps: bibliographic research; definition of the sample of organizations based on Intellectual Capital; development and application of a questionnaire; processing of data through the specific Multi-criteria Decision Support software and analysis of the results.

From the review of the literature on Intellectual Capital, the most relevant criteria for its evaluation were identified and, based on this knowledge, a questionnaire was designed and employed in order to evaluate and measure Intellectual Capital.

The questionnaire was applied to 30 software producing technology companies; it was answered by the decision-makers. Of these questionnaires, 19 were valid, 10 were not returned and 1 was rejected.

The companies investigated were medium sized, with 15 employees on average. The questionnaire aimed to explore the following main topics:

a) Investment in Innovation: the percentage of return generated by news products;
b) Investment in Human Resources: what is the percentage of employees who had graduated from top universities;
c) Investment in New Technology: the percentage of the return of capital invested in R&D;
d) Development in New Products and Processes: the annual average of return by new products and processes.

These questions are related to the criteria employed in the multi-criteria evaluation.

As Intellectual Capital is a multidimensional asset, which is difficult to reduce to a single dimension of the monetary asset type, Multi-criteria Decision Support methods can be employed to capture all of its relevant and important dimensions, by associating each criterion with one dimension of the problem.

When a characteristic is not completely known, as in the case of Intellectual Capital, or when there are uncertainties as to its behavior, it is possible to obtain information based on the prior knowledge of a specialist on the subject, which is reflected in his/her value judgments. In this way, the decision-maker establishes relative weights for the criteria and makes an evaluation of each alternative for each criterion. This information was also gathered through the questionnaire.

The decision-maker also establishes limits so that the indices of agreement and disagreement can be validated. The ELECTRE TRI method (Yu and Roy,

1992) is a decision-aiding instrument, known specially for dealing with problems of classification (TRI). It examines the intrinsic value of each action in order to supply a recommendation that would provide an appropriate optimization for each item of Intellectual Capital.

The ELECTRE family methods seek to eliminate dominated alternatives according to a group of weights assigned by the decision-maker to each objective of the problem; this is called methods of outranking. These are based on the construction of outranking relationships, which incorporate the preferences established by the decision-maker given the problem and the alternatives available.

At the same time, a critical reading of the questionnaires was begun with the aim of finding out how this process of validating the measurable criteria could be developed. Thus, the positive aspects and possible faults were analyzed, as well as assistance sought for the definition of criteria and procedures to examine Intellectual Capital in the organizations.

The data obtained from the questionnaires were put into tables and processed by the ELECTRE TRI software, which is considered the most suitable for both the simulation and obtaining of results and for later carrying out sensitivity analyses of the attributes of Intellectual Capital.

It was observed that the criteria selected were those customarily found in fact finding and directly related to the subject of the study, the examination of Intellectual Capital.

The criteria selected were: 1) Investment in company name/brand; 2) Evaluation of financial return; 3) Client satisfaction; 4) Professional and academic background; 5) Level of interaction between sectors; 6) Dedication of the human resources to the company; 7) Monitoring of new technologies; 8) Competence management; 9) Information systems; and 10) Continued decision-making.

APPLICATION OF THE ELECTRE TRI METHOD

With the aim of checking the applicability of the ELECTRE TRI method and taking into account the organizations to be analyzed, the methodology was tested using 5 reference actions, defined by b_1 to b_5 and three thresholds (q – indifference; p – preference and v – veto).

Application of the software to the data collected resulted in the values shown in Table 1, supplying the reference actions for the thresholds. These actions defined six categories of classification ($E_{1\ to}\ E_6$).

For the reference actions b_1 to b_5, the weights attributed to each criterion were considered constant. The six categories (E_1 to E_6) were: E_1 – Extremely efficient; E_2 - Very efficient; E_3 - Averagely efficient; E_4 – Weakly efficient; E_5 - A little inefficient; E_6 - Very inefficient.

TABLE 1

Reference actions and their meanings

Threshold	Reference actions				
	b_1	b_2	b_3	b_4	b_5
q (indifference)	0.5	0.5	1.0	1.0	1.0
p (preference)	1.0	1.0	2.0	3.0	3.0
v (veto)	1.5	2.0	3.0	4.0	5.0

The organizations classified in categories below the average (E_4) were considered inadequate for measuring Intellectual Capital. From the information previously obtained and considering the specific nature of the organizations to be evaluated, in other words, the specific importance of each criterion, it was decided to use criteria which could be applicable to more general categories of organizations.

The criteria for numbers 8 and 9, Management of Competencies and Information Systems respectively, were substituted by the following more general criteria: Quality control of products/processes and Plan of investment in Research and Development, respectively. This substitution occurred due to the fact that the previous criteria were classified below E_4.

The criteria were all evaluated according to a numerical scale from 1 to 7, value 1 corresponding to the worst evaluation and value 7, the best evaluation.

In fact, ELECTRE TRI allows reference actions with differentiated values to be created for each criterion.

In the specific case of this work, it was decided to define a numerical scale, which would allow the criteria to be measured from the same reference. The comparison between the actions is processed, in this way, more in function of the evaluation scale adopted than in function of the definition of the criteria for each reference action.

The degree of importance, i.e., the weight of each criterion, was also defined on a scale of 1 to 7, with 1 being the weight of a criterion of very little importance and 7 the weight of a criterion of extreme importance.

The result of the five simulations is presented in Table 2. Simulation b_1 represents the moment in which there are a greater number of non-conformities. In the following simulations, an attempt was made to incorporate possible improvements in the evaluation of the Intellectual Capital, permitting an improvement in the performance of the company benchmark, yet without it being necessary to obtain the maximum evaluation for the criteria established.

Using the values of the reference actions and the adoption of the thresholds, the ELECTRE TRI method was applied, considering the cut-off level $\lambda = 0.67$.

TABLE 2

Application of the ELECTRE TRI method

Criteria	Weight	Simulation				
		b_1	b_2	b_3	b_4	b_5
1. Investment in company name/brand	7	2	4	4	5	6
2. Evaluation of financial return	7	1	3	4	5	6
3. Client satisfaction	7	1	1	2	3	4
4. Professional and academic background	6	1	2	4	4	4
5. Level of interaction between sectors	6	2	3	5	5	6
6. Dedication of human resources	5	1	1	2	3	3
7. Monitoring of new technologies	7	1	1	3	4	6
8. Quality control products/processes	5	1	1	1	2	4
9. Investment plan in R & D	5	1	1	1	2	4
10. Continued decision-making	6	2	2	2	2	4

Employing the method and using the procedure of optimistic assignment defined the classification of the organization.

Based on the result, it was concluded that the organization would only manage to attain its maximum Intellectual Capital if the performance of the valorization was equal or superior to that presented in Simulation b_4.

The test carried out showed that, using the ELECTRE TRI method, it was possible to check, in an explicit manner, whether the evaluation performance and the asset where the company should invest would make an improvement in its market value.

If a new criterion were considered, a classification that would also vary from 1 to 7 would be obtained in the same way.

It is essential to stress that the initial proposal of this methodology incorporated the reference actions and the categories of the companies being researched, as well as the criteria, weights and thresholds previously established.

The authors adopted two scales of measurement to evaluate the performance of the companies according to each of the criteria: one of percentages varying from 0 to 100% and the other a linguistic evaluation with seven gradations.

In the evaluation with the ELECTRE TRI method, the companies were classified according to a previously defined standard, which was composed of 5 reference actions and 6 differentiated categories, according to their performance of the Intellectual Capital.

The evaluation was structured in three stages. It was decided to analyze the questionnaires of the companies that use Intellectual Capital as a means to add market value and improve competitiveness. The optimization analysis was performed from the sensitivity analysis carried out using the ELECTRE TRI method, considering the companies with a cut-off level λ equal to 0.67.

In the first stage – Classification – the results obtained in the questionnaires were discussed and 2 companies, denominated X and Y, classified from among those analyzed.

The second stage – Sensitivity Analysis – presented in two types of tests, was designed to evaluate the stability of the results obtained in the face of a change in the thresholds of the cut-off levels and the weights.

The third stage – Optimization – sought to check the sequence of improvements necessary for the companies to move up an increment in their classifications.

VALUATION

When using the ELECTRE TRI method to evaluate Intellectual Capital, the decision-maker is responsible for the consideration of criteria, cut-off levels of thresholds and weights. Even though these parameters are, in the beginning, difficult to interpret and evaluate, the decision-makers are in the best position to carry out this evaluation as they have a global understanding of the implications of these values in terms of adding market value.

The application of the ELECTRE TRI software approaches the problem of decision-making, substituting the attributes by the indirect selection of the parameters of the model. The values of the parameters are inferred from an analysis of the attributes.

The ELECTRE TRI model implements this analysis in such a way that the least cognitive effort is required of the decision-maker. The choice of parameters is made indirectly, that is, using information supplied by the decision-maker, making use of a scale of attribute values.

For the purpose of analyzing the data, tests were carried out, with the aim of evaluating the stability of the results obtained, according to changes in the parameters of the ELECTRE TRI method. A synthesis is presented in Table 3.

In the first test, L_1, the parameters of the thresholds were analyzed and two different groups of thresholds adopted (Type A and Type B), relating to the two groups of criteria, with values of cut-off levels (λ) variable from 0.5 to 1.0, with increments of 0.05. In Table 3, C_1, C_2, C_3, C_4, C_5, and C_6 are categories; where C_1 is the weakest category and C_6 is the strongest category.

It can be observed that, in general, the values of the cut-off levels presented are those where modifications were observed, while the intermediary values, which do not appear in Table 3, correspond to no alteration in the evaluation.

Combinations of the type C_1C_2 indicate that the evaluation fell between category C_1 and category C_2. In other words, the evaluation is better than category C_1, but has not yet reached C_2. As the categories are in a n-dimensional space

TABLE 3

Results from evaluations for changes in λ as well as in the thresholds

Threshold	λ (a)	Test L_1 (b)(c)		Test L_2 (b)(c)	
		Company X	Company Y	Company X	Company Y
Type A	0.5	C_4	C_1C_2	C_4	C_1C_2
	0.7	C_2C_3	C_1C_2	C_4	C_1C_2
	0.8	C_2C_4	C_1C_2	C_2C_4	C_1C_2
	0.95	C_2C_4	C_1C_3	C_2C_4	C_1C_3
	1.0	C_2C_5	C_1C_3	C_2C_5	C_1C_3
Type B	0.5	C_3C_4	C_1C_2	C_3C_4	C_1C_2
	0.7	C_2C_4	C_1C_2	C_3C_4	C_1C_2
	0.8	C_2C_4	C_1C_2	C_2C_4	C_1C_2
	0.9	C_2C_4	C_1C_3	C_2C_4	C_1C_3
	1.0	C_2C_5	C_1C_3	C_2C_5	C_1C_3

Notes: (a) the cut-off levels (λ) varied from 0.5 to 1.00; (b) a minimum performance of C_4 was established for consideration for evaluation; (c) the categories varied from C_1 to C_6.

which, in this case, implies 6 dimensions, an evolution from category C_1 to category C_3 (C_1C_3) can take place without passing through category C_2.

For company Y, considering a cut-off level between $0.8 \leq \lambda \leq 0.9$ and using the type A threshold, the evaluations remained unaltered and equal to C_1C_2. For $\lambda \geq 0.95$ an increment in the classification was observed to C_1C_3, contrasting with the evaluation C_1C_2 for $\lambda < 0.95$.

Therefore company Y had uniformity in the results, considering two groups of thresholds, when $\lambda < 0.8$. However, increments in the classification were observed (optimistic evaluation) for values of $\lambda \geq 0.95$ and $\lambda \geq 0.90$ and in the thresholds of types A and B, to, respectively, C_1C_3, in both cases.

The result observed is possibly a reflection of the values of veto lower than the cut-off levels. It can be observed that, for the same group of thresholds, the behavior of the evaluations was uniform, considering different values of cut-off levels (λ).

For company X, considering the evaluations for the two types of thresholds, Type A and Type B, and the two tests (Test L_1 and Test L_2), uniformity in the evaluation equal to C_2C_4 was observed for $0.8 \leq \lambda \leq 0.95$. When the cut-off level reached ($\lambda = 1.0$), the category evaluation passed from C_2C_4 to C_2C_5.

For company X considering $0.5 \leq \lambda \leq 0.7$, with threshold type A, the evaluations were always equal to C_4. For thresholds of type B, and the same interval of λ, the evaluation was always equal to C_3C_4.

The results obtained for company X, with $0.7 \leq \lambda \leq 0.8$ and comparing them with values of $\lambda < 0.7$, indicate that this company underwent a drop in its evaluation, passing from C_4 to C_2C_3, in its classification.

The evaluations of company X, for ($\lambda > 0.90$) in the test of thresholds (Type B) as well as in the tests (Test L_1 and Test L_2) underwent a change in the classification of the company (a rising evaluation) from C_2C_4 to C_2C_5.

Therefore, coherence was observed in the values of the differences between the two companies, as the number of non-conformities with the optimum, observed in company Y, is considerably greater than in company X.

It can be observed that the result of company Y was possibly a reflection of the zero scoring in more than one criterion. In this way, no significant improvement was observed related to the change in the thresholds. It was very different in the case of company X, where improvements for different groups of thresholds were observed, due to its better performance in all the criteria, compared with company Y.

OPTIMIZATION OF INTELLECTUAL CAPITAL

Optimization of Intellectual Capital through the use of the ELECTRE TRI Multi-criteria Decision Aiding method seeks to determine the components of a vector of global performance of Intellectual Capital. Unlike a solution derived from a single criterion optimization, the solution for the problem is, therefore, an efficient group of optimizations. Each of these evaluations is the best in the sense that no improvement can be made in a component of the global performance vector without there being devaluation in at least one of the remaining criteria. Therefore, among the optimizations proposed, the decision-maker will choose the solution that is judged the most satisfactory or Pareto-optimum.

Next, the identification of the sequence of improvements to be carried out in each company was sought. Starting from the evaluation of companies X and Y, respectively C_4 and C_2 (before optimization), the actions that would be necessary to optimize their classifications were simulated.

In this case, category C_5 was established for company X and C_4 for company Y, as optima obtainable with the minimum possible effort. In this way, company Y would also obtain a good result for Intellectual Capital. Table 4 presents the simulations for optimizing the Intellectual Capital of company X.

In total, 20 simulations (S) were carried out for company X and 34 for company Y. These simulations took into consideration investment in the diverse criteria, which were put into a hierarchy arranged in an index of increasing difficulty, varying from 1 to 5. In this way, an optimization in the evaluation of the intangible asset, in this case Intellectual Capital was obtained.

TABLE 4

Simulations for optimizing company X

	Criteria	Simulations										
		Weights	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
2	Financial Return	3	50	50	50	50	50	50	50	50	50	50
3	Client Satisfaction	2.5	90	90	90	90	90	90	90	100	100	100
4	Professional and academic background	2.5	50	50	50	50	70	70	70	70	70	70
5	Interaction of sectors	2.5	50	50	50	50	50	50	50	50	50	50
6	Dedication of human resources	3	25	30	30	25	25	30	50	50	50	50
7	Monitoring S &T	3	50	50	70	70	70	70	70	70	70	70
8	Investment in R&D	3	50	50	50	50	50	50	50	50	50	50
9	Other actions	2	50	50	50	50	50	50	50	50	90	100
Result of ELECTRE			C_4	C_4	C_4	C_4	C_4	C_4	C_4	C_4	C_4	C_4

TABLE 4

Simulations for optimizing company X. Continuation:

	Criteria	Simulations									
		S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}	**S_{17}**	S_{18}	S_{19}	S_{20}
2	Financial Return	50	90	90	90	90	90	**90**	70	70	90
3	Client Satisfaction	90	75	90	100	90	90	**75**	90	90	75
4	Professional and academic background	70	50	70	70	70	50	**70**	50	70	50
5	Interaction of sectors	50	50	50	50	50	50	**50**	50	50	50
6	Dedication of human resources	50	50	50	50	50	50	**50**	50	50	50
7	Monitoring S &T	70	70	70	70	70	70	**70**	70	70	70
8	Investment in R&D	50	70	70	70	50	70	**70**	70	70	70
9	Other actions	90	50	50	100	50	50	**50**	90	90	90
Result of ELECTRE		C_4	C_4	C_5	C_5	C_4	C_4	**C_5**	C_5	C_5	C_5
Index of difficulty				21	33			**20**	22	24	21

Note: The simulation chosen, S17, was that which presented the smallest sum of indices of difficulty.

The index of difficulty was used to place the investments needed to achieve the optimum into a hierarchy. Simulation S_{17} resulted in an index of difficulty of 20 for company X and, simulation $S_{19,}$ resulted in an index of difficulty of 34 for company Y. These indices were the lowest necessary for the companies to reach their respective optima of Intellectual Capital.

In the case of company Y, the simulations showed that it could reach category C_4 if there were an increase in investments in the criteria 2, 3 and 6.

For company X to reach category C_5, it would only be necessary to perform the implementation in criterion 6 related to the dedication of the human resourc-

es. In other words, it would be necessary to re-dimension its policy of empowering its internal collaborators through a better positioning of the management of knowledge, both tacit and explicit. The ELECTRE TRI method of Multi-criteria Decision Aiding thus proved to be efficient in the process of evaluation, measurement and optimization of Intellectual Capital.

CONCLUSIONS

The research related in this paper demonstrated the pertinence of the applicability of multi-criteria methods in the evaluation and measurement of intangible assets and, in particular, Intellectual Capital. Multi-criteria methods were able to combine the knowledge described and used by the managers/decision makers with the monitoring of the organizational system, the combination of which leads to a much better management of intangible assets.

The research demonstrated, in fact, that if the organizations used Multi-criteria Decision Support methods to create indicators as in the model, they could manage the Intellectual Capital of the organization effectively and efficiently in the frequently turbulent environment of the global world.

Multi-criteria methods are the only procedure that can deal with multi dimensions or attributes or criteria, hence it is the only appropriate methodology to deal with intellectual capital.

The ELECTRE TRI method was shown to be suited to the question of evaluation of Intellectual Capital, as it allowed not only the comparisons of previously defined standards but also the incorporation of a large number of variables in the evaluation process.

As such, the method represented, for the context of this research, a process of interactive inference, of clustering and disaggregating of parameters, considering the variations of weights and thresholds in the sensitivity analysis and the criteria adopted by the decision-maker. These, in turn, can be validated or not by the organizations for the definition of a program of optimization aimed at competitive advantage, as they re-evaluate all of the criteria in a dynamic way.

Based on the sensitivity analysis, carried out using changes in weights and thresholds, practically no variation in the result was observed, which denotes the robustness of the method.

Using the ELECTRE TRI method it was possible to check if the performance of each intangible asset was considered satisfactory, in this case, if it obtained a result equal to or above the average. It was also possible to identify the areas in which the company should invest, with the minimum effort, to improve its market value.

The method developed and employed here made it possible not only to evaluate and optimize the Intellectual Capital but also to determine the impact on organizational performance.

The conclusions of the research consequently permit a vision of new possibilities for the application of the analytical methodology for Knowledge Management and valorizing Intellectual Capital.

It is worth highlighting the fact that the analysis of the valorization and optimization of intangible assets transcends the field of one simple area of knowledge. It is to be found in various areas of knowledge, combining methods and concepts that transcend the fields of the decision sciences, administration, accounting, financial theory, and operational research itself. The theoretical studies of the measurement of Intellectual Capital of organizations depend, therefore, on a multidisciplinary vision of the organization.

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Resumo

Capital intelectual é o recurso preeminente para criar riqueza econômica. Ativos tangíveis como propriedade, planta e equipamento continuam sendo fatores importantes na produção de bens e serviços. Porém, a importância relativa deles tem diminuído com o tempo à medida que a ativos intangíveis, baseados em conhecimento tem aumentado em importância no desenvolvimento e manutenção de vantagem competitiva, criação de valor e competitividade. Este artigo prescreve políticas para otimizar ativos intangíveis tais como Capital Intelectual ou, em outras palavras, como e onde a organização deveria investir, a um esforço mínimo para melhorar seu valor de mercado e competitividade no mundo movido a tecnologia.

Palavras-chave: Capital intelectual, ativos baseados no conhecimento e criação de valor.