

KWOWLEDGE MANAGEMENT: MULTICRITERIA ANALYSIS OF INTELLECTUAL CAPITAL

GESTÃO DE CONHECIMENTO: ANÁLISE MULTICRITÉRIO DE CAPITAL INTELECTUAL

Ricardo **DASILVA**
CNPq
rdasilva@cnpq.br

Feruccio **BILICH**
Universidade de Brasília - UnB
bilich@unb.br

Resumo

Capital intelectual é o recurso preeminente para criar riqueza econômica. Ativos tangíveis como propriedade e equipamento continuam sendo fatores importantes na produção de bens e serviços. Porém, sua importância relativa diminuiu com o tempo, enquanto a importância de ativos intangíveis baseados em conhecimento aumentou, para que a organização possa desenvolver e manter a vantagem competitiva. Como o conhecimento se tornou o recurso central em termos produtivos e estratégicos, principalmente em políticas de inovação, o sucesso da organização depende cada vez mais da habilidade de medir e aperfeiçoar o Capital Intelectual. Este artigo apresenta e aplica um modelo para avaliar ativos intangíveis empregando um método de auxílio multicritérios para tomada de decisões. Esse método permite medir ativos intangíveis como o Capital Intelectual e prescrever políticas para aperfeiçoar ativos intangíveis ou, em outras palavras, como e onde a organização deveria investir, empreendendo um esforço mínimo, para melhorar seu valor de mercado no mundo global dirigido pela tecnologia.

Palavras-chave: Capital Intelectual – Ativos Baseados em Conhecimento – P&D Competitivo – Método de Auxílio Multicritérios para Tomada de Decisões.

Abstract

Intellectual capital is the preeminent resource for creating economic wealth. Tangible assets such as property and equipment continue to be important factors in the production of both goods and services. However, their relative importance has decreased through time as the importance of intangible, knowledge-based assets has increased in order to develop and maintain competitive advantage. As knowledge becomes the central asset in productive and strategic terms, mainly on innovation policies, the success of the organization depends evermore on the ability to measure and optimize Intellectual Capital. The paper presents and applies a model to evaluate intangible assets employing a multi-criteria decision aiding method. This method enables to measure intangible assets such as Intellectual Capital and to prescribe policies for optimizing intangible assets or, in other words, how and where the organization should invest, making a minimum effort, in order to improve its market value in the technology-driven global world.

Keywords: Intellectual Capital – Knowledge-Based Assets – Competitive R&D – Multi-criteria Decision Aiding Method.

Introduction

This paper presents and applies a model for evaluating intangible assets using a Multi-criteria Decision Aiding method. The intangible asset that was specifically analyzed here was Intellectual Capital. This type of asset has been considered increasingly important as a result of the changes brought about by knowledge management. Intellectual Capital can be divided into four categories: market assets, human assets, intellectual property assets and infrastructure assets.

According to Arora and Gambardella (1992, 1994), in the past, most innovations resulted from empirical 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, the attempt is also to understand the principles governing the behavior of objects and structures (recomendo que, ao invés de “the attempt is...”, os autores coloquem um sujeito (ex: “...the scientists now attempt to understand...”) The result is that relevant information, whatever its source, can now be cast placed? in frameworks and categories that are more universal. Greater universality makes it possible for the innovation process to be organized in new ways: firms can specialize and focus upon producing new knowledge, and the locus of innovation may be spread across both users and producers. More generally, the use of general and abstract knowledge in innovation opens up the possibility for a division of labor in inventive activity - the division of innovative labor.

Edvinson and Malone (1997) use a metaphor to describe Intellectual Capital, comparing an organization with a tree. The visible part represents the company structure, the financial

statements and other accounting and financial documents. The other part, which, although it belongs to the same organization, is to be found hidden below the surface, is made up of more dynamic factors which support the organization. However, as value aggregator, Intellectual Capital should be evaluated principally in high technology and service companies.

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

This being so, 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 focus on Multi-criteria Decision Aiding was adopted following a preliminary selection of multi-criteria methods. The ELECTRE (Elimination and Choice Translating Reality) family of methods was elected to be used, in particular, the multi-criteria method ELECTRE TRI (Yu and Roy, 1992).

Increasingly powerful personal computer decision analysis software has developed widespread use of decision analysis tools such as ELECTRE TRI. It has also facilitated structuring and analyzing larger decision models.

Decision aid 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. These elements tend to clarify the decision and, usually, they prescribe or simply encourage behavior that will increase the coherence between the evolution of the process and the objectives

supported by this actor.

The theories or, more simply, the methodologies, models and techniques on which it is based and which will be 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, the goals and systems of values of the one person? for whom or in whose name decision-aid is to be performed (GOICOECHEA, 1977) have to be made explicit.

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

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. In large-scale strategic decision analyses in particular, a well-defined process is 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 into formal economic models and it has been more or less neglected in economic theory. In contrast, R&D innovations will be are always? put at the very centre of analysis. It should be observed that the analysis refers primarily to interactive

processes where both parties are professional units, private or public organizations.

It should also be observed that the perspective is rather abstract and has many interesting complications. One reason for this restriction on integrated Intellectual Capital is that valuation becomes a fuzzy concept when strategic organizations are involved and this has been neglected.

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, like brand names, trade secrets, production processes, distribution channels, and work-related competencies. However, with some modifications, the approach will also be valid for services and other intangibles.

Decision analysis frameworks for R&D organizational planning processes have received particular attention regarding the use of decision analysis for R&D project selection. These frameworks emphasize the benefits of stimulating researchers to develop better projects by improving communications through multi-criteria analysis (Ensslin, 2001). As a result, considerable additional guidance is now available concerning processes for successfully conducting and implementing a major decision analysis project within an organization, which suggests changes in assumptions and practices in order to make models from these fields more widely useful to present a framework for applying decision analysis methods to R&D strategy.

The analysis presented here fully justifies itself, as today, the survival of organizations is characterized by uncertainties and by their valuation in the market, making it a great challenge to establish the criteria to be adopted in the decision-making process (ROY, 1992). Multi-criteria methods are recommended, as they permit consideration of a diversity of processes and the participation of various actors,

including decision-making under situations of uncertainty, conflicts of interest and the elicitation of judgment values.

1 Analytical framework

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

Knowledge is transforming the nature of production and, consequently, the nature of work, jobs, the firm, the market, and of every aspect of economic activity. Yet knowledge is currently a poorly understood and thus undervalued economic resource. We need new sets of attributes through which we can analyze the emerging knowledge economy and 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 (Chartrand, 2006).

Knowledge-based organization is defined as the cumulative stock of information and skills derived from use of information by the recipient. Essa é a definição de knowledge-based organization? Parece definição de Capital Intellectual. Thus, being a knowledgeable organization implies having capabilities or competencies likely to be valuable in the future as well as in the present.

An organization's knowledge capital, often referred to as its Intellectual Capital or intellectual assets, can be identified in its workforce (human capital), its customer's demands and preferences (customer capital), and its systems, products, processes, and capabilities (structural capital)

(EDVINSON; MALONE, 1997). The value of the knowledge assets of an organization may thus significantly exceed the value of its tangible assets, as shown by the market valuation of the organization.

Advances in the information and communication technology infrastructure may contribute to knowledge-based economy to have improved the ability to model complex sem sentido. The reduction in the cost of information facilitates the service of diffusing codified knowledge (COHENDET; STEINMULLER, 2000).

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 information-based economy to the broader and more powerful concept of a knowledge-based economy and apply a model to evaluate intangible assets.

In their analysis, Nonaka and Takeuchi (1995) 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, which demands the 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 knowledge-based economy and the commercial R&D process is that there are no economic forces that operate automatically to maintain dynamic efficiency in the interactions of these two organizations de que organizações vcs estão falando?. (DASGUPTA; DAVID, 1994).

In the evaluation and consequent measurement, the market must be taken into consideration, with its occasional financial instability, as well

as its possible institutional turbulence. Essa mesma frase aparece na pg. 3. Apagar.

Strategic capacity planning involves an investment decision that must match resource capabilities to a long-term demand forecast. R&D competitions offer further information about it. New technology creates new scope for introducing competition into many infrastructure sectors, like telecommunications, distance cable network, cellular systems etc. (CHASE, 2001)

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 the one whose key resources are knowledge, both explicit and tacit, providing clearly observable competitive advantages which, in a general way, are truly valued in the organizations (NONAKA; TAKEUCHI, 1995).

According to Balconi (2002), tacit skills, which have been replaced by codified know-how and have become obsolete in the most modern manufacturing processes, are those relying on the perceptions of sensory organs or on manual ability.

One fact that has great relevance for the analysis is that knowledge is not related to quantity of information, as 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 which brought success to the organizations in the past, they will be seen as the greatest obstacle in confronting the competition.

According to Sveiby (1997), the question of knowledge is the art of creating value from the leverage of the intangible assets of an organization. Starting from this argument, Sveiby argues that intangible assets are represented by the following elements: external structure, internal structure and the competence of the employees. In short, the author considers

that intangible assets are basically composed of competence, relationships and information.

For the more complex and variant theme of knowledge-based economy, está faltando alguma palavra aqui 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 the desired economic attributes (NELSON, 1982).

For Roman (1970), 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 economically and socially.

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

Intellectual Capital is, in fact, 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 in production and in 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 mainly 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.

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

Thus, much attention has been focused on Intellectual Capital, for, in the environment of competitive business, ideas and innovations are currency and information about markets and clients are being more and more valued through greater investment in: 1) the development of a competent workforce that produce gains for the organization, through their knowledge, capacity for action and creativity; 2) an internal structure which includes new management concepts, information systems, technology and use of networking, serving as support to allow the human resources cited above to develop; 3) an external structure which corresponds to the relations with the market and, principally, with customers and suppliers, in which a great investment is made in the organization's image; 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.

2 Research methodology

The methodology employed in this study used the following steps: bibliographic research; definition of a sample of organizations based on Intellectual Capital; development and application of the questionnaire; processing of

data through the specific Multi-criteria Decision Support software; analysis of the results.

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

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

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, associating each criterion with one dimension of the problem.

On the other hand, 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, called methods of outranking. They are based on the construction of outranking relationships, which incorporate the preferences established by the decision-maker in the face of the problem and the available alternatives.

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, reflected in value judgments. In this way, the decision-maker establishes relative weights for the criteria and makes an evaluation of each alternative for each criterion. The decision-maker also establishes the limits so that the indices of agreement and disagreement can be validated. The ELECTRE TRI method (YU; ROY, 1992) is a decision aiding instrument, known specially for dealing with problems of classification (TRI), examining the intrinsic value of each action in

order to supply a recommendation which would provide an appropriate optimization for each item of the Intellectual Capital.

At the same time, a critical reading of the questionnaires was started 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, and assistance was sought for the definition of criteria and procedures to examine Intellectual Capital in the organizations.

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

It was observed that the selected criteria were those customarily found in fact finding and directly related to the subject of the study, the examination of Intellectual Capital. The selected criteria were: 1) Investment in company name/brand; 2) Evaluation of financial return; 3) Customer satisfaction; 4) Professional and

academic background; 5) Level of interaction between sectors; 6) Human resources' dedication to the company; 7) Monitoring of new technologies; 8) Competence management; 9) Information systems; and 10) Continued decision-making.

3 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 b1 to b5, and three thresholds (q – indifference; p – preference and v – veto). The application of the software to the collected data resulted in the values shown in Table 1, supplying the reference actions for the thresholds. These actions defined six categories of classification (E1 to E6).

For the reference actions b1 to b5, the weights attributed to each criterion were considered constant. The six categories (E1 to E6) were: E1 – Extremely efficient; E2 - Very efficient; E3 - Averagely efficient; E4 – Weakly efficient; E5 - A little inefficient; E6 - Very inefficient.

Table 1 - Reference actions and their meanings

Threshold	Reference actions				
	b1	b2	b3	b4	b5
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 (E4) were considered inadequate for measuring Intellectual Capital. From the previously obtained information 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, respectively, Management of Competencies and Information Systems, were replaced by the following more general criteria: Quality control of products/processes and Plan of investment in Research and Development, respectively. This substitution occurred because the previous criteria were classified below E4.

The criteria were all evaluated according

to a numerical scale from 1 to 7, value 1 corresponding to the worst evaluation for those criteria and value 7, the best evaluation.

In fact, ELECTRE TRI enables to create reference actions with differentiated values 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, based on the adopted evaluation scale than on the definition of the criteria for each reference action.

The level of importance, that is, the weight of each criterion, was also defined in 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 b1 represents the moment in which there is the greatest 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, without, however, the need to obtain the maximum evaluation for the criteria established.

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. Customer 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

Using the values of the reference actions and the adoption of the thresholds, the ELECTRE TRI method was applied, considering the cut-off level $\lambda = 0.67$. By employing the method, and using the procedure of optimistic assignment, the classification of the organization was defined.

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 b4.

The test that was 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 in which the company should invest would improve its market value.

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

It is essential to stress that the initial proposal of this methodology incorporated

the reference actions and categories of the companies being researched, as well as the previously established criteria, weights and thresholds.

The performance of the companies according to each of the criteria was evaluated by the authors adopting two scales of measurement: 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 allocated in a previously defined standard, which was composed of 5 reference actions and 6 differentiated categories, according to the performance of the Intellectual Capital. The evaluation was structured in three stages and it was proposed to analyze the questionnaires of the companies which use Intellectual Capital as a means to add market value and improve competitiveness. The optimization analysis was performed based on the sensitivity analysis, which was 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 two companies, denominated X and Y, were classified from among the analyzed ones.

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 weights.

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

4 Evaluation and measurement

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, replacing 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 obtained results, according to changes in the parameters of the ELECTRE TRI method. A synthesis is presented in Table 3.

In the first test, L1, the parameters of the thresholds were analyzed and two different groups of thresholds were adopted (Type A and Type B), relating to the two groups of criteria, with values of cut-off levels (λ) varying 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.

Table 3 - Results from evaluations for changes in λ as well as in the thresholds.

Threshold	λ (a)	Test L1 (b)(c)		Test L2 (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 .

It can be observed that, in general, the values of the presented cut-off levels are those where modifications were observed, while the intermediary intermediate 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 an n-dimensional space 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 $0.8 < \lambda < 0.9$ and using the type A threshold, the evaluations remained unaltered and equal to C_1C_2 . For $\lambda > 0.95$ 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 $\lambda > 0.95$ and $\lambda >$

0.90 and in the thresholds of types A and B, to, respectively, C_1C_3 , in both cases.

The observed result 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 L1 and Test L2), uniformity in the evaluation equal to C_2C_4 was observed for $0.8 < \lambda < 0.95$. 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 $0.5 < \lambda < 0.7$, 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 $0.7 < \lambda < 0.8$ 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 L1 and Test L2), underwent a change in the classification of the company (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 zero scoring in more than one criterion. Thus, no significant improvement was observed related to the change in the thresholds. The case of company X was very different, as improvements for different groups of thresholds were observed, due to its better performance in all the criteria, compared to company Y.

5 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. In a different way 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 which 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 which 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.

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	Customer 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 (continuation) - Simulations for optimizing company X.

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	Customer Satisfaction	90	75	90	100	90	90	75	90	90	75	
4	Professional and academic background	70	50	70	70	70	50	70	70	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	C₅	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.

Overall, 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.

The index of difficulty was used to place the investments needed to achieve the optimum into a hierarchy. Simulation S17 resulted in an index of difficulty of 20 for company X, and simulation S19 resulted in an index of difficulty of 34 for company Y. These indices were the smallest ones 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 C₄ if there were an increase in investments in the criteria 2, 3 and 6.

For company X to reach category C₅, it would only be necessary to perform the implementation in criterion 6, related to human resources' dedication. 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.

6 Conclusion

The research reported in this paper proved the pertinence of the applicability of multi-criteria methods to the evaluation and measurement of intangible assets and, in particular, Intellectual Capital, combining the knowledge described and used by the managers/decision-makers and the monitoring of the organizational system. This combination 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 their Intellectual Capital effectively and efficiently in the frequently turbulent environment of the global world.

The ELECTRE TRI method proved to be suitable to the question of evaluation of Intellectual Capital, as it allowed not only comparisons of previously defined standards but also the incorporation of a large number of variables into the evaluation process. In this way, the method represented, for the context of this research, a process of interactive inference, of clustering and disaggregation 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 an optimization program aimed at competitive advantage, as they re-evaluate, in a dynamic way, all of the criteria.

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

By using the ELECTRE TRI method, it was also possible to check if the performance of each intangible asset was considered satisfactory, in this case, obtaining a result equal to or above the average, as well as to check where the company should invest, with the minimum effort, to improve its market value.

The research conclusions consequently offer a vision of new possibilities for the application of the analytical methodology to Knowledge Management, valuing Intellectual Capital. It is worth highlighting the fact that the analysis of the valuation and optimization of intangible assets transcends the ambit of one simple area of knowledge. It is to be found in various areas of knowledge, combining methods and concepts which transcend the scope of decision sciences, administration, accounting, financial theory, and operational research itself. Theoretical studies of measurement of Intellectual Capital of organizations depend, therefore, on a multidisciplinary view of the organization.

References

ARORA, A.; GAMBARDELLA, A. New Trends in Technological Change: The Use of General and Abstract Knowledge in Industrial Research. **Rivista Internazionale di Scienze Sociali**. n. 3, luglio – settembre 1992.

ARORA, A.; GAMBARDELLA, A. The Changing Technology of Technological Change: General and Abstract Knowledge and the Division of Innovative Labour. **Research Policy**, v.23, 1994. p. 523-532.

BALCONI, M. Tacitness, Codification of Technological Knowledge and the Organisation of Industry. **Research Policy**, v.31, 2002. p. 357-379.

CHARTRAND, H. H. **Ideological Evolution the Competitiveness of Nations in a Global Knowledge-Based Economy**. University of Saskatchewan. PhD dissertation in Individual Interdisciplinary Studies, 1996.

CHASE, Richard B. *et al.* **Operations management for competitive advantage**. New York: McGraw-Hill, 2001. 9th ed.

COHENDET, P.; STEINMUELLER, W.E. The Codification of Knowledge: a Conceptual and Empirical Exploration. **Industrial and Corporate Change**. n. 2, v.9, 2000.

DASGUPTA, P.; DAVID, P.A. Toward a new economics of science. **Research Policy**, v.3, 1994. p. 487-521.

EDVINSON, L.; MALONE, N. S. **Intellectual Capital: realizing your company's true value by finding its hidden brainpower**. New York: HarperCollins, 1997.

ENSSLIN, L.; MONTIBELLER NETO, G.; NORONHA, S. M. **Apoio a Decisão: metodologias para estruturação de problemas e avaliação multicriterio de alternativas**. Florianópolis: Insular, 2001.

GOICOECHEA, Ambrose. The protrade method: A multi-objective approach to decision-making. *In*: STARR, M. K.; ZELENY, Milan. (ed) **Multiple Criteria Decision Making**. Amsterdam: North-Holland Publishing, 1977.

KEENEY, R. L. Modeling values for telecommunications management. *IEEE Trans. Enging. Management*, v.48, n.3, 2001. p. 370-379.

NELSON, R. R. The Role of Knowledge in R&D Efficiency. **The Quartely Journal of Economics**. v. 97, n. 3, Aug. 1982. p. 453-470.

NONAKA, I.; TAKEUCHI, H. **The Knowledge-Creating Company**: How Japanese Companies Create the Dynamics of Innovation. New York: Oxford University Press, 1995.

ROMAN, D.D. Technological Forecasting in the Decision Process. **The Academy of Management Journal**, v. 13, n. 2, Jun. 1970. p. 127-138.

ROY, B. "Decision science or decision aid science?" **European Journal of Operational Research**, v.66, n. 2, 1992. p.184-203.

SVEIBY, K.E. **The New Organizational Wealth**. San Francisco: Berret-Koehler Publishers Inc., 1997.

YU, W.; ROY, B. "ELECTRE TRI - Aspects Méthodologiques et Manuel d'Utilisation". Cahier du Lamsade, Document n.74. Paris: Université de Paris Dauphine, 1992.