Multi Model to Assess the Technology Transfer Process Performance in Highly Complex Spectrum under Uncertainty and Unpredictability

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Abstract

The present paper aims to contribute to the planning policy in technology transfer. To achieve that, it presents a multi-model proposal to assess the technology transfer process performance in high complexity spectrum in conditions of uncertainty and unpredictability according to the following phases: Phase 1: Determine the information needs in technology transfer process (TTP); Phase 2: Determine the technology transfer process; Phase 3: Identify the barriers in the technology transfer process; Phase 4: Assessment of barriers of the technology transfer process based on the technology categories (types); Phase 5: Determine the degree of technology transfer process effectiveness. The research focus was developed based on the literature and involved the intervention of experts on the study subject, which were selected using technical-scientific criteria. The data were collected through an assessment matrix, which the experts used to issue their opinions on all variables. To reduce subjectivity in the results, the following methods were used: Law of Categorical Judgment - psychometric scaling (Thurstone, 1927) and Artificial Neural Networking (ANN), Multivariate Analysis statistical methods and method Compromise Programming, Electre III and Promethee II - multi-criteria analysis; and Neurofuzzy Technology. The mains results obtained demonstrated that.

Key Words: Multi model; Assessment; Technology transfer process performance; Highly complex spectrum.

I Introduction

The introduction of new technologies is clearly evident in innovative products and it is considered one of the most remarkable ways of promoting new functionalities and improving the performance of existing products (NIOSI, HANEL and FISET, 1995; SEHROR! and ARTEAGA, 2000; MADU, 1989), in addition to being one of the inducers to create competitive advantages in the global market (BARANSON, 1970; CAVES, 1974; CONTRACTOR, 1980; DUNNING, 1979; KOJIMA, 1975; LA1 and STREETEN, 1977; MASON, 1981; MORLEY and SMITH, 1977; NEGANDHI, 1975; PRASAD, 1983B; WELLS, 1973). In fact, technology transfer crosses borders and is evidence in significant benefits frequently quoted in theoretical excerpts, frequently turned into return in the investments made; market participation and efficiency in the production process (KAPLINSKY, 1976; NIOSI, HANEL e FISET, 1995; JACOB and GROIZARD, 2007). It is a fact that the opportunities come along with risks and uncertainties that come from factors unfavorable to the technology transfer process (TTP), which, frequently confronted with social-economic and political problems are not so easily identified (MOHAMED, et.al., 2012; REISMAN, 2006; GLASS and SAGGI, 1998; PACK and SAGGI, 2001; MADU, 1988; MADU and JACOB, 1989; DUNNING, 1983; VERNON, 1966; STREIT, 1949). These factors are structurally dependente and, as such, have to be analyzed according to the reality of each country (MADU, 1989; VENANZE, 1996; KAUFMANN and ROESSING, 2005; KAPLINSKY, 1976; SALIOLA and ZANFEI, 2009).

The survival capacity of the new technology will also depend on how well it will deal with the host system; moreover, it is feasible that the new technology may present a common incremental value to the countries. This also depends on the capacity of the integration of the technology to the cultural systems and values of the host country, which in its usual form are complex and require careful analysis.

In addition to that are the use of strategies, lack of professional qualification, errors in necessity estimations, imperfect objectives and technical capacity, impracticable research and development, high cost in the transference of technology, incapability of implementing the new technology, inadequate analysis of the market and complexity degree of the technology, and others factors (REISMAN, 2006; GLASS e SAGGI, 1998; AMESSE and COHENDET, 2001). From the theoretical excerpts (Komoda, 1986; Baranson, 1970; Caves, 1974; Contractor, 1980; Dunning, 1979; Kojima, 1975; La1 and Streeten, 1977; Mason, 1981; Morley and Smith, 1977; Negandhi, 1975; Prasad, 1983b; Wells, 1973), the TTP must be oriented and conditioned to the technological necessities of the one who transfers it. It should also be noted that the necessary resources are available to serve them. It is obvious that there may be factors common to both countries.

The receiving country must need the technology and the sending one must see it as profitable. However, this is not always possible. Several times, the country receiving the technology is not sure whether the technolgy about to be transfered is favorable to its needs and potentialities or not. On the other hand, the sending country may bring the technology only to reduce costs. The logic presumes that the country receiving the technology is able to manage the changes and also to adjust it according to the feasibility of its reality (RODRIGUES, 1985).

Traditionally, the TTP is successful when the citizens see and comprehend that the new technology will provide them with better style and quality of life. The majority of the studies about technology transfer acknowledges the importance of considering the human factors in the execution of the process (MESHKATI, 1989). These dimensions must be carefully managed to favor the referred process. Within this spectrum, the present paper aims to contribute to the planning policy in technology transfer. To achieve that, it presents a multi-model proposal to assess the technology transfer process performance in highly complex spectrum in conditions of uncertainty and unpredictability. From the findings in the literature, there are many models to analyze the TTP (CALANTONE, LEE, e GROSS, 1990; LIN e BERG, 2001; MALIK, 2002). However, none of these studies (Calantone et. al., 1988; Boddewyn, 1981, Lin e Berg, 2001; Malik, 2002; Mohamed et.al., 2012) assessed the TTP with basis on the limiting factors, as well as presenting one inconsistency or another. The work is divided according to the following sections: 1 – Modeling and Discussion; and 2 – Conclusion e Implications. The procedures are detailed below:

2. Modeling and Discussion

The goal of the current article is to contribute to a planning policy in the technology transfer. To achieve that, it presents a multi-model proposal to assess on the technology transfer process performance in highly complex spectrum under uncertainty and unpredictability. The research focus was developed based on the literature and intervention of experts on the study subject, which were selected using technical-scientific criteria. The data were collected through an assessment matrix, which the experts used to issue their opinions on all variables. The model is structured according to the following phases:

1 *Phase 1: Determine the information needs in technology transfer process (TTP);*
2 *Phase 2: Determine the technology transfer process;*
3 *Phase 3: Identify the barriers in the technology transfer process;*
4 *Phase 4: Assessment of barriers of the technology transfer process based on the technology categories(types);*
5 *Phase 5: Determine the degree of effectiveness of the technology transfer process of degree.*

The procedures are detailed as it follows.

Phase 1: Modeling the Information Needs in TTP
This phase is subdivided into: modeling the CSFs (Critical Success Factors) and modeling the information areas.

Step 1: Modeling the CSFs

This step is focused on determining the CSF, and is itself structured in two stages: (A) identification of CSF and (B) evaluation of CSF. (A) *Identification:* The identification of CSF is based on the combination of various methods (Liedecker and Bruno,1984):

1. *Environmental analysis (external variable: political, economical, legislation, technology, among others.);*
2. *Analysis of the industry structure (users' needs, the evolution of the demand, users' satisfaction level, their preferences and needs; technological innovations);*

3. *Meeting with specialists and decision makers; and*
4. *The study of literature.*

The experts' intervention is crucial to evaluate the CSFs. Once the CSFs are identified, the next step is to group them for a better understanding, using the "cluster" technique, according to the tree structure principle, which distributes the CSFs in different processes or areas involved, but always observing the relevant relationship (Table 1).

Table 1: CSFs in TTP

CSFs	C1	C2	C3	C4	$(\Box i = \sum_{j=1}^{4} Zij$	Ranking
Policies	-1,2209	-0,8	-0,43	1,22064	-1,23029	**1º**
Market	-1,2209	-0,8	0,43073	1,22064	-0,36956	**2º**
Economical and Financial	-0,7647	0,13971	1,22064	1,22064	1,81628	**3º**
Technical	0,13971	3,86499	3,86499	3,86499	11,7347	**4º**

After organizing the CSFs groups, for each "cluster" (elements and subelements), the next step is to apply Thurstone's psychometric scaling method (1927) to evaluate the grouped CSFs, in other words, prioritize the "clusters" according to their classification: first, the Political / Judicial Factor; second, the Technical Factor; third, the Economical and Financial Factor; and fourth, the Market Factor.

Step 2: Modeling the Information Areas (IAs) in TTP

After determining the CSF, the determination of the areas of information ensues. Thus, after their identification, the IAs is evaluated in order to establish a ranking by relevance. Here the scale model of categorical judgments designed by Thurstone in 1927 has been adopted. This model starts from the mental behavior to explain the preference of a judgment (individual) concerning a set of stimuli $\{O_1, O_2, \ldots, O_n\}$. Thus, the evaluation of the IAs is systematized in the following steps: 1: determination of the frequencies by pairs of stimuli; 2 - determination of the frequencies of ordinal categories ; 3 - calculation of the matrix $[\pi ij]$ of the relative frequencies accumulated. It is highlighted through the results to be achieved in Step 3 that reflect the probabilities of the intensity of the specialists' preferences regarding the stimuli, the IAs in this work. As a result, a hierarchical structure of IAs is obtained.. The goals of the information areas information define specifically what must be achieved by these areas to meet one or more objectives The result has allowed defining four groups that represent the areas of information: *first*, the Governmental Area on Public Policies; *second*, the Market Area; *third*, the Economical and Financial Area*; fourth*, Technical Information from the projects of the product development (business), contributing for the enhancement of the project performance as to quality, productivity and profitability.

Step 3: Performance of AIs in Relation to CSFs

Again, these information areas are ranked by application of the same Categorical Judgment Method of Thurstone (1927) and put into relation with the CSF. At this moment the following tools have been adopted: (a) Multi-objective utility – multi-attribute, in this case Compromise Programming ™, which represent mathematically the decision makers' preference structure in situations of uncertainty; (b) selective, taken on account for the situation, Promethee II ™ and (c) Electre III ™. The result has allowed defining four groups that represent the areas of information: *first*, the Governmental Area on Public Policies; *second*, the Market Area; *third*, the Economical and Financial Area*; fourth*, Technical Information. The result is determined in the sequence (Table 2).

Table 2: Ranking IAs

Information Área	**Ranking**		
	Promethee II	Compromise Programming	Electre III
Policies	**1ª**	**1ª**	**1ª**
Market	2ª	2ª	3ª
Economical/Financial	3ª	3ª	2ª
Technical	4ª	4ª	2ª

Phase 2: Define the process of technology transfer

In this section, the procedures of technology transfer are presented, according to the following steps: 1) definition of the concept of technology; 2) definition of the TTP, according to the following sub-steps: 1 - Determination of the concept of knowledge/technology; 2 - Identification and capture of knowledge/technology; and; 3 – Evaluation of knowledge/Technology. These procedures are detailed as it follows:

Step 1: Definition of the concept of technology

From the theoretical excerpts, the concept of technology was defined. Phaal, Farrukh and Probert (2004) put technology as being the specific knowledge that can be incorporated to a physical artifact such as a machine, component, system or a product. In a complementing way, Kaplan and Tripsas (2008) conceptualize it in the light of the physical manifestation of the knowledge incorporated to a physical artifact. Moreover, it can be the application of a scientific knowledge with the purpose of obtaining a practical result (Roussel, Saad, and Bohlim, 1992). Or, it is the set of knowledge, means and knowhow (Ribault, Martinet, and Lebidois, 1995). From the presented definitions, all of them have basis on knowledge. This paper conceives technology as the knowledge applied to a physical artifact/practical application/practical result with a specific purpose. In this perspective, the technology transfer brings along with it this concept of knowledge.

Step 2: Definition of the TTP, according to the following sub-steps:

1 - Determination of the concept of knowledge/technology;
2 - Identification and capture of knowledge/technology and evaluation of knowledge/Technology

The three dimensions are identified on the literature and intervention of experts. These procedures are detailed as it follows:

1 - Defining the Knowledge Concept (Nonaka and Takeuchi, 1995; Probst, Steffen, Romhardt, 2002; Seufert, Von Krogh, Bach; 1999): The main concepts and elements are summarized in this work. The sources are selected according to their relevance. The definition that permeates this application follows the proposal by Moresi (2001): data (processing), information (elaboration), knowledge (synthesis) and intelligence, respectively. Data - discrete and objective set pertaining to the facts of a particular event or object. Therefore, a company's quantifiable and objective information and knowledge is stored in databases or documents. Information: message containing a transmitter and a receiver, whose meaning involves a new interpretation of something, based on a data set. The term knowledge is therefore defined as something that cannot be fully structured, cannot be fully captured. Knowledge follows the logic of Davenport and Prusak (1998), which is the most valuable information because someone gave it a context, a meaning, interpretation, someone thought about knowledge, adding his own knowledge insight, considering its broader implications. Davenport (2001), Moresi (2001); Bukowitz and Williams (2002); Probst, Steffen, Romhardt (2002) stress that knowledge is information produced, refined, evaluated on its reliability, its relevance and its importance. And it is through the synthesis of information that information is converted into knowledge. Next, this synthesis, information is assembled in blocks so that it can later be used by experts who filter it and standardize it to apply it to a specific situation.

Once this stream of defining "Knowledge" elements is exposed, the "Context Information - (CI) and the "Theoretical Bases and Concepts - (TBC) are adopted as a definition of knowledge in this application.

Context information means the information analyzed and evaluated from the information areas in Phase 2, where such information was identified and captured (internal and external environment), from the specialized literature and through interviews (semi-structured forms) by the experts as needed in order to supply the development of activities and actions coordinated for the projects. Such information is basic for the efficiency and success of the projects. The Theoretical Foundations and Concepts are understood as the conceptual skills. The conceptual skills represent the skills that involve the outlook of the organization or organizational unit as a whole, the ease of working with ideas and concepts, theories and abstractions. Next, we address how this knowledge will be identified and captured.

2 - Identifying and Capturing Knowledge: Identifying knowledge is the first step in the Knowledge Management process.

Two fronts should be analyzed: context information and theoretical bases and concepts. The context information will be identified, captured and mapped in the making of Phase 1, through semi-structured interviews and forms applied and confirmed by the experts with knowledge about the object of study/implementation in the information areas (study/application object). Thus, once this stage is identified and captured, they will be elaborated, reviewed and evaluated to become understandable to the decision makers (information users) in the project assembly and management, application object, following the analogy and hierarchy of data, information and knowledge. Then, this information will be reviewed, organized and validated by the experts involved directly or indirectly with the application object (in this case, the process of product development – technology-based company). The procedure to identify the information derives from determining the relevant theories and concepts that are necessary to achieve the operation and management of such projects. Next, the capture of this previously identified knowledge.

“After analyzing and validating the information, comes the knowledge stage, i.e., the information understood. It is through knowledge that those who advise on decisions seek a more effective understanding of the problem situation” (Moresi, 2001). And this analyzed and evaluated information produces knowledge, which is the information elaborated, refined, abd evaluated regarding its reliability, its relevance and its importance. Knowledge is obtained by the interpretation and integration of various data and information to start building a framework of the situation (Moresi, 2001; Bukowitz and Williams, 2002; Probst, Steffen, and Romhardt; 2002), and suggests the following methods as information analysis tools: SWOT Analysis, Synergies, “Benchmarking”, Management Profiles, Technological Monitoring, Morphological Analysis, D'Aveni’s Competitive Dynamic Analysis, Porter’s Value Chain, and Scenario Techniques. The SWOT analysis was used in this work. Knowledge acquisition involves the extraction, interpretation and representation of knowledge in a given domain and is considered to be the most difficult and precarious stage. The capture process is the acquisition of knowledge and experience required to create and maintain the selected and mapped essential skills and knowledge areas.

Acquiring the knowledge (from specialists) implies, according to Buchanan (2002) and Kululanga and Mccaffer (2001) the obtaining of information from specialists and/or from documental sources, classifying it in a declarative and procedural fashion, codifying it in a format used by the system and validating the consistence of the codified knowledge with the existent one in the system. Therefore, at first, the way the conversion from information into knowledge is dealt with, which is the information to be understood by and useful for the decision making in projects TT. First the information is gathered. Then the combination and internalization is established by the explicit knowledge (information) so that it can be better understood and synthesized in order to be easily and quickly presented whenever possible (the information must be useful for the decision making and for that reason, it must be understood). In this work, we aim to elaborate the conversion of information into knowledge.

First, the information is collected. Next, combination and internalization through knowledge is set up, from explicit to explicit, because the information is already mapped and formalized so that it is better understood and synthesized to be presented so that, when possible, everyone has access to easier and faster understanding (information should be useful in decision making, thus it must be understood). The simple activity of comparing and contrasting information is a form of analysis. Here are some procedures to capture knowledge: (Thiel, 2002): Interview, Mapping Information, Mapping Knowledge and Communication. To convert information to the knowledge stage (transformation), the following procedure is adopted: first, the comparison of how the information related to a given situation can be compared to other known situations is established; second, the implications brought about by the information for the decision making are analyzed and evaluated; third, the relation between new knowledge and that accumulated is established; fourth, what the decision makers expect from the information is checked. Others criteria was adopted:

1. *Determining the relevance and value of knowledge or information;*
2. *Determining the degree of reliability of that knowledge;*
3. *Identifying and consolidating useful knowledge and disposing redundant knowledge;*
4. *Hiring; reducing uncertainty of unproven knowledge;*
5. *Identifying and proposing solutions to problems related to conflicting knowledge, and finally,*
6. *Setting up multiple views for non-selected cases of conflicting knowledge.*

The conversion (transformation) takes place as follows: first, the comparison of how the information related to a given situation can be compared to other known situations is established; second, the implications brought about by the information for the decision making are analyzed and evaluated; third, the relation between new knowledge and that accumulated is established; fourth, what the decision makers expect from the information is checked.

The conversion of information into knowledge is assisted by the information maps (elaborated in the previous phase by areas, through analysis and evaluation of the information). We highlight that the information taken into account is both the ones externally and internally originated. The information from external origins has as a main goal to detect, beforehand, the long-term opportunities for the project (Célis, 2000). The internal information is important to establish the strategies, but it has to be of a broader scope than that used for operational management, because besides allowing the evaluation of the performance it also identifies its strengths and weaknesses.

Following from this, the proceedings for the acquisition of theoretical background and concepts are dealt with. Such proceedings begin with the areas of information, one by one, where the concept and the theory on which is based the performance of the actions (articulations) developed in those areas that allow to guarantee the feasibility of the technology transfer projects (TTP) are identified. In other words, which knowledge and theory are required to be known in order to ensure the success of technology transfer projects in that area.

Then, the analysis of surveys in public and private institutions about the job market for these institutions takes place, bearing in mind the demands of similar areas studied in this work. As for the offer, we intend to search for the level of knowledge required by the companies and other organizations in those areas, as well as what concerns technical improvement (means) for the professionals. By this approach, the following knowledge was identified: P*rocess automation*, Quality control , S*tatistical quality control*, D*evelopment of new* technologies, T*ools* and equipment; New production processes development, N*ew product development* (*NPD*); new Prototypes development; Sustainable Development in Production Engineering , Product Engineering ; Production Strategies ; Manufacture of new equipment ; Innovation Management , Maintenance Management , Technology Management , Management Systems Production & Operations Performance; Operations Management and Services; Productive Process Management, Project Management, Natural Resource Management, *Production Management System* (PMS), Knowledge Management in Manufacturing Systems , Management and Markets Strategy and Products; Energy Management, Logistics and Supply Chain Management and Distribution, Maintenance of machinery and equipment; Methodology of Product Design , Modeling , Analysis Simulation ; assembly of components and final products ; Industrial Organization , Market Research , product Planning , Production Planning and Control , Cleaner Production and Eco-efficiency; Factory Project and Industrial Facilities , results of research and development (R & D) in new generations of products, techniques of production organization , and Simulation Techniques production. Next, the knowledge objects are grouped for a better understanding.

They are grouped in “clusters”, according to the tree structure principle, which distributes the knowledge objects into different areas or processes, but always observing the relevance relationships, and supplemented by the pairing or “cluster” methods, in order to gather the sample data into groups (knowledge objects), classifying them in such a way that there is homogeneity within the group and heterogeneity between groups. *Seven clusters were identified: 1) Production Management (PM) 2) Quality Management (QM), 3) Economic Management (EG), 4) Product Management (PM); 5) Operations Research (OR) 6) Strategic Management and Organizational Knowledge (SMOK) and 7) Environmental Management of Production* Processes and Sustainability (EMPPS).

Phase 3: Identify of the barriers in the technology transfer process

The barriers were extracted from the theoretical excerpts and combined with several methods (Leidecker and Bruno, 1984; Williamson, 1981; Coram, 1967; Vaupel and Curhan, 1974; Dunning, 1958; Dunning, 1983), in which more than 300 titles were selected in the period between 1750 and 2010. From the findings in the literature, some characteristics can be highlighted in this historic period in the light of this investigation. Through this way, the investigation was based on the evolution of the technological progress and industrial growth. Some relevant information is highlighted. According to Streit (1949), from the 327 important inventions made between 1750 and 1850, Great Britain was responsible for 38. France was responsible for 24 and Germany 12. Eventually, the USA was responsible for 16. The second historic period (1870-1914) was characterized by a great technological progress, with significant progress compared to the first industrial revolution. In the third stage (1919-1939) the total particpation load of foreign capital (in monetary terms) increased significantly (1914 and 1938) the number of foreign branches, particularly in the market sector of developed countries. It was a time of aggressive impulse abroad for manufacture multinational companies to guarantee access to primary products for its domestic plants, for instance, oil, rubber and non-iron metals and also to meet the consumer goods market expansion. The fifth stage (1945-1965) was characterized by the high international production. During these years, the United States technological predominance was outstanding.

The sixth stage (1965-1980) was characterized by the increasingly growth of the multinational companies position in the global economy. There was a boost in the technological creation and spreading (Dunning, 1983), which has increased significantly in the last decades (1980 to 2010). Thus, a systematic review of international theoretical excerpts on the investigated topic was conducted, in which experiences and study cases, either successful or failed, in technology transfer were analyzed. Soon after this procedure of identification of barriers, the next step was the application of filters and organization of the barriers in clusters for a better comprehension. The clusters and their sub-elements were submitted to trial by specialists with knowledge on the object of study, selected by techno-scientific criteria. The data were extracted by means of a scalar-type matrix of judgement, in which the experts put their impressions, establishing priorities by importance, designating values to the barriers. Parallelaly to the theoretical excerpts, the following methods to identify the barriers in the technology transfer were used:

1. *Environmental analysis;*
2. *Structural analysis of the industry;*
3. *Consult with experts (business); and*
4. *Time /intuitive factors.*

The research was oriented to high tech inudstries/ highly complex spectrum. It should be highlighted that the intervention made by experts was determinant in the judgment of the barriers. It was identified over 273 barriers in technolgy transference (1750-2010). The most significant ones that support this current investigation are: Canada; Cuba, Korea, Niger; China; Holand; England; Germany; the USA; France, Japan; India; Taiwan, and others.

Grouping of barriers: The next step was to group the barriers in the TTP for better comprehension and interpretation. The rearrangement was made by clusters or pairing, meeting the “principle of arborescence”, which allows the unfolding of the barriers in the TTP in different processes or involved areas, but always observing the pertinence relations.

Stages to Apply Pairing:

1. *Select the componentes to be grouped;*
2. *Calculate the distance between the initial clusters;*
3. *Select the grouping process to find the most similar clusters;*
4. *Group the “clusters” to produce a single one;*
5. *Calculate the distances of the new cluster to all the other ones; and*
6. *Repeat the steps of grouping in a way that all the cases are placed in only one “cluster”.*

The next step was assess / prioritize by relevance the barriers in the TTP. To make the comprehension and the interpretation of results easier, the referred barriers were called Issues of technology transfer. Thus, the barriers were not considered in different ways once one Issue can be considered unsuccesful or failure. Therefore, the prioritizing/assessment of the Issues was done with the support of method of the Law of the Categoric Judgement of Thurstone (1927) (Phase 2).

Phase 4: Assessment of the barriers according to the categories (type) of technology using Thurstone’s LJC method

As referenced earlier, the prioritizing/assessment of the barriers was done with the support of method of the Thurstone’s LJC psychometric scaling method. The method allows a scale by importance. Thus, let πij = Prob [O_i Î C_1 U C_2 U ... U C_j], the probability of stimulus Oi located in one of the j first categories ordered increasingly C_1, C_2, ..., C_j. It can be written that πij = Prob [O_i Î C_1 U C_2 U ... U C_j] = Prob [ei £ nj]. With the hypotheses formulated, it follows that:

$$\pi ij = \text{Prob}\left[\varepsilon i - nj\right] = \text{Prob}\left[\frac{(\varepsilon\varepsilon - nj) - (\mu\mu - cj)}{\sqrt{V(\varepsilon(-nj)}} \leq \frac{(\mu\mu - cj)}{\sqrt{V(\varepsilon(-nj)}}\right]$$

That is: $$\pi ij = \text{Prob}\left[\boldsymbol{N}(0,1) \leq \frac{(\mu\mu - cj)}{\sqrt{V(\varepsilon(-nj)}}\right]$$

Where πij is an estimator of πij and considering value Z_{ij} such that, $\text{Prob}[N(0,1) \le Zij] = \hat{\pi} ij$, we have

$$\frac{(\mu\mu - cj)}{\sqrt{V(\varepsilon(-nj)}} = -\boldsymbol{Zij}$$, Where µµ is value of scale.

The experts (judges) express their preferences with pairs of stimuli (barriers), and these were submitted to the ordinal categories C1=5th place; C2=4th place; C3= 3rd; C4=2nd place; C5=1st. These events occur in different moments, in which the scale values vary depending on the dynamics of their own mental process, which result in replacing the idea of preference for the probability of preferences. The procedures to apply the instrument are systematized in the following steps:

***Step 1: Determining the frequencies of preferences for pairs of stimuli (barriers*),** where O_i is equal to barriers and O_j to the experts – $O_i]O_j$. The systemized data were extracted from the experts' preference regarding Knowledge (through field research using an assessment questionnaire/matrix).
Step 2: Determination of the frequencies of ordinal categories, based on the data extracted from the previous step. The matrix [πij] of the cumulative relative frequencies is then calculated. The results are classified in ascending order of importance. To better understand the technique, we recommend the following literature (Souza, 1988; Thurstone (1927).

Step 3: To determine the matrix [πij] of the cumulative relative frequencies from the results of the frequencies of ordinal categories we calculate the matrix of the cumulative relative frequencies.
Step 4: To determine the inverse of the standard normal cumulative frequencies (INPFA), from the results obtained in the previous step, calculate the inverse of the standard normal cumulative frequencies. The results reflect the experts' preference probabilities in relation to stimuli (barriers). Considering that C1 contains less intense stimuli than C. In a psychological continuum the stimuli are translated by scale values of µi and the categories (C1, C2, C3...), by an interval partition of the real line, such that C1 is represented by the interval (-∞, C1) and C2 represents the interval (m-1, + ∞). The result of preferences is then presented in order of increasing importance. The results are detailed to following figs. 1 to 6.

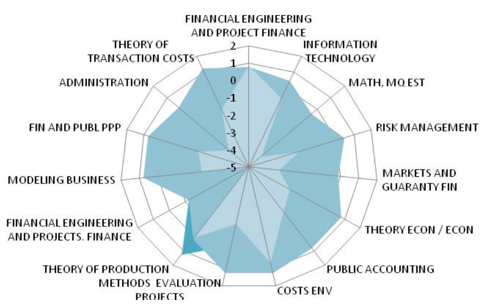

Fig. 1: Economic and Financial Barriers

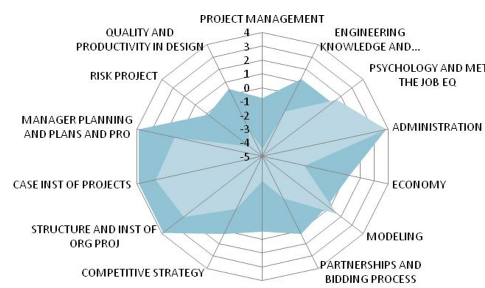

Fig. 2: Technical Barriers

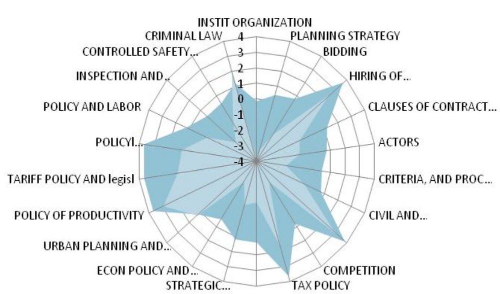

Fig. 3: Legal Barriers

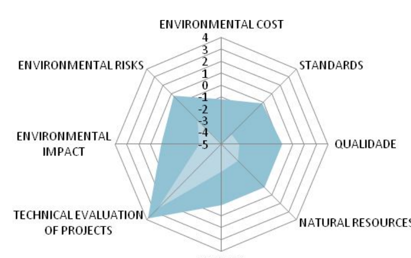

Fig. 4: Environmental Barriers

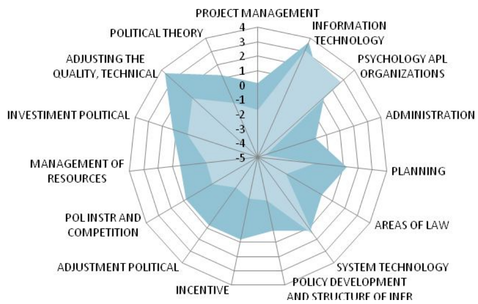

Fig. 5: Political Barriers

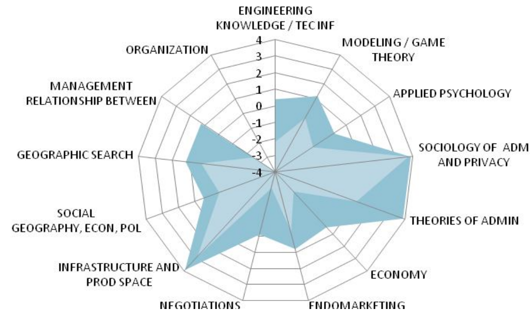

Fig. 6: Market Barriers

Economic and Financial Barriers: From the economic and financial dimensions identified and prioritized there is a predominance to the barriers – 1st return of the transference of technologies and Cost of technology; Cost of the transference of technology – 2nd Return rate, unrecoverable Costs, Comparative Costs, low Costs of Transactions, Interest Rates; Profit; and Risk Analysis. These results reflect the state of the art (KAPLINSKY, 1976; NIOSI, HANEL and FISET, 1995; JACOB and GROIZARD, 2007). The literature shows that, initially, the determining factor in the TTP is associated to the return over the investment (ROI).

Technical Barriers: When analysing the technical barriers, a predominance can be verified 1st – Competence in the TTP, Adeqaute Resources; R&D structure; Infra-structure; qualified labor force, Management Capacity, degree of dependence of domestic personnel and innovation input, Management philosophy; Nature of the management practice; Potentialities of reallocating installations of R&D; Capacity of increasing the sources of information and knowledge; Significative technological and resources force, Knowledge on product and production technology. This logic demands capability in managing changes (Rodrigues, 1985) and requires capability of planning and organizing the resources to implementing the new technology. It includes the participation and involvement of the parts in the process (Achebe, 1959), infra-structure, systems of social values, cultural values, traditions and habits, spirit attitudes, level of abilities, and taboos of the acquiring population (MESHKATI, 1989).

Environmental Barriers: The main barriers in the TTP are the natural resources and the environmental risks. Combined with the absence of planning, this factor represents a significant restriction to the TTP.

Political Barriers: The political priorities are: political stability, economic policy, investment policy, restrictions in direct investments, restrictions to imports, inability of resisting to external shocks, and culture of trust. In addition to these questions, there is the policy so that the process can be implemented in a plausible way.
The main *Legal Barriers* are: contracts and licences combined in diferente ways, protection against Market failures, nationalization and excessive regulation; protection to license practice; of intelectual property; concessions or licences to use patent formulas, drawings, models, procedures or specific parts of technological knowledge.

Market Barriers: There is a predominance in the barriers: Growing and sophisticated Market, with adequate scientific and technical infra-structure, International competiton; Market structure, industrial concentration, distribution channels, capability of integration with other markets and fragmentation of International markets.

1.1. Soon afterthis procedure, the Issues performance was determined (global performance assessemnt) according to the type/category of each technology. In other words, it was established a priority, by importance, of the categories (types) of transferred technologies in relation to the barriers. Within this spectrum, it was possible to verify the global performance of the barriers in relation to each category of transferred technology, which enables the technology managers to guide in a more plausible and feasible way their efforts in this process, and with that, make it more efficient. This procedure was elaborated with the support of the multicriteria methods in the light of the data obtained by the specialists.

The methods used were *Compromise Programming, Electre III and Promethee II*. The *Compromise Programming* due to its wide diffusion and application simplicity and understanding renders it an alternative to evaluate problems as referenced in this application. The problem solution compromise is the one that comes closest to the alternative. This method was designed to identify the closest solution to an ideal one, therefore it is not feasible, using a predetermined pattern of distances. In *Promethee II* there is a function of preferences for each criterion among the alternatives which must be maximized, indicating the intensity of an alternative to the other one, with the value ranging from 0 to 1. Of the *Electre* family *(I,II,III,IV and V)*, *Electre III* is the one considered for the cases of uncertainty and inaccuracy to evaluate the alternatives in the decision problem.

All these methods enable to analyze the discrete solution alternatives, and taking into consideration subjective evaluations represented by numerical scores and weights. As these are problems involving subjective aspects, the methods that best fit the situation of this research are the methods of the family Electre and Promethee. It should be mentioned that although the Compromise Programming method is not part of this classification, it has similar characteristics, showing much simplicity in order to understand its operation, which makes it feasible for this application. Within this perspective, the multicriteria methods are viable instruments to measure the performance of the Barriers in TTP. The results are presented as it follows (Table 1). The results produced by the methods demonstrate the Political Barriers as the most significant ones to ensure the performance of the TTP. When comparing the results in terms of performance, the Compromise Programming and Promethee II methods did not differ in their classifications. For Electre III, the results were incompatible.

Tab. 1: Assessment of the barriers according to the categories (type) of technology using multicriteria methods

	Ranking		
Barriers x Categories (types) of transferred technologies	Promethee II	Compromise Programming	Electre III
Political Barriers	1ª	1ª	1ª
Market Barriers	1ª	2ª	3ª
Economic and Financial Barriers	3ª	3ª	2ª
Technical Barriers	4ª	3ª	2ª
Environmental Barriers	4ª	4ª	3ª

And this is because the p, q and v veto thresholds, respectively, of indifference, strong preference and veto or incomparability have a discrepancy in the structure of their results (classification). Electre III presents a set of solutions with a more flexible hierarchical structure. This is due to the conception of the method, as well as the quite explicit consideration of the indifference and incomparability aspect between the alternatives. The results referenced by the Promethee II and Compromise Programming methods reflect the preference, according to the experts, for Political Barriers. In fact, a TTP requires clarity in the objectives to be reached with the transference of technology. From the theoretical excerpts and results produced in the light of the conditions in the TTP, the "capability of planning"and adequate resources" are considered fundamental in the TTP. In addition to that there is the capability to manage human resources to reach the efficiency of the process.

It is important to balance where resources are placed, the operational management and at the same time take into account issues in people management such as leadership, motivation, organization and team work (MENKE, 1994). Studies have shown the capability of R&D as one of the inducers to technologies transfer. It is evident that the management of R&D, by its own nature, is characterized by uncertainties and requires a complex interaction between different actors and variabes. It is important to reaffirm the importance of favoring investments in R&D and use the local research center resources efficiently generating favorable environments to the transference of technology, considering that the survival of high tech/complex environment companies depends mostly on its research and development. Transference or expansion of R&D facilities in abroad areas depends not only on government fundings, but also on the availability of scientists and technicians that, when combined, enhance an adequate infra-structure of R&D in a certain market.

1.2. Phase 5 – Determination of the Effective Rate of TTP

This stage focuses on determining the Rate of Effectivity (RE) in TTP, with regards to using the Neurofuzzy Modeling. Seeing that it is a process whose attributes mostly have characteristics of subjectivity and the experience of the decision-maker is quite significant, there is a need for a tool that allows the association of quantitative and qualitative variables converged to a single evaluation parameter (Oliveira, 2004; Cury; 1999; Von Altrock, 1997). This model adds the technology of Neural Networks to the Fuzzy Logic (Neurofuzzy technology). Here, this model supports the chain supply managing and is adapted from the model of Oliveira and Cury (1999).

In such Neurofuzzy, the entry data can be quantitative and qualitative and are grouped to determine the comparison parameters between the alternatives. Since the exact models suitable for this type of calculation have a complex application, the Neurofuzzy methodology enables and simplifies the human decision of reproducing the process. This methodology is structured from a combination of all of the attributes in blocks of inference that use base fuzzy rules and linguistic expressions, so that the preference for each alternative of knowledge priority decision, in terms of benefits in TTP, can be expressed by means of a “grade” varying from 0 to 10.

Within this spectrum, this stage presents a modeling to evaluate objects of knowledge to provide support to the TTP, based on quantitative information and also on the specialist’s qualitative information, using the Neurofuzzy technology. The qualitative parameters are difficult to measure and may indicate high levels of subjectivity, hence justifying the application of methods that allow the convergence of these parameters to a single coefficient, therefore enabling the decision-making taking into account all of the relevant attributes. The stages of the model are described to follow:

Stage 5.1: Determination of the Entry Variables and Linguistic Terms

It focuses on determining the entry variables (EV). These variables are categorized according to the quantitative or qualitative types. Also, the linguistic terms attributed to each EV are presented: High, Medium and Low. Thus, the EVs shown in the Model are: Political Barriers; Market Barriers; Economic and Financial Barriers; Barriers Technical; and Environmental Barriers (Figures 1-6).

Stage 5. 2: Determination of the Intermediary Variables and Linguistic Terms

The entry variables go through the process of fuzzy inference, resulting in linguistic terms of Intermediary Variables (IV). Thus, the linguistic terms attributed to the IV were: Low, Medium and High, including some variables: Slow, Moderate, Fast – Bad, Regular and Good.

The extracted intermediary variables were: Political Performance; Economic and Financial Performance; Market Performance; and Technical Performance. CONFIGURATION Technical - Mercadology Benefit. The proposed design is made up of seven configurations of fuzzy specialist systems, two entry variables (EV) that go through the fuzzy process and through the inference block, therefore producing an exit variable (EXV), designated intermediary variable (DV). In turn, such DV joins with another DV, hence forming a set of new EVs, consequently configuring a sequence until the last layer of the network. In the last layer, the definite variable EXV of the Neurofuzzy Network is produced. This EXV then undergoes a de-fuzzing process to achieve the final result: the TTP.

Stage 5.3: Determination of the Exit Variable – Effective Rate of TTP - ERTTP

The Exit Variable (EXV) of the Neurofuzzy model proposed was denominated Effective Rate in TTP, resulting in the processes of:

Fuzzyfication: This process includes determining the functions for each of the entry variables. If the entry data, the calculation results and observations are precise values, then it is necessary to perform the structuring of the fuzzy arrangement for the entry variables, which consists of the fuzzyfication process. In case the entry variables are obtained in linguistic values then the fuzzification process is not necessary (Cury, 1999). The fuzzy arrangements can be characterized as a generalization of the Boolean sets, where the pertinency function can assume values at fixed intervals. Usually, the interval [0,1] is considered, when it is not correct to assume that an element belongs to a specified set, but that it does indeed present a certain degree of pertinency. Therefore, a fuzzy set, besides an X universe, is a set of orderly pairs represented by Equation 1.

$$A=\{(\mu_A(x),x)|x \in X\} \quad (1)$$

Where $\mu_A(x)$ is a function of pertinency (or degree of pertinency) of x in A and is defined as the mapping of X in the closed interval [0,1], in agreement with a Equation 2 (Pedrycz and Gomide, 1998).

$$\mu_A(x):X \rightarrow [0,1] \quad (2)$$

***Fuzzy inference*:** The ground rules of fuzzy inference is made up of the IF-THEN type, which are responsible for the association of the entry variables and the generation of the exit variables in linguistc terms, with their respective pertinency functions. The fuzzy inference is structured by two components: (i) aggregation, which means the computing from the SE of the rules; and (ii) composition, regarding the THEN part of the rules. The Degrees of certainty (DoC) that determine the linguistic vectors resulting from the processes of aggregation and composition are defined by the Equation 3.

$$GdC;:max[FC_1 . \min\{GdC_{A11},GdC_{A12},...,GdC_{1n}\},...,FCn . \min\{GdC_{An1},GdC_{An2},...,GdC_{Amn}\}| \quad (3)$$

Defuzzification: In some applications the interpretation of a result is enough, as for instance, when a qualitative or verbal response is desired. However, in other applications, a numeric value as a result from the system is deemed as necessary (as for instance, arrangement and comparison). In these cases, after the fuzzy inference, a defuzzification process is necessary, that is, transform the linguistic values from their pertinency (Von Altrock, 1997) functions. Usually, the Maximum Center method to determine an exact value for the Exit Variable linguistic vector is used. From this method, the certainty degree of the linguistic degrees are defined as “weights”, associated to each of these values. The exact resolved value (RV) is determined by considering the weights in relation to the typical values (maximum values of the pertinency functions), in agreement with the definition of the Equation (Von Altrock, 1997)

$$RV=\frac{\sum_{i=1}^{n} DoC_i . X_i}{\sum_{i=1}^{n} DoC_i . X_i} \quad (4)$$

Where DoC represent the degrees of certainty of the linguistic terms of the final exit variable and X indicates the typical values for the linguistic terms that correspond to the maximums of the fuzzy sets, which define the final exit variable.

The results can be seen in Figure 7, extracted from the Neurofuzzy model, which associates the EVs with its intermediary and exit layers, by means of inference blocks, where the inference rules for each pair of the considered variables are contained. The result of each implementation is the (RDE), defined between 0 and 10, in an increasing scale according to the adequate decision-making in TTP, regarding benefits for performance. The (ERTTP) indicates choosing the best alternative to concentrate the endeavors in barriers in TTP. Meaning, that at first sight, it is vital to focus on monitoring the external ambient (Market and Politics), afterwards, the Technical and Economic and Financial issues (external ambient). It should be taken into account that comparison among variables should take place permanently and recurrently.

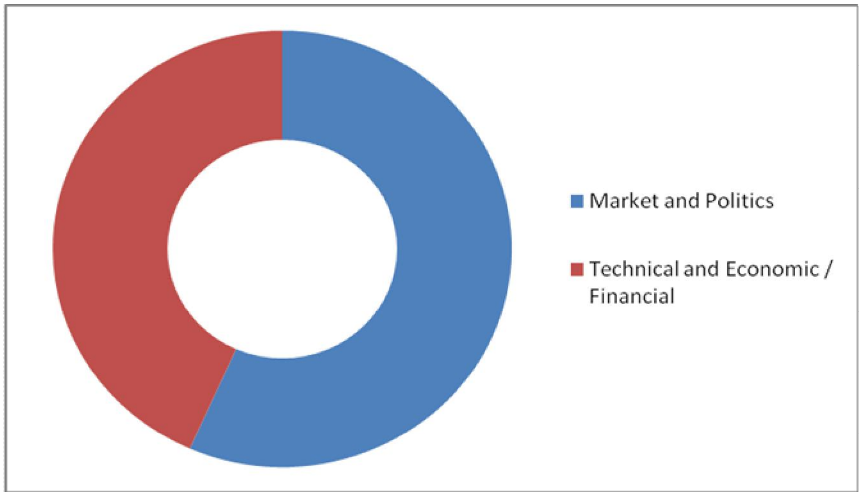

Figure 7: Effectivity Rate of TTP - ERTTP

Comparatively, the Market alternative demonstrated greater effectivity in the priority decisions of barriers in TTP. With regards to the Market and Politics variables, special attention must be given to TTP external variables. Allied to this, a space opens up to define the new managing strategies, while seeking to make the decision spectrum more intelligent. For decision choosing, the Neurofuzzy model is a more efficient instrument to compare options. From the association of intervening objective and subjective variables in the decision choosing process, through a hierarchic neural network using a fuzzy inference process to convert information, it is possible to generate a numeric value denominated Effectivity Rate in TTP. The greater the ERTTP, the more effective the chosen alternative for decision making for the situation hereby presented.

2. Conclusions and Implications

The present paper aims to contribute to the planning policy in technology transfer. To achieve that, it presents a multi-model proposal to assess the technology transfer process performance in high complexity spectrum in conditions of uncertainty and unpredictability. The model is simple, strong and has its basis on the factors that restrict the technologies transfer. The presented modeling proposal gains emphasis, for the diversity of methods combined is a valuable instrument and one of high potential and combined value of great span, contributing to the modeling strength. The research was oriented to the technologies transfer in high tech industries. Evidences for a successful TTP were produced in this study. The benefits derived from the transference of technology in the light of the empiric results imply in the creation of value to the business. This article presented a structure for decision taking which considers the variable of technology in the planning. It was possible to present an integrated and chained in the light of some technical implements. This research sought to expand previous researches that demonstrated that the technologies transfer aggregrates value to the business. From the analyzed theoretical excerpts, it was possible to identify 273 barriers, covering the period from 1750 to 2010. The data were filtered applying several filters and statistic treatments with multivaried analysis techniques. The political and market barriers are the most significant ones in the TTP.

The present work about TTP comes to an end, and hopes to have contributed for methodological discussions that need further investigation. Moreover, there is a need to understand TTP regarding social demands that are created within their appropriate social, economic and political context. And evidently many questions remain to be untangled in future studies of this type, specifically of planning in highly complex spectrum of, as the TTP.

From the many analyzed dimensions, the results show that there are no great predominances of one barrier or another, but it is right that those barriers when considered in a combined way (interactions) have a significant effect in the results expected by the companies, society and the country. Therefore, they are in the day order and should be taken as a priority of the moment, in the context of the systemic efforts guided by the definition and redefinition of new innovative project planning strategies in the long run. It is plausible to say that the impact of the barriers takes place during a continuous and dynamic process and converges to the desired profile, which is in constant transformation through new barriers that emerge in the long run in the TTP.

By this way, the management of technologies will have to be attached to an instrumental planning, seeking for quick answers to the challenges that arise in high complexity environments. It is also clear that the list of priorities of the identified and analyzed barriers in this research is dynamic. From the findings in the state of the art and results produced from this investigation, it is reasonable to say that this research is vulnerable to criticism. This study had a number of limitations, which also contributes to identify new research gaps and foster future studies.

The research sought to cover a broad spectrum of smples (1750-2010), which was very significant to the accuracy of the results reached. It is important to highlight that in spite of having a consistent sample, those are variables of qualitative nature and, therefore, involve a high degree of subjectivity and one that can increase the level of uncertainty in a certain way. It was a longitudinal application, which has become a trend to the reduction of the uncertainties inherent to the process of investigation. The technology had its basis on the knowledge applied to practical results, following the allignment of the mais theoretical excerpts. In this aspect, this research gains emphasis, for it was possible to materialize the concept of technology and contribute to trace a route for a project of transference of technology. It is recommended that this research is reproduced and duplicated broadening the number of specialists for higher accuracy in the results reached.

It is also important to reaffirm the importance of new applications in a permanent basis and recurring in the long run. From the findings derived from the research, the high technology industries bear with themselves quick changes, intense competition and highly uncertain and risky environment. It confirms the state of the art. Shanklin and Ryans (1984) suggest that high tech companies seek for technical and scientific that give quick answers to the existing techniques, allowing to attend the demands of markets to be built or altered. It is reasonable to focus the efforts on R&D, thus creating an internal stock of scientific knowledge, which enables the development and the introduction of new products, reduction of production costs, more competitive prices and a higher financial return. (KAFOUROS, 2008a, 2008b). This logic must be kept by opening more spaces for the many layers: partners, providers and clients. Be as it may, a project of transference of technology in high tech companies will have to be attached to an efficient planning policy. It is reasonable to say that the high tech industry in Brazil still have a long way ahead and a great potential growth. It is hoped that Brazil becomes a technological and competitive nation.

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