Leveraging and Challenging Factors in the Use of Technology Road Maps in the Context of Public Research Institutions

Lilian R. Laraia[1], Willy H. Sousa[2]
[1]Master Graduation Program at IPEN -University of Sao Paulo, Brazil
[2]Planning and Management Director at IPEN - Instituto de Pesquisas Energéticas e Nucleares, Brazil

Abstract--**Technology Plans (TP) can represent a significant challenge to the planning efforts of organizations. The most common problems are flaws in project forecasting, whether they are new products, services or processes. To perform this study, a unit analysis was selected for the survey and a data collection protocol was developed. A research – divided into phase 1 and phase 2 – was carried out in order to identify the factors that can influence the technology planning process. The first phase of the construction methodology of the current Technology Plan, which basically consisted of periodic meetings, was investigated. The second phase, the T-Plan methodology was considered and applied to the construction of a new technology plan, which resulted in a ten-year Technology Map. The factors investigated in both phases, were organized in dimensions (planning, development and implementation) that have been segmented into search variables (viability, commitment, communication, drivers, prioritization, monitoring guidelines, learning, revalidation, application and replication) . The process of elaboration of the TP was analyzed considering two perspectives - quality and satisfaction - according to the perception of the respondents, depending on the interview results, they were classified them as *leveraging* or *challenging*. The unit analysis was the Center for Hydrogen Fuel Cell - CCCH, a department of The Energy and Nuclear Research Institute (IPEN) located in Brazil. The factors that were analyzed were classified, in both phases, into: (1) Leveraging; (2) Potential Leveraging; (3) Potential Challenging and (4) Challenging. After the interview process and data analysis we found the following results: For the phase 1 as Leveraging factors: we found Commitment and Communication; as Potential Leveraging: Replication; as Potentially Challenging: Viability, Prioritization, Monitoring, Learning, Revalidation and Challenging: Drivers and Application. Unlike phase 1, in phase 2 all factors were classified as Leveraging, namely: Viability, Commitment, Communication, Prioritization, Monitoring Guidelines, Learning, Revalidation, Application and Replication. This study allowed us to conclude that by applying the T-Plan methodology there is a significant change from Challenging to Leveraging factors when changing from the traditional methology to the T-Plan methodology. These results allow us to conclude from the investigated case that the application of the T-Plan methodology is both viable and even recommended in the context of technology plans for research units of Public Research Institutions.**

I. INTRODUCTION

The technology management of organizations, whether public or private, is only effective in its function and results when an organization narrows the connection between the needs of the threads in which it operates and the products it offers. The effective integration of new technological fronts with strategic planning is an aspect of great importance to ensure the future performance of the organization in the segment in which it is in.

To Phaal et al, 2003 [1] the challenge for managers is the ability to, at present, justify which investment will be carried out to generate future results. This activity occurs based on three factors: strategic analysis, technical analysis and budgeting. Furthermore, to be convincing and correctly interpreted by the greatest number of people, transparency is essential throughout the process. All content should be very well structured to facilitate the alignment of new technology with the current organization context, considering specific and contingent factors.

In an environment of future decisions regarding current investments in human resources, equipment and materials for new technology projects, these investments are added to the package of tools used in the Technology Plans.

In General, Technology Plans - TP - are viable for the project planning of new technologies, but there are some possibilities of failure. The most common problems are flaws in the predictions for the projects regarding new products, new services or new processes. An example of these problems is when the technological direction of an organization submits deviations from its route, thus committing investments and resulting in reduced competitiveness for the organization and, consequently, loss of credibility in the planning tools and processes.

To address these factors, this paper presents a case study in the context of a public research institution seeking to identify which factors would have a positive influence, for the success of the process of drawing up a technology plan and what factors would have an opposite performance. These factors, once identified, were named as leveraging and challenging.

II. RESEARCH PROBLEM AND OBJECTIVE

The literature on the application of Technology Road Maps - TRM - which focuses on generating knowledge on the dimensions of technology, product and process in the context of private sector organizations is available and has been used with some ease. However, the same is may not be true for public research centers, especially in the developing countries, as the case investigated in this paper, because the maps generated by the organizations of this sector depict a demand for knowledge to solve Government problems and strategic guidelines and thus are not enough to be deployed in actions to identify the need for knowledge to support the processes aiming to generate knowledge, technologies, processes, or even new products in Science and Technology Institutes - CTI's.

Another factor that was also possible to identify during the preparation of TRM's, both for the public and the private sectors, was the lack of visibility and credibility of the tool stimulated by factors that are not easily identified and controlled, but that significantly influence the results.

The gaps were analyzed and they allowed us to identify how we can improve the methodology application process in the following contexts:

1 Although there is a significant amount of research that deals with technology route maps, most of them have dedicated their focus to companies, but not to the public sector. However, technology planning managers in the public sector have also actively discussed this tool in practice. There are large and recent public sector projects that have been created to carry out the development, in the long run, of the next generation of technologies related to energy, transport and sustainability. Public sector research and development conducted by the Government or by a research institute diverge from the private sector when it comes to the development of technology routes maps [2].

2 R&D in the public sector differs from that of the private sector in several ways. First, the public sector generally does not offer a product, implying that the structure of traditional script to perform the TRM is not suitable for the public sector. Secondly, most of the TRM ' s Public sector deals with social and technical issues, as they are required to satisfy public demands. R&D efforts, especially in developing countries, usually begin in the laboratories sponsored by the State, meaning that the Government's role is crucial. Finally, public sector technology roadmaps don't seem to have a single form, and are divided into many different types. Some scripts emphasize a vision, while others focus on action and strategy to be undertaken. Due to its heterogeneity, public sector technology roadmaps should be organized and categorized systematically to reflect their distinctive features [2].

Considering the lack of published studies on the application of TRM in the context of Brazilian public sector organizations, and with a view to a better understanding of the process of Technology plans, two main questions were formulated:

- How can technology routes maps be dealt with in the context of a public sector institution?
- What are the factors that can leverage or challenge the process of technology plans in the context of public research institutions?

III. LITERATURE REVIEW

Technology planning revealed itself as an effective and efficient process of creation and visualization of the relationships between technological demands, strategic planning and business plan of an organization. Its application as a strategic tool in organizations has the potential to promote the connection between tactical decision-making processes and various administrative functions through time [3].

According to Gehani, 2007 [4], a technology plan provides the alignment between production and operational resources for the launch of a new innovative product, with a strategic medium and long-term visions and requirements of the market sector where the organization operates. It also states that it aligns and builds connections between the technology and budgetary planning scenarios with the strategic vision of the organization. The technology plan involves multidisciplinary collaborative efforts of specialists.

To Phaal and Muller, 2009 [5], the approach of Technology Planning through Route Maps (TRM) and its many derivatives have become the most widely used management technique to support innovations and strategies of national and sector-level organizations. This approach initially developed for Motorola for more than 25 years has been adapted and adopted by many organizations, initially those technology- intensive ones in the fields of electronics, aerospace and defense, and then reaching other areas of the market.

The literature review allowed for the gathering of the largest number of characteristics and factors possible that can turn into leverage or challenge, which will collaborate with the success of the technology plans/maps. There are several applications of the use of TRM’s in the technology industry. Many National Research Laboratories made technology road mappings [6][7]. However, according to our literature research, it seems that strategic technology roadmaps produced by applying T-plan method were not often published; even they have been investigated, produced and used inside the house

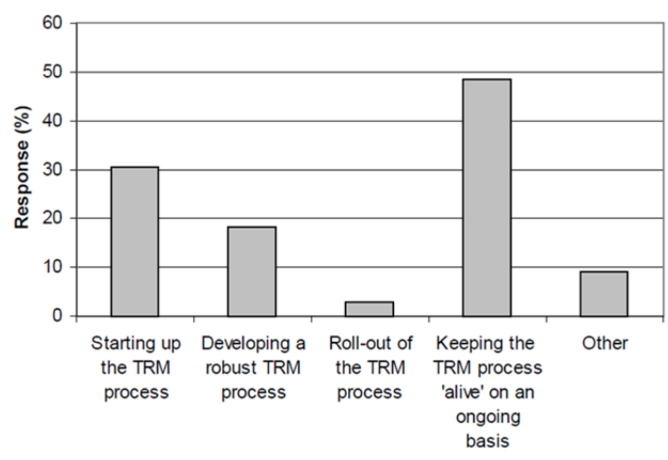


Figure 1: Key challenges for organizations applying the TRM

A research carried out by Phaal, Farrukh and Probert involving 2,000 manufacturing companies in England [8] indicated that 10% of the companies (mostly large enterprises) have applied the TRM, and approximately 89% of these companies have already used this technique more than once or continue using the same bases. However, the implementation of this approach presents considerable challenges to organizations when a structure and a simple concept are presented. The challenge for the success of the methodology is to keep the process alive and continuously updated by mapping its bases (which represents 50%), followed by starting the process (which represents 30%) and developing a robust method (which represents 20%) see **Figure 1**.

Other factors that contribute to a successful TRM are presented in **Figure 2.** Among these factors is the demand to include a clear and articulated need in the desire to develop effective administrative processes having the right people involved and the commitment of top managers.

The factors that may pose particular problems and difficulties for the TRM to be successful include unattainable initiatives, distraction of short-term objectives, information and lack of knowledge.

The entire value of the TRM can only be achieved if the information it contains is constantly updated as the events occur.

The main benefit of the TRM is to share knowledge and develop a common vision towards where the company is directing the technological path.

IV. METHODOLOGY

To obtain the answer for the main research question, we applied the methodology of TRM for TP's as a basis, as proposed by Robert Phaal and developed a research plan which consists of two phases: the first one aims to identify what factors play a role in the elaboration process of a conventionally devised technology plan – this is done without the use of the TRM; as for the second one, we identified and analyzed these factors in a technology plan drawn up by following Robert Phaal's methodology. The present work aims to report on the results achieved in the second phase implemented at the CCCH-Center for Fuel Cell and Hydrogen in 2013.

As it owns a technology plan and due to its easy access for both the leaders and researchers involved in this project, we have chosen the CCCH - Center for Fuel Cell and Hydrogen, the IPEN - Instituto de Pesquisas Energéticas e Nucleares – a Federal Institute that integrates the National Nuclear Energy Commission. This Center is focused on the development of technologies in the area of renewable energies and operates in R&D and technological innovation on fuel cells in order to contribute to the national development of the area. The technology research and development goals of the program/CNEN IPEN-SP are guided by the goals set in the Brazilian program of PROH2 fuel cells of the MCTI-Ministry of Science, Technology and Innovation. The IPEN/CNEN-SP actively participates in this program, acting in all networks created (PEM, SOFC and HYDROGEN systems) and technically managing one of signing SYSTEMS, along with FINEP's Covenant three networks: PEMFC, SOFC and systems, and the Covenant of creation of networks of the program.

There are more than 50 full time or part-time professionals, among whom we can find researchers, technologists, scholarship holders of scientific initiation, masters, doctors and post doctors. Six laboratories are in operation in R&D in the areas of polymer fuel cells (2), solid oxide (2), fuel cell systems (1) and the production of hydrogen (1). Eight graduate courses are taught; 10 master's degrees and 7 doctorates have been completed, and more than 30 guidelines are underway. The development results of the program have culminated in 11 patents filed and more than 50 publications in indexed journals, as well as in several participations in national and international events.

Figure 2: Success and barriers factors

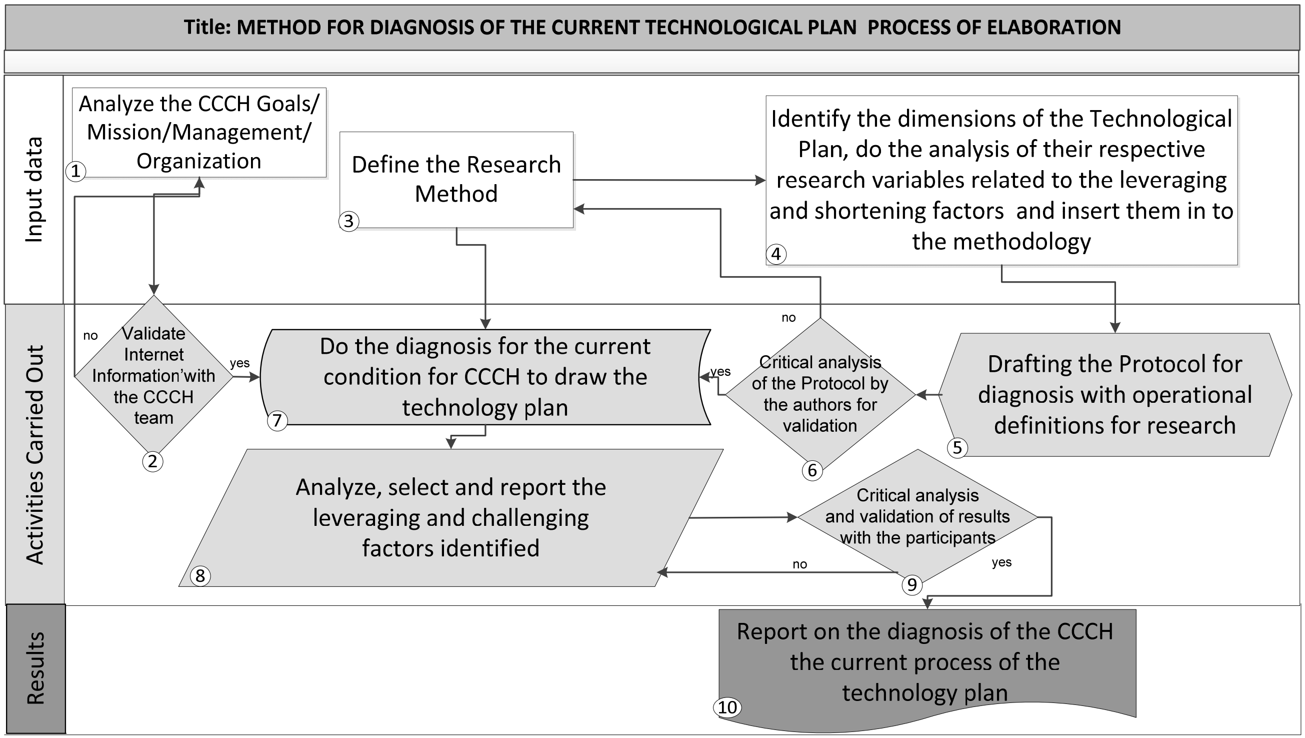


Figure 3: Methodology applied to diagnose the current process of the CCCH for the development of technology plan.

The first phase considered the current process to make the technology plan at CCCH – IPEN. According to our observation, it is conventionally drawn without many formalities. The methodology to determine the technological platforms, research lines, their projects of new technologies, resource demands, deadlines and budgets are tactically oriented by meetings with the leaders of the research groups, managerial meetings with the senior management and alignment with the strategic plan of IPEN, which strategically participates in meetings with the MCTI through the CGEE-Center for management and strategic studies for strategic policymaking in the industry.

The methodology and the flow of research developed for this phase of the survey are illustrated in **Figure 3**.

The flow shown in **Figure 3** describes the steps and activities of the methodology adopted in this research. It represents the diagnosis process to identify the leveraging or challenging factor for the current elaboration methodology of the technology plan.

The diagnosis process is executed in three layers. The first layer was named as "*Input Data*"; it is intended to survey the CCCH data. In the second layer "*Activities Carried Out*" - the methodology was applied and a specific survey was developed - protocol data. Then the data were processed and the leveraging and challenging factors were identified. The result of the critical analysis of these factors was presented in a specific report on a third layer called "*Process-Results*".

In the second phase of this research project, the elaboration of the CCCH Technology plan followed the T-Plan methodology, Phaal et al, 2003 [1]. Four workshops were developed: W1: Market; W2: Product; W3: Technology and W4: Map construction. The first W1 happened in November/2013 and the W2, in June/2014. There was a long interval between W1 and W2 due to the need of a data based analysis that was supposed to be completed before such analyses as SWOT, strategy, competitors position, among others.

Based on an adaptation of the methodology of TRM published by the *Depository Services Public Works and Government of Canada, Ottawa, Ontario Canada* [9] and by a *case Study developed by Nathasit Gerdsri, Ronald s. Vatananan, SasawatDansamasatid*" [10], we identified the dimensions and variables used to elaborate the technology plan factor analysis. **Table 1** presents the relationship between dimensions, variables, and basic research questions as the bottom line assessment that evaluates the position of the organization.

TABLE 1: DESCRIPTIVE TABLE OF THE DIMENSIONS AND SEARCH VARIABLES OF THE TECHNOLOGY PLAN

Technology Plan		
Dimension	**Search variables**	**Bottom line assessment**
Planning	1. Viability	Is there an active and functional process to create the technology plan to guide the research and development of future technology?
	2. Commitments	Is the technology plan followed up and periodically checked and adjusted?
	3. Communication	Is the technology plan followed up by a robust and systematic process of communication by the all stakeholders involved?
	4. Drivers	Are there strategic drivers to guide the technology plan?
Development	5. Prioritization	Is there any prioritization criteria and critical analysis of the portfolio or a list of selected technologies to be developed?
	6.Monitoring Guidelines	Are the leaders coordinating (monitoring, measuring and performing) actions to achieve the desired results by the technology plan?
	7. Learning	Are the leaders and stakeholders developing a strategy for the continuous improvement of the technology plan and encouraging actions that require subsequent iterations?
Application	8. Revalidation	Are the leaders establishing processes and guidelines to define the respective critical milestones to implement and monitor the plan?
	9. Application	Are the leaders helping to solve problems, coordinating efforts and promoting policies, priorities and direction for the technology plan?
	10. Replication	Are the leaders and researchers using the results and other benefits to improve the technology plan elaboration and to stimulate other areas to carry out this process and thus develop subsequent strategic actions?

Once the technology plan was built, based on the T-Plan Methodology, the participants of the process were invited to evaluate the experience according to two attributes:

- **Quality**- as a dichotomous variable defined by the presence (yes/no) and formality (formal/informal) of an specific variable under investigation. Quality is a subjective concept and is related directly to each individual's perceptions for these two reasons, the questions are designed to obtain dichotomous responses. This criteria is determined by the answers to the questions of substance of each variable. The quality of the technology plan is considered "Good Quality" when the search variable is present and if there is some sort of record (formal) and is considered "Poor Quality" when these two aspects are absent. It is also considered a "Not Formal" and "No Protocol" when the presence of the search variable is not detected and when the variable Protocol is present, respectively. The result was evaluated on the basis of the quadrant with the highest number of votes allocated by each researcher for each variable of research.
- **Satisfaction** - as a gradual variable. The satisfaction attribute allows us to reach the contentment level results of the investigated variable, both for the current condition and for the desired condition. It evaluates the product, service or process to designate a logic variation. It is measured by the use of sorting tables where people answer a report. The rate of satisfaction is measured on scales of 1-5 (where 1 represents "not at all satisfied" and 5 represents "extremely satisfied"). It was evaluated in current and desired conditions. The result was evaluated by the averages of the scores obtained from the interviews for the current and desired conditions for TP's elaboration

V. ANALYSIS OF THE RESULTS

A. Results For First Phase

The results of the interviews were analyzed for each researcher individually as well in groups.

1 Attribute Quality

In Figure 4 the results considering the votes of all participants are presented.

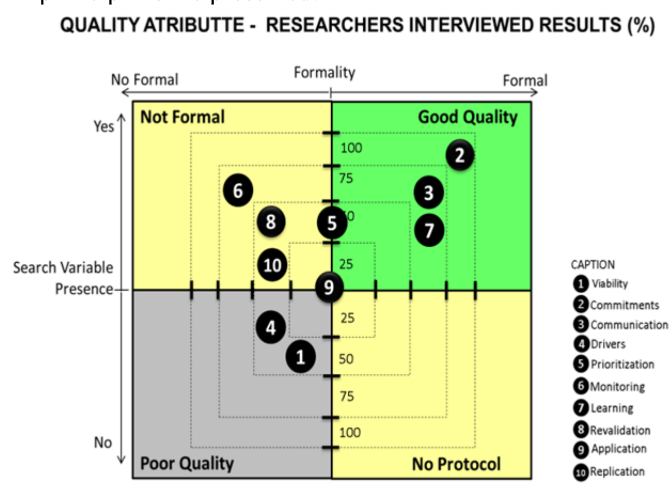


Figure 4 - Result of the votes of the researchers for the quality of the elaboration process of the technology plan

The analysis of these results led to the following discussion:

- 100% of the votes in good quality for "Commitment"
- 75% of the votes in good quality for "Communication" and "Learning".
- 75% of the votes in not formal for "Monitoring".
- 50% of the votes in the middle term between not formal and good quality for "Priorization".
- 50% of the votes in poor quality for "Viability".
- 50% of the votes as inadequate quality to the "Drivers and Replication".
- 50% of the votes in not formal for "Revalidation".

Dimension	Search Variable	Current Medium	Current Standard Deviation	Desired Medium	Desired Standard Deviation	CHANGE Desired	Standard Deviation Added
Planning	1. Viability	3,5	1,2910	5	0,000	1,50	1,2910
	2. Commitments	4	0,0000	4,25	0,500	0,25	0,5000
	3. Communication	4	0,0000	4,25	0,500	0,25	0,5000
	4. Drivers	3,25	2,0616	5	0,000	1,75	2,0616
Development	5. Prioritization	4	1,1547	5	0,000	1,00	1,1547
	6. Monitoring	3,5	0,5774	5	0,000	1,50	0,5774
	7. Learning	3,25	0,5000	5	0,000	1,75	0,5000
Application	8. Revalidation	3,5	0,5774	4,75	0,500	1,25	1,0774
	9. Application	3,5	1,0000	4,5	1,000	1,00	2,0000
	10. Replication	4,25	0,9574	5	0,000	0,75	0,9574

Figure 5- Data processing from the interview answers

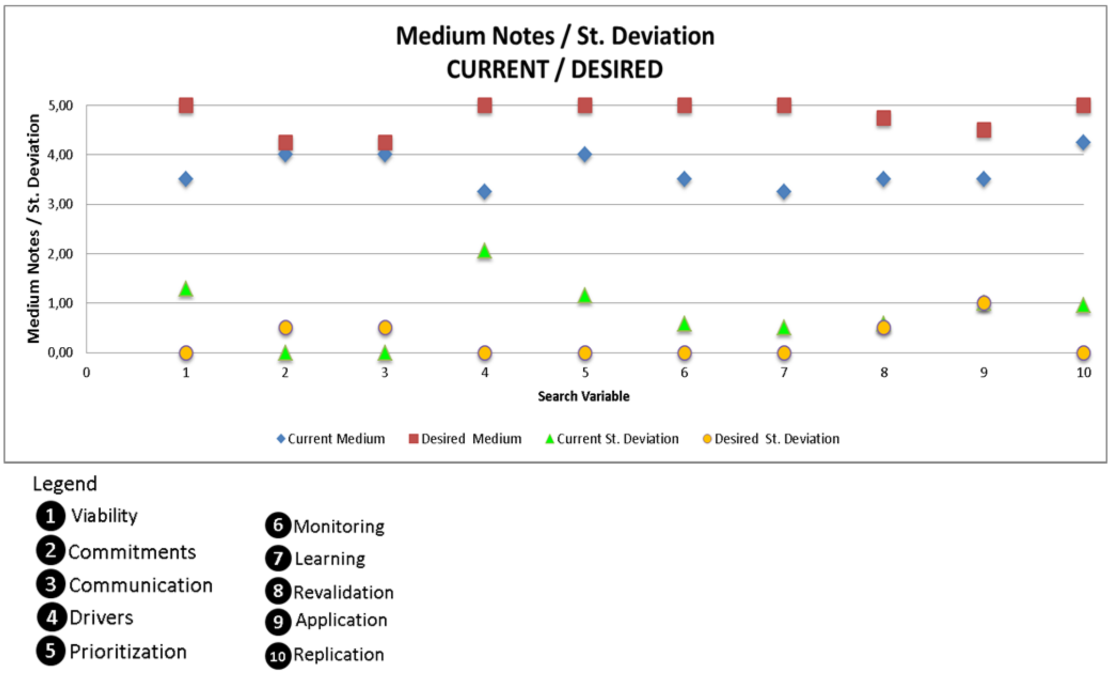


Figure 6- Scatterplot of the averages of the grades and the standard deviations for the 10 variable searches

- 25% of the votes in the middle term of formality and quality for "Application".

2 Attribute Satisfaction :
The criteria considered for Satisfaction are:
Figure 5 presents the results for the averages of the score from the researchers interviewed and their standard deviations. In this figure, the results considered the current and desired conditions. And in the **Figure 6** there is a scatterplot of the averages of the scores and the standard deviations for the 10 search variables

The critical analysis of the results led to the following discussion:

- To express the size of the variation or "dispersion" in relation to the average we use the standard deviation for the analysis of the result.
- A low standard deviation indicates that the grades assigned by researchers tend to be close to the average; a high standard deviation indicates that the data is more distributed.
- The averages of the values of satisfaction for all variables are above 3 (average value of the scale), both for the current condition as for the desired condition.
- There are higher values of the standard deviation for the current condition in the "*Viability*" research variables and "*Drivers*", expressing the greatest breadth of opinions among respondents in this case.
- When comparing the variations of the averages of the desired and actual grades that there is an expectation of improvement for most search variables. The exceptions are for commitment and communication variables, which confirm their satisfaction for these two variables.
- For variables with standard deviation in current condition above 1 ("*Viability, Drivers and Application*"), we understand that there was significant variation of opinion among researchers. Special mention to the search variable "*Drivers*", because it showed the highest dispersion

between the opinions of researchers, i.e. standard deviation equal to 2.

- The desired condition showed standard deviation less than 1 for all research variables, so there is uniformity in the expectation of improvement on process variables in the technology plan.
- The analysis of the variations of the standard deviations for each variable allowed us to verify that, in addition to the occurrences of standard deviations with greater dispersion and others with less dispersion, there were deviations with intermediate values that have potential to become larger or smaller.

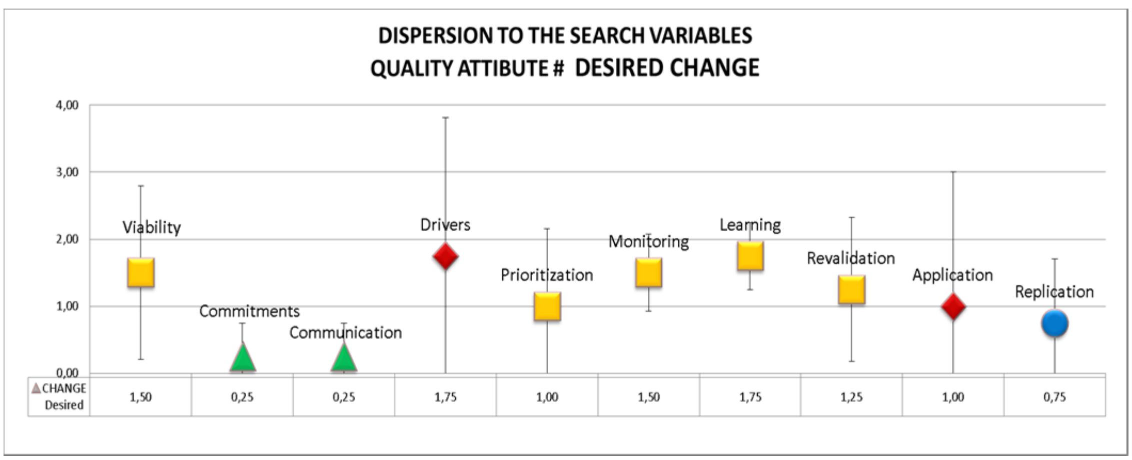
Factors that may Leverage and/or Challenge during the TP construction -Variable Resulting

Evaluation criterion of Leveraging and Challenging Factors:

- The attribute Satisfaction was defined from an expectation of quality of researchers in relation to the process variables.
- The factors Leveraging and Challenging were identified based on the variance between the current x desired score for the attribute Satisfaction.
- To determine the classification of the factors we consider the starting point defined for Satisfaction based on continuous scale, for the differences between current and desired averages of each variable of research, so that the total range is 0 to 4.
- Then we have the following distribution of the factors (F) on which the classification is made based on the greatest distance, i.e., in the worst case of uncertainty (higher standard deviation).
- F = factor to be defined as leveraging or challenging
- Whereas the shortest distance between the current condition and the desired condition represents the lower difficulty of the question by the Satisfaction research variables technology plan and, as part of the variations of Satisfaction above, we have that:
  - If $0 \leq F < 1$ (F is a leveraging factor)
  - If $1 \leq F < 2$ (F is a potential leveraging factor)
  - If $2 \leq F < 3$ (F is potential challenging factor)
  - If $3 \leq F < 4$ (F is challenging factor)
- **Figure 7** graphically represents the dispersion to search variables in Leveraging and Challenging Factors and **Table 2** presents its classification. It considers the classification of factors to the question Satisfaction for the desired change.

TABLE 2 – RESULTS OF THE SEARCH VARIABLES, CLASSIFICATION BY SIZE, LEVERAGING AND CHALLENGING FACTORS

Technology Plan		
Dimension	**Search variables**	**Factor Classification**
Planning	1. Viability	Potential Challenging
	2. Commitment	Leveraging
	3. Communication	Leveraging
	4. Drivers	Challenging
Developing	5. Prioritization	Potential Challenging
	6. Monitoring	Potential Challenging
	7. Learning	Potential Challenging
Application	8. Revalidation	Potential Challenging
	9. Application	Challenging
	10. Replication	Potential Leveraging



Caption:

Challenging: Drivers and Application

Potential Challenging: Viability, Prioritization, Monitoring, Learning and Revalidation

Potential Leveraging: Replication

Leveraging: Commitment and Communication

Figure 7 - Classification of search variables in Leveraging or Challenging Factors based on greater distance in the worst case of uncertainty the standard deviation is higher.

B. Results For Second Phase

As a result of the effort for the development of the technology plan for CCCH it was possible to obtain the TRM for CCCH, as illustrated in **Figure 8** below.

It is structured in layers that have followed the guidance of Phaal et al, 2001 [11], with minor adjustments for application in the R&D area from the public sector.

The first layer of the map is dedicated to internal and external strategic drivers. For the private sector, the external drivers are generally customers, competitors and perceptions of senior management, or market area. However, the CCCH, a unit of a public research institute, the external drivers are related to Brazilian public policies from the MCTI – Ministério da Ciência, Tecnologia e Inovação and MME – Ministério de Minas e Energia, governmental and development lines in lower demand areas of R&D of other institutes, or even private companies. In **Figure 8** one can see TRM, the demand for clean energy generation that does not cause the greenhouse effect, as well as the nationalization of fuel cell components and the composition of the energy matrix, as the main drivers that determine the investments in R&D for the selection of projects to be carried out over the next 10 years by the CCCH.

Other items to be highlighted in the analysis of the Roadmap of the CCCH regard the Internal Drivers. For the R&D areas of the private sector the technology demand comes, in most cases, to satisfy the increased revenues or the cost reduction aiming to increase the competitive advantage. In the public sector, science is present to generate knowledge, human resources capacitation and IP - Intellectual Property - continuously; the letter ' P ' on the map means that this is permanent.

For the product line, the main objective is to get a low-cost prototype for a certain niche application by 2024 and so achieve the internal goal and a broader participation of the fuel cell in the energy matrix, with the caveat that this step will not allow the CCCH to produce fuel cell for the consumer. This moment is the point where the production's mission seeks another entity to invest capital in serial production. The greatest paradigm-breaking moment in the technological process occurs in the five-year Milestones, when technological change turns into a new concept of fuel cell fuel by making the product more robust and competitive in the market.

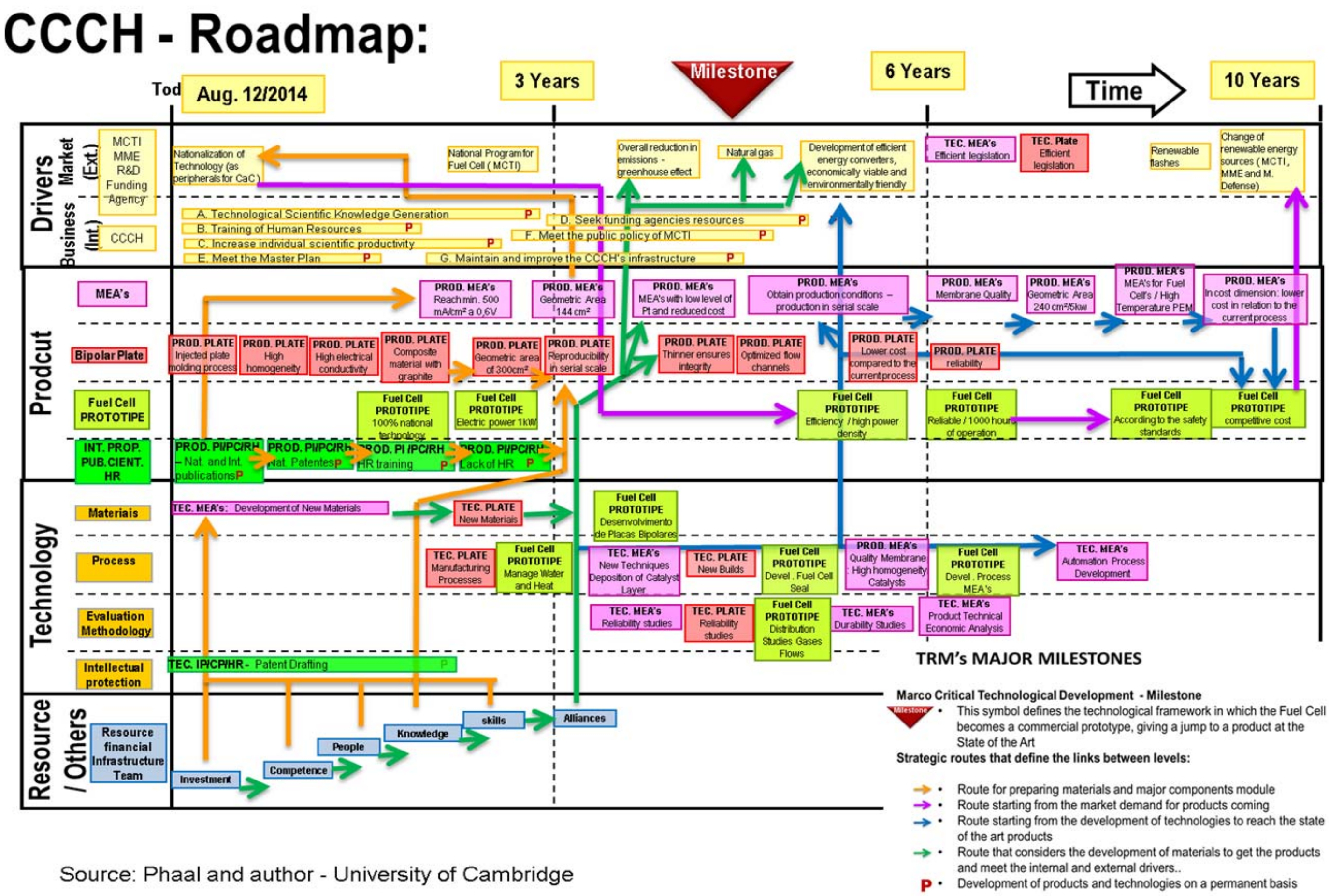


Figure 8- CCCH Technological Road Map
Source: Own elaboration

The issue of partnership with Electrocell for the production of bipolar plate, one of the components of the fuel cell, presents a situation that deserves to be highlighted because, right now, it acts on a map as a client and as a supplier. This proximity greatly facilitates direct communication which provides a more direct and quick relationship.

The prioritization of projects and technologies held during the Workshop 2 and 3 reduced the time for this kind of activity and helped to choose the best technological routes that were set into the following fronts:

- the orange route, which focuses on the development of technology for the production of membranes MEAS, as it has 1 or 2 items that drive up the cost of the final product.
- the green route was mapped out seeking alliances, resources and partnerships for the development of devices and molding techniques and materials, with the aim of accelerating the pace for the race of the launch of the new product.
- the blue route has a focus on the development of the processes to obtain the products.

The most important fact of route design is that it is built and viewed by the coaches and managers during Workshop 4 when the dynamics of the construction of the map are being developed.

The great advantage of technology planning using this methodology is the high level of communication and alignment between the participants to reach the common goal in the end. The presentation of the Map TRM (Technology Road Map) is a management and communication process among those involved.

The identification of leveraging and challenging factors is presented below. It represents phase two of the survey, considering the results of the interviews and individual analyses for each of the researchers and in groups:

1 Attribute Quality

The quality criteria considered the presence or not for each search variable (yes or no), as well as its formality (formal or not formal). **Figure 9** shows the results obtained by considering the set of all participants:

RESEARCHERS INTERVIEWED RESULTS (%)

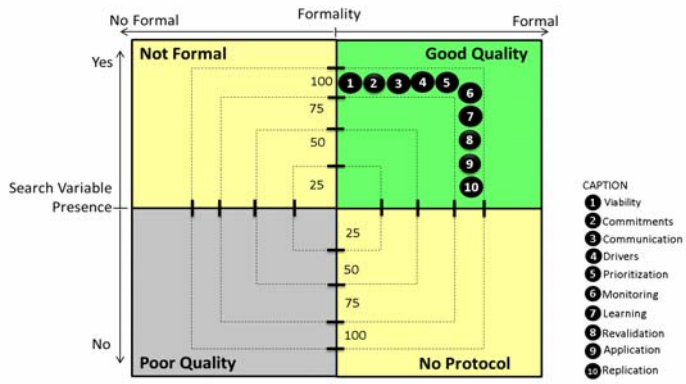


Figure 9 – The results of the votes from the researchers for each variable of the dichotomous variables research the quality regarding the elaboration process of the technology plan.
NOTE: 100% of the grades in quality are suitable for all search variables
Source: Own elaboration

2 Attribute Satisfaction.

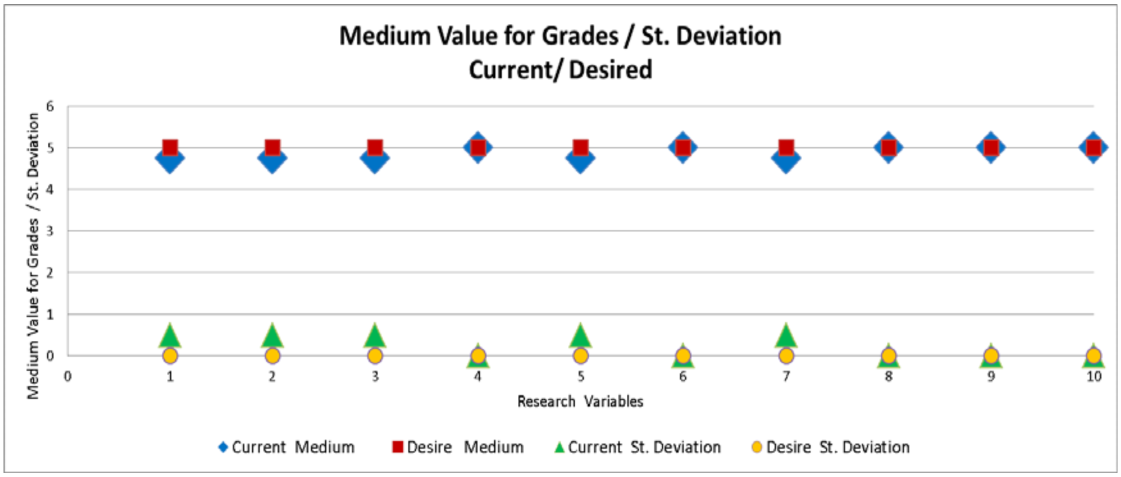
The quality criteria and scale of the satisfaction variable from the researchers' interviews answers considered the current and the desired methodology for the Technology Plan elaboration. The quality result for each search variable was determined by the median and standard deviation answer of all interviews.

Figure 10 presents the result for the average grades of the researchers interviewed and their standard deviations. For both scoreboards were considered the current condition and the desired condition were considered.

The graphs of **Figure 11** present grade dispersion averages and the standard deviations for the 10 search variables.

Dimension	Search Variable	Current Medium	Current St. Deviation	Desired Medium	Desired St. Deviation	Changge Desired	Standrard Deviation Added
Planning	1. Viability	4,75	0,5000	5	0,000	0,25	0,5000
	2. Commitments	4,75	0,5000	5	0,000	0,25	0,5000
	3. Communication	4,75	0,5000	5	0,000	0,25	0,5000
	4. Drivers	5	0,0000	5	0,000	0,00	0,0000
Development	5. Prioritization	4,75	0,5000	5	0,000	0,25	0,5000
	6. Monitoring	5	0,0000	5	0,000	0,00	0,0000
	7. Learning	4,75	0,5000	5	0,000	0,25	0,5000
Application	8. Revalidation	5	0,0000	5	0,000	0,00	0,0000
	9. Application	5	0,0000	5	0,000	0,00	0,0000
	10. Replication	5	0,0000	5	0,000	0,00	0,0000

Figure 10 -Data Processing-Interviews
Source: Own elaboration



Caption: Search Variables: 1. Viability / 2. Commitments / 3.Communication / 4.Drivers / 5.Prioritization / 6.Monitoring / 7.Learning / 8.Revalidation / 9.Application / 10.Replication

Figure 11- Scatter plot of the grade averages and the standard deviations for the search
Source: Own elaboration

The Satisfaction evaluation shows that the opinions converged into a high degree of satisfaction with the new Technology Plan construction process to achieve the maximum value. The desire to improve is aligned with those involved in the process.

Factors that may Leverage and/or Challenge during the TP construction -Variable Resulting

Evaluation criterion of Leveraging and Challenging Factors:

The interview results for the search variable were classified into Leveraging and Challenging Factors depending on the 'distance' between the current and the desired grade value for the satisfaction rating according to the respondents. In the light of the results obtained two new 'sub-category' results were identified: "Potential Leveraging" and "Potential Challenging", as will be explained below.

To determine the classification of the factors, the starting point defined for satisfaction was considered, as mentioned on Page 8 of this article, and the tracks were laid down, on a continuous scale, for the differences between the current and the desired averages of each variable of research, so that the Total Range is 0 to 4. Then the following factor distributions were devised based on the greatest distance, that is, in the worst case of uncertainty (standard deviation).Then we have the following factor distributions on which the classification is made based on the greatest distance, i.e., in the worst case of uncertainty (higher standard deviation).

- F = factor to be defined as leveraging or challenging
- Whereas the shortest distance between the current condition and the desired condition represents the lower difficulty of the question by the Satisfaction search variables technology plan and, as part of the variations of the Satisfaction above, we have that:
- If $0 \leq F < 1$ (F is a leveraging factor)
- If $1 \leq F < 2$ (F is a potential leveraging factor)
- If $2 \leq F < 3$ (F is potential challenging factor)
- If $3 \leq F < 4$ (F is challenging factor)

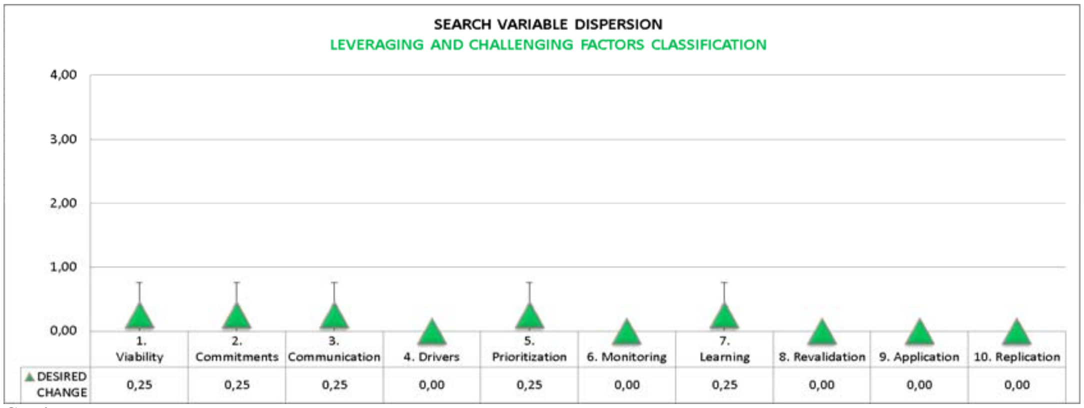
The **Table 3** presents the search variables and its factors classification and **Figure 12** graphically represents the dispersion to search variables in Leveraging and Challenging Factors. It considers the classification of factors for the Satisfaction for the desired change.

Resulting Variable - LEVERAGING AND CHALLENGING FACTORS - Tracks

TABLE 3 – RESULT OF THE CLASSIFICATION SEARCH VARIABLES, RESULTING IN VARIABLE LEVERAGING AND CHALLENGING FACTOR

Technology Plan		
Dimension	**Search variables**	**Factor Classification**
Planning	1. Viability	Leveraging
	2. Commitment	Leveraging
	3. Communication	Leveraging
	4. Drivers	Leveraging
Developping	5. Prioritization	Leveraging
	6. Monitoring	Leveraging
	7. Learning	Leveraging
Aplication	8. Revalidation	Leveraging
	9. Application	Leveraging
	10. Replication	Leveraging

Source: own elaboration
NOTE: 100% of the votes for the factors are classified as Leveraging



Caption:

Challenging:

Potential Challenging:

Potential Leveraging:

Leveraging: Viability, Commitment, Communication, Drivers, Prioritization, Monitoring, Learning, Revalidation, Application and Replication

Figure 12 - Classification of search variables in Leveraging and Challenging Factors based on greater distance - in the worst case of uncertainty (standard deviation)
Source: Own elaboration

VI. CONCLUSION

Based on the results of the present study, it was concluded that the methodology we researched, developed and applied to build a Technology Plan for a Research Institute allowed us to identify the leveraging and challenging factors with success, for both of the process in use first phase – current processes and second phase by adopting the T-Plan methodology [11], but customized and applied for the first time to a Research Center (CCCH-fuel cell Centre of IPEN).

The evaluation of the factors that can influence the development of a technology plan considered three large blocks of the T-plan methodology: planning -, development and implementation activities considering their respective search variables (viability, commitment, communication, prioritization, monitoring guidelines, learning, revalidation, application and replication) as shown in **Table 3**. The classification of these factors as leveraging and challenging was possible with the numeric result generated by interview answers, considering the values obtained for the attributes of quality and satisfaction, both individually and in the relationships between them.

The prominent conclusion is that the kind of assessment adopted in the present study allowed determining potential leveraging and challenging factors that can affect a technology plan elaboration process. By identifying such factor, it is possible to generate actions to turn them into facilitators, minimize them or dispose of them at a time that is more convenient to the process and the organization.

The elaboration process of the technology plan based on the T-Plan methodology proposed by Phaal and Muller, 2009 [5], proved to be effective for the Public Research Institute we investigated.

The first phase of the T-Plan methodology, which deals with the identification of strategic positioning, was of vital importance to the development of the case study of the Public Research Center CCCH, once the model reflects the benefits of these research center interactions with partners who demand technologies to be developed. At this point, we identified a significant difference when applying this methodology to a Public Research Institute and businesses in general: in the private sector, it is very clear who the claimant is, how this technology will be applied and what result is expected. While such factors are not evident in the public sector, it was exactly at this point that the methodology contributed significantly to the technology planning process. The methodology provides the process flow with specific reflection time that allows for the development of new technology and what is expected to meet the need of those who will make the most of this benefit. The reference considered here is "Workshop 1 - Market", because at that stage there is reflection and an analysis of the factors, and the characteristics and activities are influenced by the technology planning.

Although the authors of the T-Plan methodology suggested the use of this methodology in enterprises and organizations in the corporate environment [5], we identified that it is possible to apply this methodology to a Public Research Institution by means of adjustments and more flexible arrangements, such as the ones we made for the first workshop of the process, which is market oriented, herein understood as an organism that demands and supplies technologies that need to be developed.

It was also essential that the research team recognized the lack of prior knowledge of business strategy and organization, and this fact was very well identified later [12].

Aware of this possibility, several meetings took place with the group for its strategic position in the Organization, through the identification and prioritization of the driving forces and segments, as well as SWOT analyses (strengths, weaknesses, opportunities and threats) to draw a competitive positioning analysis and perform the proposition of creative solutions, aiming to achieve the objectives of this research. Certainly, these proposed solutions must be carefully checked with regard to the reality of the facts of the CCCH.

By applying the methodology T-Plan, it was possible to identify sensitive change of evaluation in leveraging and challenging factors related to the methodology applied to phase 1 of this research. This fact demonstrates that the search variables for the analysis of quality and satisfaction had significant variations regarding its contribution (as leveraging or challenging factors) for the technology plan. This conclusion is based on the following items for the T-Plan methodology:

- The process of realization is simple to understand and to put into practice;
- The format of the Map Technology provides greater time-driven visibility for the management and, thus, those involved can participate and interact more frequently;
- The presentation of the Map makes it explicit what the CCCH wants to reach and what the key strategic drivers, milestones, goals and deadlines to be achieved are;
- The Map is a flexible tool in the application, and may be suitable for other research centers of IPEN;
- Engagement of those involved in the plan, since they were the ones who built the Map;
- Simple Prioritization and objective criteria;
- The T-Plan allows participation of all those involved and encourages the necessary adjustments over the time;
- The Map allows the monitoring of the research progress over time;
- The great benefits of the process of creating a technology route map is to involve and bring the various stakeholders of the Organization together and, by means of joint sectoral guidelines, establish reflections and technological policies in order to increase the competitiveness of the sector. Phaal, Farruckh and Probert recommend that the participants of the workshops include technical and commercial functions (such as research and development, manufacturing, marketing, finance and human resources) [1].

This methodology allows their managers to map the prioritization and the adoption of strategic actions in short, medium and long term, in order to generate product solutions that are innovative and competitive for customers and end users. More than applying it to a particular scope, the analysis method and the tools used can be employed in studies applied to other technological aspects, or other branches of technology, thus proving the utility of this research in the academic field, especially in the area of innovation management.

Some limitations to the results of this research need to be pointed out:

1. This study considered the search variables identified in the elaboration process of the technology plan. It was developed by taking into account the guidelines of the Canadian s/d rear shelf, Evaluating Technology Road Maps. The Framework for Monitoring and Measuring Results, which suggests three dimensions or phases: the first one being the planning that reflects the considerations, expectations, communication and commitments; The second one regards the development of the use of the tool in the map elaboration process, identifying issues with monitoring, iterations generation and subsequent learning; The third and last objective deals with the dimension to adopt the methodology routinely, sustainably and broadly. Future studies could consider other variables external to the process that can also be evaluated as leveraging and challenging factors in mapmaking the technology route.

2. The methodology describes that different stakeholders should be responsible and attend the workshops, but for this case study, only two of them participated. During the development of the case study, the manager was promoted to Director and a researcher was promoted to Manager. Therefore, the hierarchy changed during the interviews, but all of them continued participating. In the end, there were three hierarchical levels: researchers, managers and director.

3. The phase 1 evaluation process took way much longer to complete when compared to the time it took to be elaborated.

4. Workshop 1 – Market took place from November 6th to November 8th, 2013, while Workshop 2 - Technology took place on June 26th, 2014. During that interval, such materials as SWOT, competitors, customer and supplier analyses needed to be prepared. As this plan was evaluated under the effect of its results, it is possible that a delay might have adversely affected the elaboration process. Consequently, there was a seven-month gap between Workshop 1 and 2; that is, the time span was so great that the results achieved needed to be remembered and discussed, thus jeopardizing Workshops 2, 3 and 4. This problem does not happened for Workshop 3 and 4, because they took place respectively in August 5th, 2014 and in August 12th, 2014.

5. Not everyone was able to attend the meetings and the workshops together, so, in this case, coworkers had to be called in for discussions and controversial issues to align different viewpoints and add four new items that had been previously discussed without everyone's participation.

6. The results of this research in relation to methodology (factors, quality and satisfaction) are limited to the CCCH. Soon, studies in other research environments need to be developed, in order to provide an external validation of these results concerning methodology.

Despite those limitations, the results herein identified conclude that, from the case investigated, not only is the application of the methodology of the T-Plan viable, but also recommended in the context of Technology Plans in public research institutions.

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