Design of a Methodology for Measuring Technology and Innovation Management on Research Units

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Abstract--**This initiative proposes a new tool to measure and diagnose technological and innovation capabilities on research groups, based on an existing tool actually being applied to companies. This new option includes important deep-in changes, adapting the language according to the idiosyncrasy of research personnel and institutions.**

Literature research showed a lack of methodologies that apply directly to research units. After re-design, the developed tool was applied to three research groups/units in a private Colombian University, with interesting findings about strategic thinking, productivity and the group's human and organizational integration.

I. INTRODUCTION

The majority of applied research groups in Colombian Universities are not prepared to meet companies' needs, making even more difficult to establish a natural technology transferring process. Culture, market knowledge, infrastructure, enough human resources are sometimes missing from the scope from the research side. Consultancy companies are centering their efforts on improving technological and innovation managerial skills on big sized enterprises with wide possibilities to make their own research. Small and medium sized companies however, do not have enough resources for research, development and innovation. The ideal Innovation system relies on Universities' capabilities to develop new technology and transfer it for commercialization purposes, but research groups in Colombia are just beginning to talk about technology transfer and research results commercialization and are not prepared to meet real sector necessities.

A Colombian Ministry decided in 2011 to make a technology and innovation capabilities diagnostic for both companies and universities. The Technology Transferring Offices (TTO) of each university were provided with a Technology Management Matrix (TMM) developed by Zartha J.W & Quintero S. [1], which fitted perfectly for companies, but made no sense for research groups.

Some examples of the questions asked to the research groups are stated in Table 1, and give into account that the language used made it difficult for research units to answer.

TABLE 1. EXAMPLES OF QUESTIONS STATED IN THE ZARTHA & QUINTERO'S TMM ENTERPRISE TOOL

QUESTION	1	2	3	4	RESULT
TECHNOLOGICAL PROFILE					
About the management technologies, the company has implemented in the last year:	No managerial technology has been implemented	Quality management and/or continuous improvement (TQM, BMP, HACCP)	ISO 9000, ISO 14000, OHSAS	Prospective, scenario planning, EVA	
From the crosscutting technologies acquired, how has been its contribution to profitability?	There has been no contribution	There has been low contribution	They have contributed significantly	They have greatly contributed	
Which technology has contributed to increase the sales percentage	None of them	Basic technology has contributed to sales increase	Emergent technology has contributed to sales increase	Key technology has contributed to sales increase	
INNOVATIVE PROFILE					
The company has invested in technology innovation (product/service or process) for:	Increase labor productivity	Increase in the capital productivity	Reduce the percentage of returns	Increase product quality and perceived value, reflected in a social and economic impact for the customer and the organization.	
The process of new product development/service process involves:	Production Area	Marketing Area	Production and Marketing	Production, marketing, R&D, quality control	

Problems during the interviews were, for example, that research groups don't manage information about profitability of the institution they belong to. They also are not aware, or are little involved, on managerial technologies. That kind of information is handled by other research support areas of the institution, leading this to the fact that there are always different instances for the technological and innovation management of research groups.

Another type of problems arose when they were asked about "sales", "marketing" and its relation with technologies acquired or new product development, given the condition that research groups in Colombia are not yet prepared to relate these concepts due to their low commercialization capabilities.

Other complains came up because of the time spent in the diagnose, because the structural analysis was done using Godet's Crossed Impact Matrix (MICMAC) method, in which the development of the matrix was long and exhausting for the consultants and the researchers.

In accordance with Technology Management Policy Research group from the Universidad Pontificia Bolivariana (UPB), who applied the same tool, it was agreed the conclusion that the tool required adaptation of its methodology and orientation of the questions for a successful application in academic and research environments.

II. THEORETICAL FRAMEWORK

The term "entrepreneurial university" which refers to an academic revolution, makes a transition for the concept of universities from a research environment to one entrepreneur or corporate. Given the above, it is clear that the research groups currently are operated by both public business and private entities that seek to profit from the work of these groups, and thus the research groups are defined as "quasi - firms", as stated by [2]: "Some research groups operate as businesses similar organizations, only to lack from the need to generate "profits". The trend of research groups worldwide is the orientation towards the expansion of academic entrepreneurship, i.e. towards organizational growth that directly impacts the regional and national strategy for social and economic development." [2]

There is little or no literature related with general diagnose of research groups, and scarcity of tools to measure multi dimensional criteria. The Rathenau Institute, published in 2012 the results of two research and assessment projects for research diagnosis, however, they were focused mainly on measuring leadership in research groups [3] and its comparison to high performing research groups [4], leaving aside other criteria within the infrastructure of knowledge and innovation generation.

In accordance to this context, arises the problem that measurement of innovation in research groups is very low, at least at the Colombian national level, because strategies have focused on the management of R+D [5]. There is actually a need to create and implement methodologies that deliver both clear and precise quantitative and qualitative indicators that reveal the degree of innovation management of a particular research group. A couple of important elements to consider in implementing this methodologies are a) the amount and b) the quality of the technological products produced by the groups, quality being the most significant and whose measure can be calculated accurately using models or stylized features of research productivity [6].

III. PROBLEM

Currently the TTO's and research management departments of universities and research Colombian centers, among others, lack of effective tools to map the variables of technology management and innovation in research groups, so that the supply and demand of research, development and innovation management are carried out in a controlled and efficient manner [5]. These entities work with empirically developed models, which obey to a business-need demand, which generally occur when the researcher directly makes contact and negotiates the scope of the project on his own or pushes from projects funded internally by the university [7], leaving the TTO's offices with the responsibility to "straighten" the process through ex-post intervention towards an appropriate innovation management for the product obtained.

The TMM systems to find industrial profiles and technological innovation inside enterprises have been extensively studied [8] and are constantly used in the practice of innovation management for production units in traditional economic sectors. However, when it comes to research groups, it is not possible to apply the same matrix, because the particularities of a research group are very different from one economic unit based on products or services. These groups focus on knowledge generation and technology development in different areas of research and live within a body of higher level (Higher education institutions, research institute or center).

Zartha J.W & Quintero, S [1] developed a TMM used to identify technological and innovation capabilities in companies. The developed tool in this project is not limited only to measure technological and innovation capabilities of the group, but also to increase merits valuation in order to improve the possibilities of better financial leverage for research projects [6].

The problem tree shown in Fig. 1, identifies a missing management technology and innovation methodology that serves to diagnose research groups in Colombian universities.

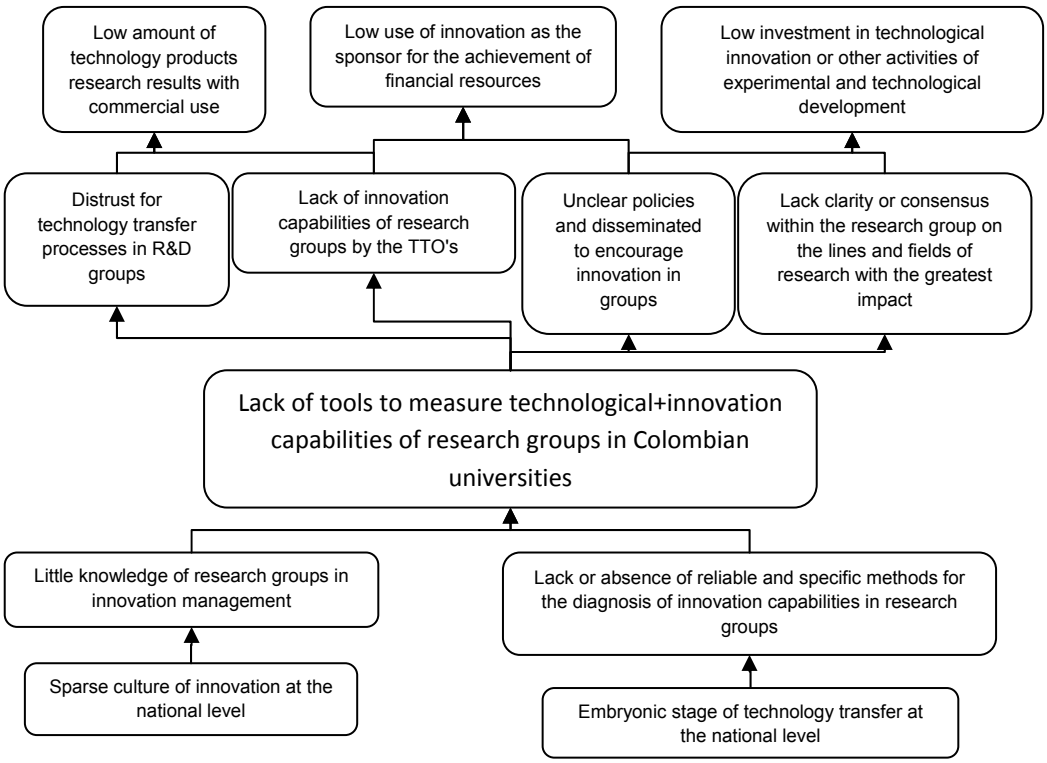

Figure 1. Problem Tree. Source: Prepared

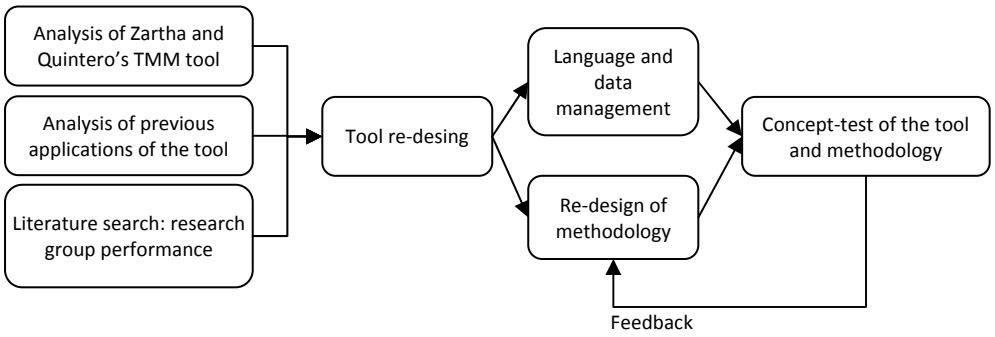

Figure 2. Process diagram of the methodology. Source: prepared.

This project addressed two causes of the problem: 1) the design of a tool and methodology for managing innovation in research groups and 2) culture of innovation management in groups, limited to the concept-test of the tool.

In order to include in the assessment tool the different criteria within the context of technology and innovation management and the context of a high performing research group, we followed the process shown in Fig. 2

First there was an analysis of existing literature about innovation measuring methodologies used in research groups globally and then we adapted the tool to meet the standards and requirements found in the different sources. Finally we conducted a concept-test of the tool.

IV. SCOPE

The developed tool only applies to research groups in "hard" sciences, especially engineering, which are more likely to develop technological products or administrative sciences that have the possibility of producing services. It does not cover social innovation or humanities groups.

Given the nature and complexity of the research groups and institutions, this methodology is focused only on technology and innovation profiles and it does not include other strategic matrixes. The release or spread of this tool was not included in this project.

V. ANALYZING INFORMATION ON CURRENTLY EXISTING METHODOLOGIES USED FOR MEASURING INNOVATION.

The analysis began with the application of a semi-structured interview to the Technology Management Policy research group from UPB, who had already applied the original TMM tool to other research groups, under the project EPICOS Defense Ministry survey. The results of the application of the TMM gave results described in "Diagnosing innovation strategy research group of the Universidad Pontificia Bolivariana" [5]. In addition, analysis of the experience gained by the author by applying the same survey to research groups at the University of Medellín is included.

Other sources were analyzed in search for alternative theoretical angles that may be applicable for research groups: TMM methodology [5], diagnosis of Albacete's innovation and innovation capacity assessment from University of Cataluña [9], Zartha J.W & Quintero, S [1], Franco Castro & Burbano Eraso [10] and Cordoba Zuluaga [11]. Complementary information from the Department of Science, Technology and Innovation (Colciencias) [6] were also analyzed.

A) Technology Management Policy Research Group survey.

As a starting point, the analysis began with the application of a semi-structured interview to the Technology Management Policy Research Group from the UPB, who applied the enterprise TMM tool to more than 52 research groups from the same university, by means of diagnostic for institutional improvement and also academic research. A survey was carried to the members of the group who participated in the field research. Author's responses were included in the analysis for its expertise in the application for other Research Groups from University of Medellín in 2011.

Answers were tabulated for each of the questions and categorized through qualitative content analysis. These guidelines were taken into account when making changes in the original TMM tool.

The most important findings in the application of this tool focused on:

- Groups recommended adjusting the language of the survey to match the research group language, and not the stated text for established companies.
- The possibility of extending the term "machine" to "technology", referring to some research groups that used computer platforms as the basis for developing its own technologies (groups whose orientation was ICT and other groups in the finance field using platforms like Enterprise Arkitect, IEEE, ACM, @ risk, Mathlab, Reuters, etc.).
- In the "Industry Profile" for the concepts of product and services, the researchers stated that it was necessary to replace them with the concepts of research lines, projects, and in some specific cases technology products and technologies developed.
- Since the concept of productivity in a research group is oriented towards intangible products codified in articles, books, book chapters, patents, registrations, spin-offs, Thesis consulting (undergraduate and post-graduate) and other types of academic product's production, it was necessary to include this type of products.
- Most groups interviewed had no administrative, accounting and financial management, as in the case of the University of Medellin, there is a "project management unit" responsible for all administrative, accounting and financial process, for which the term "financial standing" did not apply for groups, but instead to the whole institution.

B) Methodology for technology management – Technology Management Matrix (TMM).

Application in three food-business companies [1]**.** The components of this tool include technological inventory, technological Profile, Innovative Profile, Industry Profile, Structural analysis with MICMAC method, Strategic Matrix, Action Plan (Objectives, Strategies and Projects) and R&D Project Portfolio. Technological profile is segmented with Dispersion Analysis or 6 M's (Machine, Methods, Manpower, Money, Management, Materials) and innovation diagnostics detects capabilities of developing innovation on Product/Service, Market, Organization and Process cross-linked with Planning and Administrative Processes, Human Resources, Investment and Communications.

This tool has the most favorable configuration for the implementation of innovation strategies in the research group field.

C) Methodology of technology project management in the organization [11].

The performance measurement includes some components of technology management functions. One of the contributions that [11] made, was the inclusion of the function "protect", because of the importance of intellectual property on the results of the R+D+i in institutions that develop Science, Technology and Innovation (STI). The involvement of researchers, private companies, nonprofit organizations, state agencies and the institution containing the group, complex the scenario and relationships between them and the economical resources involved.

D) Statistical analysis of relation between variables of technology management in small and medium enterprises [10].

This project contributed to the multivariate statistical analysis tool, defining the variables measured and statistically verifying correspondence.

Examples adapted from the work of Franco Castro Eraso Burbano and can be found in Table 2 below:

TABLE 2. TECHNOLOGICAL PROFILE VARIABLES. ADAPTED FROM [10].

Question	Technological profile's variable name	Variable Code
1	M1. Technology acquisition	Tec_aquir
2	M2. Capital incorporated Tech	Tec_capital
3	M3. Transversal Technology	Tec_transv
…	…	…

TABLE 3. INNOVATIVE PROFILE VARIABLES. ADAPTED FROM [10].

Question	Innovative profile's variable name	Variable Code
1	Innovation strategy	Strategy
2	Organizational resources and infrastructure for innovation	Resources
3	Innovation Qualification	Qualification
4	R&D+i Included on the strategic plan of the research group	R&D+i_strat_plan
…	…	…

The same process is done with the questions of innovative profile, as shown in Table 3, adapted from [10].

E) Department of Science, Technology and Innovation (Colciencias) ScienTI[1]- rated research groups.

Colciencias has motivated the optimization of the ScienTI tools GrupLac, CvLac and InstituLac as a control mechanism for research groups at the national level, empowering researchers and group leaders to keep updated information, improve accuracy on knowledge production in the platform and forcing the endorsement of the Institutions to the research group.

VI. ALTERNATIVE METHODS FOR GAP PRIORITIZATION EVALUATED.

The following methodologies were analyzed to find alternative processes for prioritizing gaps:

- **Analytic Hierarchy Process-AHP** [12]: It is a system similar to MICMAC, with the advantage that AHP uses the upper triangular matrix of the comparison variables and proposes the lower triangular matrix as the reciprocal, facilitating calculations. The "weights of the variables" are obtained from the frequency values obtained in the matrix and are used as a vector to subsequently perform the prioritization of gaps. This method may be interesting and may require less time than MICMAC, however the fact of making the upper triangular matrix process can generate a large burden on both the consultant and the research group. AHP also ranks the level of importance of the variables, not their level of dependence or independence.
- **Barriers to Innovation –"U" Innovation Coefficient** [13]: While it is not really a system to prioritize barriers, its main function is to identify the types of barriers to innovation related to money, time, physical resources and information. This method which is in turn related to the equations of heat transfer, associates the value for thermal conductivity coefficients and other variables in the model in order to give greater or lesser weight to a particular gap.
- **Methodology for business support in the management of innovation** [14]. In this model, "the identification of priority gaps is done in coordination with the manager of the company and the priority gaps are selected according to the objectives of companies in the short, medium and long term.", indicating that is are the consultant and manager who define empirically the gaps found in the previous diagnosis. This prioritization process is done with inputs such as benchmark studies, results with other evaluating consultants and other factors such as the internal process capabilities, investment and human factors.
- **Transfer Tool - Application projects** [15]: This simple tool assesses by grading between 1, 5 and 10 criteria for R&D+i in order to recommend to public institutions, the most appropriate route for technology transfer. Although it is not a prioritization tool, it does suggest that the models can operate with simple empirical approach of the consultant or the client.
- **Contingency table** [16]: This method is generally used in public health studies to relate variables through statistical measures (or frequency) of a given variable comparing them with others. However, in the case of prioritizing gaps, this model would also be statistically complex, requiring the evaluation of dependence/independence of variables using log-linear models and somehow distorting the main object of the work to improve the applicability of the tool. Additionally, models of contingency tables only apply to variables with quantitative and/or qualitative data into defined categories versus individuals. For these reasons, it precludes the use of this system for analysis.

Some of the methods analyzed where discarded because of the need to reduce the complexity of their application, despite being scientifically robust methodologies for the analysis of variable dependency. An interesting fact was that some of the methods were self-assessment processes, relying on manager and/or company's personnel experience to select the gaps.

[1] International Network of Information and Knowledge Sources for Science, Technology and Innovation Management. http://www.scienti.net/php/index.php?lang=en

VII. RE-DESIGN OF THE TOOL.

Based on the results obtained from the analysis of the sources and the experiences with the implementation of the previous tool, it was decided to use the Zartha & Quintero's TMM tool with two types of deep-in adaptations in the process of measuring innovation capabilities of research groups:

- Language and context
- Methodology of analysis and prioritization of gaps

One of the reasons that lead to keep the actual configuration of the TMM tool is that all the templates relate to the technological functions stated by [17].

- Inventorying: The template "Technology Inventory" is intended to identify technologies actually managed by the research group.
- Evaluate: The original enterprise tool contains the templates "Innovative Profile" and "Industrial Profile". The last one was re-labeled "Research profile" and both templates where re-designed to acquire the data for the group's technological and innovation potential, and possible weaknesses and strengths.
- Enrich: From the analysis of the profiles and the identification of gaps in technology management and innovation, the tool can guide the group to propose projects to close gaps, focused on the acquisition of competitive advantages.
- Optimize: With an alternative method that aims to prioritize the gap variables and thus raise the action plans according to the needs identified for the group and/or institution.
- Protect: The Innovative Profile references this function to find out how the group is aware of the importance of intangible products and its management. The existence of clear processes in the group or institution to detect potential products worth protecting and the knowledge of laws, policies and relationships between each participant and the product.

As shown in Fig. 3, the difference with the methodology of Zartha J.W & Quintero, S, lies in finding alternatives to the use of MICMAC matrix, because when 15 or more dependence variables are being evaluated, the analysis may become slow and heavy for researchers and the consultant or TTO.

Adapting the language. All questions of the original tool were reviewed and changes to the language orientation were done. Adding or removing questions that proved relevant or irrelevant in any case, or do not apply to the context of the analysis of the research group were also modified. Addition or removal of categories, the fine tuning of the calculating formulas and the inclusion of additional side tables to facilitate analysis of the results were also included.

Adapting the context. As discussed previously, the tool must not only deliver results to the research group, but also for the institution that contains it. Groups and its institutional relationship vary from one university to another, depending on policies, managerial and organizational structures. In this sense, the tool simultaneously performs a diagnosis between what applies to the group, the institution or both. Figure 4 shows the different contexts that apply to the analysis of innovation capabilities at different levels of magnitude, such as the investment budgets of STI, the scope of innovation policy, management level, among others.

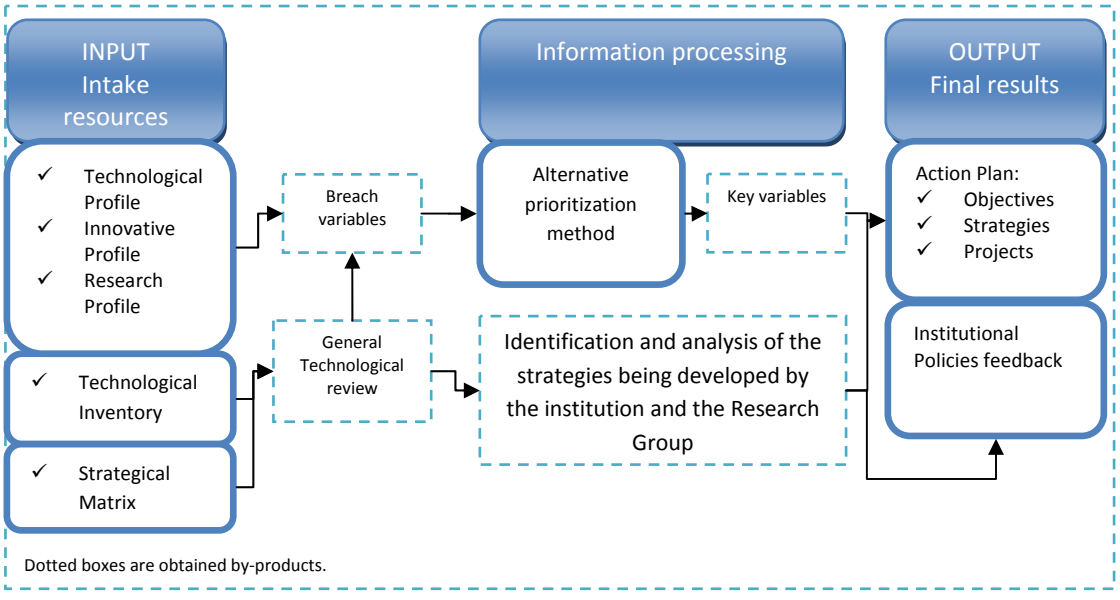

Figure 3. Resource interaction tool, based on [1].

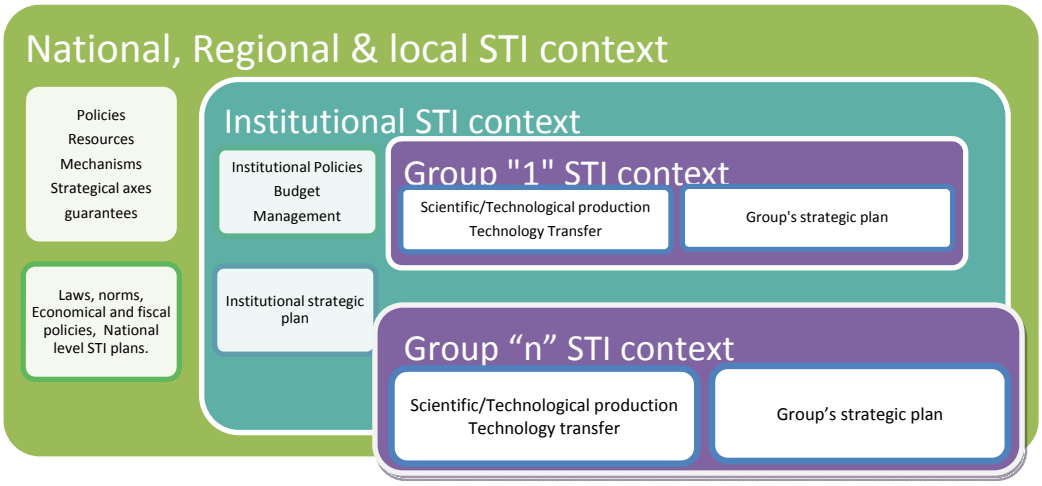

Figure 4. Context levels for science, technology and innovation (STI). Source: Prepared

It is important to note that each group and each institution has its own particular context. E.g. the possibility that groups have their autonomous budget or access to the budget only through calls, the possibility to link students to the group or the requirement of linking the researchers to the institution to have a place in the research group, etc.

To solve this feature, the tool incorporates two columns at the right of each question, indicating whether it applies to the group, institution, or both. Enabling or disabling this operator modifies the statistical analysis process because a gap may appear for the group only and not for the institution or the other way around, relating the responsibility of the institution to assure the conditions to improve research and innovation processes. A Boolean operator (0, 1) is used to enable or disable the context of the question.

Table 4, illustrates the use of this technique to separate the application context and results orientation to the institution or research group.

Adapting the methodology. Changes in the methodology refer mainly to the method used to prioritize the gaps. The process applied as an alternative to MICMAC, is based on self-assessment by the research group and the institution. This includes an additional table with a suitable format for researchers to answer a simple survey to prioritize gaps (see Fig.5).

TABLE 4. EXAMPLE OF USING THE APPLICATION CONTEXT IN THE TOOL

TECHNOLOGICAL PROFILE									
#	5 M's IDENTIFICATION	EVALUATION CRITERIA						APLICATION CONTEXT	
		1	2	3	4	5	ESTIMATED VALUE	GROUP	INSTITUTION
Identifying MANPOWER									
26	How important is the amount invested on each researcher/year for qualifying on research, development and innovation?	There is no investment on researcher qualification.	Advanced courses, diplomas or post-graduate studies	Foreign land qualification, bringing international experts from other countries into the research group	Msc and/or PhD financing, foreign land qualification, bringing international experts from other countries into the research group.	Not Applicable		0	1
Identifying MONEY									
28	Is there a process and it's responsible for searching financing, grants and money for research projects?	There is no process defined, not even a responsible	There is no process, but there is a responsible within the institution	There is no process but there is a responsible within the group	There is an existing structured process for financing resource search for projects and it's articulated between the group and the institution	Not Applicable		1	1
3	…	…	…	…	…	…			

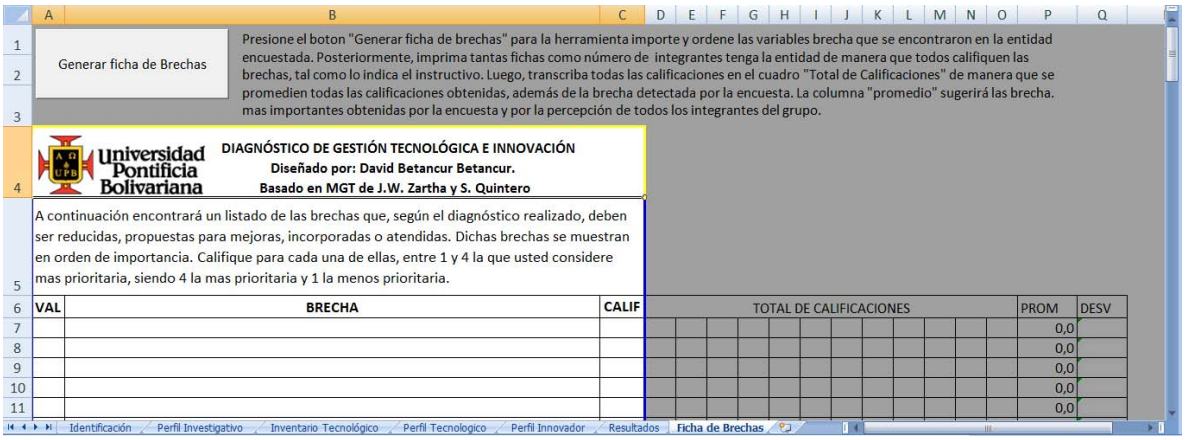

Figure 5. Listing gaps, MGT Research Groups.

The gaps obtained after the application of the tool, uses weights and criteria of the research group and the consultant to prioritize gap variables to be tapped after diagnosis. The resulting survey must be printed according to the number of members of the research team and the support team of the institution, who will fill the survey with their own criteria, assessing the most important gaps or areas that need to be strengthened.

These individual assessments are again fed into the tool in the fields of "TOTAL GRADES". There can be as many grades as the number of researchers and institution managers or personnel that filled the survey. The highest averages of each gap are automatically calculated, so is the standard deviation for the whole grades, giving as a result the list of gaps adjusted, being the highest gap the one with the highest average and the lowest standard deviation.

Final configuration of the tool. The following templates were included or re-designed:

- **Identification.** Used to identify the group and institution which will be diagnosed. Contains the list of its members and their level of education, plus relevant information on their scientific ranting.
- **Research Profile.** Based on the "Enterprise Profile" from the original TMM tool, this template collects the necessary information to determine the characteristics of the group in terms of strategy, organization, funding, scientific profile, quality, international visibility, among others.
- **Technological Inventory.** Used for research groups that use technological infrastructure for their research, such as robust equipment (laboratories, workshops, servers and networks, etc.), and how their management is carried out.
- **Technological Profile.** As proposed in the original TMM tool, this profile includes questions designed to determine the level of technology management in the group, and preserves categories Manpower, Management, Money, Methods, Machine and Materials. The Machine category is reinforced through the technological Inventory. The Materials category is not included because the raw materials do not affect the quality or quantity of research or the results of their investigations.
- **Innovative Profile.** Like the original TMM, this contains the questions that will shape the research group towards the application of knowledge and later phases of the development of applied knowledge to determine its impact on the market.
- **Results**. After including the important data and all questions are answered, the consultant can open the "Results" template, which highlights the scores of each of the categories in the tool for each of the profiles, finally showing the most important gaps in the diagnosed research group. Since the list of variables is large, the tool includes table "Gap Variables ", explained below.
- **Gap Variables.** The "Gap generator" button will automatically generate a list of gaps, listed by level of importance, which must be printed out and filled by the group members.

VIII. CONCEPT-TEST IN THREE RESEARCH GROUPS

The tool must be ideally filled by the whole research group. In any case, the answers to each of the questions should be arranged by a diverse group of people to generate discussion during the exercise. Each table should be carefully filled out by the consultant, who must read the question, clarify any doubts and guide the research group to the most applicable answer, without inducing any response.

The process of implementing of the tool was dynamic; as the surveys were conducted meanwhile adjustments were made to the tool. At the end of the whole research, the final tool was updated from the last survey. It is important to note that the findings and diagnostics made to the 3 groups are not included in this report, since the object of this work is the development of the tool.

A) Test 1: Research Center for Refrigeration and Air Conditioning UPB.

The Research Center for Refrigeration and Air Conditioning - CIRCLI has three product and services lines: Refrigeration, Air Conditioning and Cold Chain. The Center began operations in 2012 after building a test camera for refrigeration equipment and components, in cooperation with a private company. Since the Centre begun operations, interest is to involve innovation management processes.

Major findings on the use of the MGT tool after application in CIRCLI relate to:

- The tool achieves the goal of identifying the weakest strategic points within the CIRCLI, concerning the team about the work that is being done and what should be achieved to improve not only the processes of technology management and innovation, but also general strategic processes that are currently neglected.
- The process of involving members in the assessment and prioritization of gaps was well received by researchers.
- CIRCLI managed to incorporate interesting evidence to improve the competitiveness of its services and especially the planning, promotion and brand positioning needs.

B) Test 2 Public Health Research Group UPB.

The comments incorporated where result of the survey headed by Dr. Juan Guillermo Jiménez Jiménez, head of the research group since 6 years ago.

- It was necessary to review and adjust the literalness of some questions, because if strictly read, a negative forced response will arise. E.g. the question "29.MP Within administrative processes, has the research group or institution marketing plans and sales involving R+D+i?", it has the answer: "there is a sales marketing plan and it is monitored weekly". If interpreted literally, the group has a marketing plan but not administered weekly, they will not take this response because of its literalness. Responses where adjusted so that the possible answers do not invalidate the results.
- The researcher believed that it is very important to supplement with arguments the questions that have gaps, because it will serve of support for further analysis. Hence the "Comments" box was adopted throughout the survey.
- The researcher found the “context” field very useful, because he answered everything as Research Group, and stated that there are some clear questions in which the researcher must select the context.
- The researcher emphasizes the concept of "hard sciences" such as engineering for the implementation of the survey.

C) Test 3: Research Group in Textiles.

Although the group is not constituted as a research group, the Program Director of Textile Engineering, Ph. D Ana Elisa Casas Botero, has the will to create a research group that brings together the efforts of 3 PhD’s from the Textile Engineering Program and their 2 years research work, along with 8 students that are currently developing projects.

Some findings from this latest survey on the development of the tool are:

- After applying the tool to two of the research leaders (Ana Elisa Casas Botero and Adriana Restrepo Osorio Teaching), it was possible to notice the improvements in the design of the tool and the speed with which the interview was achieved.
- While adjustments in wording can improve, the tool presents an optimum shape for application to other research units
- It is proper that the application is made directly by the expert consultant, as if the group directly delivers, it may arise interpretive elements that do not allow the successful application of the tool.

IX. CONCLUSIONS

In the literature searches performed, there were no exercises or tools that would measure innovation capabilities in research groups. Most of tools available applied only to companies. It was necessary to adapt the entire contents and re-design of the TMM tool developed by Quintero S. and Zartha J.W., because most of the questions and answer choices did not apply to the contexts and languages of research groups

The redesign of the TMM tool included substantive changes. The strategy of dividing institution and the group’s gaps independently was necessary because the context and scope of both entities and their dependency set the conditions for innovation. The time of application of the tool and its subsequent analysis improved significantly. The assessment experience was a pleasant discussion for the three groups, as the analysis and prioritization of gaps with all members, became a constructive space for improvement opportunities and team integration.

The three concept tests of the tool were successful, finding both, groups and institutions, important issues at the time of application of the tool and its final results. The three diagnosed groups expressed their satisfaction with the tool, because the mere fact of reading the questions and wonder about research group life, opened important aspects of their strategic vision and lit alarms on processes that were not being carried out, or postponed.

A greater amount of testing is need. The tool needs to be applied to a greater number of research groups and use statistical analysis to determine the correlation between variables and categories, as Franco Castro and Eraso Burbano [10] did in their project. The analysis of a set of groups within an institution may be supplemented by Multiple Correspondence Analysis or other tool to statistically determine the important relations between the variables for the development of institutional policies to strengthen the quantity and quality of its research groups.

It is necessary to pursue the subject of characterization of research groups, as there is evidence that an "excellence group” or “high performance group” has certain special

features to manage R+D+i, and those features can be taken as a reference for other research groups. The shift in the threshold adopted by Colciencias, is another indication of improvement for such features.

The project succeeded in the mission of developing a tool for the assessment of technology and innovation management on research groups. This becomes a reference point for future work aimed at strengthening diagnosis on research groups, as in the prior literature this issue was not addressed in depth.

With the creation and implementation of the tool designed, research groups and TTO's will be able to:

- Analyze and implement strategies that encourage the development of high impact technology products to the industry
- Strengthen the ability to identify or articulate this products to higher national merits evaluation and recognition
- Improve access to budget for research by its institutions or other sources of research funding
- Allow the TTO's to make decisions about priority needs of the groups to facilitate these strategies.

The proposed tool will support the TTO's to deliver information to the groups and institutions and propose relevant improvements not only for research units but also propose policies within the institution and promote the improvement of competitive groups, striking on key parameters: strategic direction of research groups, selection of innovation projects, collaborative strategies, innovation protection, new product development process management and high-tech equipment management.

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