Mapping out technological capabilities in research institutions as tool for prospecting R&D outsourcing opportunities: a methodology developed for the R&D centre of a major car assembler

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Summary
The paper discusses the results of a project aimed at developing and testing a methodology for the identification, qualification and classification of capabilities of Brazilian research groups (RGs) in technologies applicable to the automotive industry. The project was commissioned by the major R&D centre of a multinational corporation in the business of car manufacturing. The point of departure is the literature pointing out the need for firms to manage systematically rather than empirically their external sources of innovation. Regarding routines for prospecting and qualifying external R&D (Research and Development) partners, an important function in managing external sources, the paper introduces the concept of strategic search. The major steps of the methodology developed and tested by the authors are described. Such methodology is presented as a tool for strategic search. The result of the implementation of the methodology is a database with quantitative and qualitative information on Brazilian technological competencies applicable to the automotive industry in the technological areas of Materials, Powertrains and Fuels, Manufacturing Technologies, On-board Electronics and Ergonomics. The databank comprises 265 research groups in various science and engineering disciplines. And some of its aggregate results are presented and illustrated.

1. Introduction

The importance of the contribution of external sources of knowledge for the process of innovation in manufacturing and services firms is widely recognized as a distinctive feature of innovation under the current forces driving competition. Yet, few corporations have adopted a systemic approach to the management of external sources of innovation, be it related to routines for prospecting and selecting sources and partners, be it related to designing and managing the contract of partnership. The literature emphasizes that firms lack such capabilities, but it also lacks the proposition of concepts, tools and methodologies to fill the gap. This paper intends to contribute to this debate by presenting and discussing a methodology for firms to prospect and qualify potential external R&D partners. The paper discusses the results of a project aimed at developing and testing a methodology for the identification, qualification and classification of capabilities of Brazilian research groups (RGs) in technologies applicable to the automotive industry.

The paper is based on an on-going research project commissioned by Renault to the research group composed by the authors[i]; the objective of the project is mapping research competencies in Brazilian Research Institutions (RIs). Data refer to research groups in Brazilian universities and research labs, most of them working on frontier technological issues in disciplines such as Chemistry, Physics, and Materials, Chemical, Mechanical and Metallurgical Engineering[ii].

The paper is organized in five sections, including this introduction. Section (2) introduces the discussion on firms lacking capabilities to organise and manage their external sources of innovation and the need for a systemic approach to such management. Regarding the prospecting of external partners for innovation, which is a key phase in the management

of external sources, the paper introduces the concept of strategic search. The following section (3) is the core of the paper, as it presents the basic steps of the methodology, which is considered a tool for strategic search, and discusses some of the critical difficulties in each step: 1. definition of scope, strategy and concepts of the mapping out methodology; 2. identification of the potentially relevant research groups; 3. methods for approaching informers and collecting data; and 4. data treatment: organization of database. The result of this project, that is, of the implementation of the mapping out methodology, is a database with quantitative and qualitative information on technological competencies applicable to the automotive industry in the technological areas of Materials, Powertrains and Fuels, Manufacturing, On-board Electronics and Ergonomics. The databank comprises 265 research groups in various science and engineering disciplines. These and other features of the database are explored in section 4. Finally, section 5 draws conclusions addressing the applicability of the methodology to other countries and business contexts.

2. The importance of managing the external sources of innovation and strategic search of external partners

Many corporations lack capabilities to identify and manage external sources of knowledge and innovation as a crucial process for their businesses, as such sources complement and contribute to strengthen innovation processes (Chatterji, 1996). So common questions managers ask when dealing with such issues are: How to identify and select partners and how to manage links with them? How to manage well the distinctiveness of external innovation partners, who comprise from business oriented suppliers to knowledge oriented research partners? What is the actual contribution of external partners for innovation?

The innovation surveys carried out in Europe and the US in the past two decades, such as the CIS – European Community Innovation Survey (in 1993, 1997 and 2000), have brought light to the understanding of the requirements, restrictions and determinants influencing the contribution of external sources to the firm's innovation process, particularly regarding research sources such as universities and public labs. Possibly, the most important finding of such surveys is that the capability for searching and selecting external sources of innovation depends on the building of internal technological capabilities. This is so because the knowledge which is relevant for technological innovation is sector and firm specific, thus, only the interested firm can be able to make choices between alternatives. The knowledge accumulated by the firm is a sound basis to sustain focused and organized search and selection. Moreover, such knowledge is requisite for learning from the external partnership.

The literature exploring innovation surveys has also revealed structural determinants or conditioning factors affecting the quality and intensity of links between firms and universities. Among such factors are the influence of the size and age of the firm, the particularities of the business sector, the nature of the innovation process and the science area involved. For instance, Cohen et al (2002) have drawn on the Carnegie Melon Survey to suggest that public research is more critical for industrial research in certain industries, particularly regarding the advance of sciences like biology and physics. The study has also shown that rather than outsourcing research in order to generate new innovation ideas, firms are likely to use public research as complementary to their capabilities and knowledge in on-going projects or in problem solution. In this respect, Santoro and Chakrabarti (2002) see a clear cut between the large and the small business firm, as the latter would be interested in finding solutions for their crucial problems, rather than building complementary capabilities in the long run in non-as-yet--core areas. Cohen et al (2002) also pointed out that, although

large firms are in general more inclined to source public research than small firms, research institutions are very important for science-based *start-ups*.

However, such studies are limited as they focus exclusively on the structural aspects of the firm, leaving aside the central issue regarding the strategic and managerial choices. Laursen and Salter (2004) suggest that, although structural aspects such as the size and age of the firm do play a role in determining the propensity to search links with universities and the chance of success, such decisions are also related to strategic choices regarding how to manage the innovation activities.

Even though an increasing number of large firms are stepping up their outsourcing and external linkages with universities and public labs, most of them have not adopted systematic practices to manage such links. Their approach is rather informal, imitative and empirical (Linder, Jarvenpaa and Davenport, 2003). Yet, organized practices comprising the identification, selection, monitoring and assessment of external research links are critical for making sure the best choices are made and to warrant the desired integration of research partners in the internal process of innovation. Although universities and public labs have been ever more demanded as partners in corporations' global innovation strategies, both in the developed economies and in the emerging economies, the evidence is rare when it comes to firms systematically managing the search for sources of innovation and linking their use of public sources to their strategic innovation objectives (Lauersen and Salter 2004). Other authors (Linder, Jarvenpaa and Davenport, 2003; Gomes and Kruglianskas, 2005) emphasize that most firms lack strategic direction to command their search for external partners, as well as a holistic approach to managing the various sources of innovation. Linder, Javenpaa and Davenport (2003: p.43-44) introduce the idea of managing external sources as channels of innovation-related ideas and knowledge ("innovation channels"), in the same way as they deal with specific distribution channels to reach end costumers. Such an approach suggests the importance of dealing differently with external partners which are distinctive in nature, culture and objectives.

This paper is concerned with a particular aspect of firm practices for managing external sources, that is, the prospecting and identification of opportunities for partnering in R&D with universities and public labs. This is part of the routine Chatterji (1996) points to as "identifying and coordinating innovation opportunities through formal and informal external networks", in his model of management of external sources of innovation. The paper presents a methodology for mapping out technological competencies and opportunities in universities and research labs, which is adequate to the Brazilian S&T (Science and Technology) environment. It is a tool which has been developed with the aim of supporting the strategically oriented search of external sources of scientific and technological knowledge for innovation.

An approach to prospecting and selecting R&D partners which has become quite disseminated in various countries, including Brazil, is the adoption of internet-based search. There are two basic groups of practices, which are based on internet search. On the one hand, practices based on information mining of databases, which are in most cases public database organised by government agencies in the field of S&T policy. The most important in Brazil is the CNPq Lattes database (CNPq - National Council for S&T Development), which will be discussed in the next section. Such data mining may focus distinctive aspects of a firm's interest, such as patents, publications and other qualifications of researchers and research groups registered in such databases. On the other hand, government agencies and private corporations in Brazil have been increasingly relying on the building of open innovation portals, aiming at matching supply and demand of technological competencies. The most

recent and significant case in Brazil are the Portal Inovação of the Ministry of S&T (http://www.portalinovacao.mct.gov.br) and the Portal de Tecnologias of Siemens do Brasil (http://www.siemens.com.br/templates/coluna1.aspx?channel=6782). These tools rely primarily on the spontaneous offer/submission of competencies by researchers and research groups of universities and public labs, even though the government Portal de Inovação also utilizes information of the Lattes database. The objective of such portals is to intermediate the contact between firms and institutions in need of competencies and the "owners" of such competencies.

However, the spontaneous, offer oriented construction of such portals may allow an unaware search to their users, but is not likely to be enough to allow strategic search. Inspired in the suggestions made by authors like Lauersen and Salter (2004) and Linder et al (2003), regarding the need for firms to adopt a systemic approach to the management of external innovation sources, we distinguish the **strategic search** of external sources, which is aligned to strategic innovation objectives and requires a more pro-active management of the search, identification and qualification of and interaction with external partners, from **unaware search**, which is based on empirical and informal methods for accessing external partners. Even though portals which rely on spontaneous offering are not empirical or informal in terms of the procedures for their building, the consequences for search may lead to results similar to the typical unaware search.

In the following section, a methodology for firm strategic search of R&D partners is presented and discussed. It is a methodology for mapping out technological competencies and opportunities in universities and research labs, which is adequate to the Brazilian S&T environment. The methodology is result of a project commissioned by Renault's R&D centre, in Paris, to the team composed by the authors. The project aimed at developing, testing and implementing procedures for mapping out, qualifying and classifying the capabilities of Brazilian research groups (RGs) in technologies applicable to the automotive industry and which are relevant for Renault's innovation objectives. Even though the methodology was developed having in mind the automotive industry and the Brazilian ST&I (Science, Technology and Innovation) environment, we suggest in the conclusions of this paper that the guidelines can be utilized in other institutional and business contexts.

3. The methodology for mapping out technological opportunities and research competencies and prospecting research partners

This section presents the methodology of the joint research project involving Renault and the group of authors and aiming at developing and testing a methodology for mapping out technological capabilities and opportunities applicable to the automotive industry in Brazilian research institutions/groups (RIs/RGs). The project was commissioned by the Research Strategy and International Networks division of Renault to the Research Group composed by the authors. It started in March 2004 and is planned to present the final results in July 2006. The project team comprised one professor, two PhD researchers, one PhD student and two engineering undergraduate students. The aim of the project is to identify and characterize major scientists and research groups, who work in Brazilian research institutions on technologies (at least potentially) applicable to the automobile industry. The search is oriented by Renault's initial indication of relevant technologies and by a permanent and systematic widening of the scope of technological opportunities learned in the very work of data collection. The project intends to look not only for researchers' competencies, but also to identify possible technological opportunities they have developed in their work.

The section describes the major steps of the methodology, discussing some of the critical difficulties in each step: 1. definition of scope, strategy and operational variables of the mapping out methodology; 2. identification of the potentially relevant research groups; 3. methods for approaching informers and collecting data; 4. data treatment and organization of databank and 5. validation of methodology.

3.1 - Definition of operational variables, scope and strategy of the mapping out methodology

The early decisions faced by the research team in the project were critical for the definition of the following steps of the methodology. They refer to the initial definitions adopted in order to guide the development of the methodology: the operationalization of the concept of research competencies, the definition of unity of analysis, the scope and strategy of research.

The construct capabilities/competencies adopted in the project has been operationalized by means of a wide scope of indicators, which refer to both inputs (researchers' background, size of research group, grants obtained, lab facilities, and so on) and outputs (patents, publications and major scientific and technological achievements) of research groups. This decision guided the elaboration of research tools that are described below. Another important aspect is that the interest of the project was not only to identify researchers' competencies applicable to the automobile industry, but particularly the ones which were willing to engage in research partnership with the industry. This is why it was so important that the characterization also took into account the partnership background of the researcher/research group.

Another early and important methodological decision was to take research groups (RGs) as the unity of research and, therefore, the smallest identifiable part of research to be considered in the project. RG here refers to the organized unit of research involving one or more senior(s) scientist(s), their students, associate researchers and technicians. RG do not require necessarily an S&T certification, as the one the Brazilian CNPq (the National Council for S&T Development) grants to groups registered in its directorate of research groups (although the most part of the selected groups have been registered). What makes a RG distinct is rather its capability to mobilize competencies and resources in a scale that raises substantially the productivity of research. Adopting RG as the unit investigated in the project has facilitated both the identification and the characterization of competencies.

The scope of research referred to the areas and technologies to be investigated, as well as the type of research institutions to be included in the mapping out. In the very beginning, it was agreed with Renault that the search and documentation of RGs should be oriented to 5 major technological fields: Materials, Powertrains and Fuels, Manufacturing technologies, On-board electronics and software and Human/machine interface (Ergonomics). Indeed, this definition helped organizing the implementation and upgrading of the methodology, as the project evolved through steps or modules, each of them addressing one major technological field. Before mapping out a given field, Renault provided a detailed list of the field, comprising the technologies the company was interested in. No restriction has been adopted regarding Science and Engineering areas or disciplines. Yet, in terms of type of institutions, an important value for Renault was scientific excellence, which has restricted the research to Brazilian universities and few outstanding public research labs.

The strategy of research, understood as the combination of major methods of investigation and sources, comprised one basic definition: given the objective of the project, relying on data-mining in secondary sources was not enough. Having knowledge of the Brazilian sources of data on S&T activities and institutions, it was clear for us that the

mapping out methodology required some form of primary data produced by means of direct contact with research groups.

3.2 - Identification of the potentially relevant research groups

Given the objectives of the project, the approach to make operational the concept of capabilities (competencies) and the unit of analysis adopted, the following challenge was defining procedures for finding and selecting the relevant RG to be surveyed. Our learning process as the project has developed led to the adoption of a mix of techniques comprising searches in databases (mainly CNPq's Lattes database and CAPES[iii] database), interviews with experts in the respective technological fields to be investigated and the technique of snowball sampling, in this case, snowball of peers (Atkinson and Flint, 2001).

Among the Brazilian S&T databases, CNPq's Lattes Platform (Plataforma Lattes) is the most extensive and complete. The Lattes Platform is a digital information system designed by the federal National Council for S&T Development – CNPq, as information tool for implementing its S&T funding programmes. Supporting on-line services related to research funding, the Lattes Platform comprises a database of RGs, namely the Research Group Directory (Diretório de Grupos de Pesquisa) and of individual researcher CVs (Sistema Eletrônico de Currículos), which can be accessed through CNPq's web portal. By inserting broad keywords related to technologies and science areas, lists of researchers can be produced for specific technology fields. This information can be complemented with group leaders'CV information drawn from the Lattes. Even though this information has been interesting in order to get a broad picture of research in a given technological field, it is not detailed enough as to produce precise clues to find the most interesting groups working with new technologies applicable in the automotive industry (or any given business area).

The effective selection of RGs to be surveyed for the project database required the help of expertise on the various technology domains and specific technologies which were relevant to this research. Yet, organizing expert support in order to "read" the available S&T databases would be very costly and time consuming. An alternative way of gaining expert support was adopted, which has proved to be relatively fast and less expensive: utilizing the method of snowball sampling in order to reach the population of researchers working on the relevant technologies and issues and with potential application in the automobile industry.

In its simplest formulation snowball sampling consists of identifying respondents who are then used to refer researchers on to other respondents' (Atkinson and Flint, 2001). The technique takes advantage of the social networks of identified respondents and is particularly useful in finding "hidden populations", usually belonging to both social extremes: the deprived and the elites. In this project, the population to be "uncover" comprised researchers/research groups whose achievements and capabilities were potentially applicable to the automotive industry. It seemed to be an effective and non-expensive means to engage experts in our search: a snowball of scientists and technology researchers referring to their peers, in each specific technology domain.

However, the adoption of this method required a good starting point – the first list of RG/researchers to begin the snowball sample, in order guarantee the completeness, diversity of schools and academic representativeness of the final sample. How could we guarantee that a large part of the most relevant researchers in Brazil, in a given technological field, were included in the databank? How could we assess the level of seniority and maturity of the researchers included? The solution was to introduce a further procedure in the picking-up of the starting list of researchers, which is based on the level of academic seniority/importance. For the starting list in each domain, we have adopted a search based on the crossing of the

two major Brazilian academic criteria for quality: the classification of researcher seniority by CNPq and the CAPES classification of grades given to postgraduate programmes. Thus, the typical initial list of the snowball consists of researchers filling both requisites: being ranked in the two most senior researcher level at CNPq (levels 1A and 1B) and belonging to the researcher/lecturer staff of postgraduate programmes with grades 5 or 6 or 7 at CAPES, in the specific technological area/discipline, as long as his or her research work was pertinent to our search.

3.3 - Approaching informers and collecting data

As the procedure to find relevant respondents was defined, data collecting was planned to occur in two phases: 1. Designing the first version of questionnaire, approaching procedures and forms of data collection aimed at testing and validating in a small sample (at the University of Campinas); and 2. Adoption of improved and validated methods of data collection in a wider sample.

The design of the questionnaire was the most important step in the development of methods in this research. It implied a choice of issues to be investigated and a structure and hierarchy of information to be collected. These should be sharp enough as to guarantee that information collected would allow the attainment of the objectives of the project, as well as lean enough as to attract the good will of respondents.

The following guidelines or major aspects of investigation were defined in order to guide the design of a questionnaire; they in fact have warranted that the resulting data was in line with the project objectives:

- To characterize the main features of the RG, in order to be able to measure its academic excellence and importance;
- To identify the major technological and scientific advances/attainments of the group;
- To identify the applicability of RG's competences and attainments in technologies applicable to the automobile industry;
- To map out RG's experience in technological cooperation with corporations and its willingness to engage in such cooperation.

Soon we realized that Brazilian secondary sources were good enough to provide the basic information regarding RG's publications (Lattes), patents (INPI – the Federal Institute for Intellectual Property) and the status of the group at CNPq. Moreover, the RG's web pages have worked as complementary sources, when available. Thus, we adopted the procedure of consulting secondary sources before interviews, so that interviewers meet the respondent with a previous and considerable knowledge of the RG's features, publications and patents. This has also helped to increase the good will of respondents, as it contributed to reducing the time spent in interview.

As regards approaching and type of interview, initially (in the first four months of collecting) researchers/RG was approached by an email that presented the objectives of the project and the partnership with Renault, as well as it required the researcher to concede an appointment to our project researchers for a live interview. The questionnaire was sent attached, so that the researcher could get a clear idea of what the interview would be about. As the electronic confirmation of reading was received, a phone call was used to organize the interview appointment.

After this period, an additional approach and type of data collection began to be implemented: electronic questionnaires. This was used mainly (but not exclusively) in order to get information from respondents outside the state of São Paulo (location of the University of Campinas). In this case, a distinct email message was sent, asking researchers to send back

the questionnaires filled, via email. In the case of electronic questionnaires, phone calls were used to follow-up the process. More importantly, phone calls were decisive to establish a trustful relationship with the targeted respondents, assuring them confidentiality and ethical utilization of the required information. Questions regarding the contribution of RG to the scientific and technological progress in their respective research domain might raise rejection and doubts regarding the actual objectives of the mapping out project. This is a critical and exhausting phase in the mapping out, in which "researchers may encounter initial hostility and suspicion from targeted individuals" (see Atkinson and Flynt, 2001). Eventually, the experience with phone calls did work well, although it was very hard, time consuming, labour intensive and expensive to contact, by long distance calls, researchers from all states of the country. In the case of respondents who did not reply to the first email, more emails were sent and more calls were attempted, until a positive or negative answer could be obtained. The rate of reply [(electronic questionnaires filled + no useable)/total questionnaires sent] was 46,9% (Table 1).

TABLE 1
Rate of reply of respondents:
materials, powertrains and fuels, manufacturing, on-board electronics and ergonomics

All technologies	Frequency	%
Electronic questionnaire filled	265	46,9
No answer yet	199	35,2
Participation refused	55	9,7
Problems on contact	25	4,4
No useable	22	3,9
Total	**566**	**100,0**

Source: fieldwork

After interviews or after receiving a filled electronic questionnaire, an acknowledgement email was sent to respondents; the message asked the researcher permission for further contact, if necessary, in order to solve doubts about the information sent.

3.4 - Data tabulation and organization of a database

Data on individual RGs obtained from questionnaires, as well as secondary source information, has been organised, in English, in a database designed for MS Access. In terms of information blocks, the structure of the database followed the same guidelines presented in section 3.3 and the descriptions of technologies and functional areas provided by Renault. Information of every RG mapped in the survey should be fitted to the same structure.

The Renault team gave suggestions of simplification for the fist version, which led to the current form of the database. In the current version, it is possible to obtain reports combining the following filters:

- technology of interest
- research institution (university)
- patent according to World Intellectual Property Organization (WIPO) code

Two types of reports can be produced from the database: a simpler one (only basic RG information, technologies and patents of the RG) and the complete one (all information regarding the RG). The database format meets the project's objectives, and is friendly in terms of both entering new information and creating new reports.

4. Some findings of mapping out: technologies, institutions, regional location and contracts of research groups

4.1 - General characterization of the Database sample

This section is based on information regarding the 265 research groups belonging to the technological fields of Materials, Powertrains and Fuels, Manufacturing, On-board Electronics and Ergonomics. It is shown the main characteristics of the Research Groups mapping out in relation to Research Institution, Knowledge Area, State, Patents and Research and Services Contracts with firms in the auto industry (suppliers and assemblers). It is interesting to notice the distribution of research groups by major technological fields: manufacturing technologies, with 73 RGs, and Ergonomics, with 26 RGs, represent the two poles in terms number of groups, which reflects the relative maturity and consolidation of the respective domains of technological research in Brazil (Table 2). The research groups in the database are distributed in 53 distinct research institutions (universities and public laboratories), which are located in 14 Brazilian states.

TABLE 2
Database overview
Frequency of Research Groups, Research Institutions and States by major technological field

Technology	Research Groups	Research Institutions	State
Materials	50	12	5
Powertrains and Fuels	53	19	6
Manufacturing	73	24	10
On-board Electronics	63	24	14
Ergonomics	26	13	8
Total	**265**	**53[1]**	**14[2]**

Source: fieldwork
1. Refer to the total number of Research Institutions covered in fieldwork.
2.Refer to the total number of States covered by the fieldwork.

The RG investigated are distributed in 17 disciplines or knowledge areas (Table 3), which shows the diversity of knowledge areas dedicated to research on the technologies relevant in this project. The background of by far the largest share of RGs covered in the data base is in the engineering disciplines: Mechanical Engineering (94 RGs), Electrical Engineering (51 RGs), Materials and Metallurgy Engineering (30 RGs), Operations Engineering (19 RGs), Computational Engineering (15 RGs) and Chemical Engineering (8 RGs). These are followed by significant shares presented by Chemistry (15 RGs), Design and Ergonomics (14 RGs) and Physiscs (6 RGs). It is important to notice that the knowledge area of Mechanical Engineering alone accounts for 35% of the database RGs and these are distributed between all major technological fields considered. This is possibly a consequence of the prominence of the metal-mechanic industry in Brazil.

TABLE 3
Database overview: frequency of research groups by knowledge area

Knowledge Area	Research Groups Frequency

Mechanical Engineering	94
Electrical Engineering	51
Materials and Metallurgy Engineering	30
Production Engineering	19
Chemistry	15
Computational Engineering	15
Design And Ergonomics	14
Chemical Engineering	8
Physics	6
Agricultural Engineering	3
Mecatronics Engineering	3
Food Engineering	2
Construction Engineering	1
Metallurgical Engineering	1
Environmental Health	1
Naval Engineering	1
Physical Education	1
Total	**265**

Source: fieldwork

Another important structural outcome of the database is the concentration of research in both regional concentration and institutional terms. Research identified in the database is concentrated in few states, particularly in the Southeast (181 RGs) and South (59 RGs) regions of Brazil. Indeed, this situation reflects the concentration of economic development in Brazil, as industrial activity, post-graduate education and research are concentrated in these two regions. Moreover, the concentration of the database RGs is particularly strong in the state of São Paulo (132 RGs or 50%). This is so partly due to the fact that there may be some bias stemming from the fact that the research team of the project is located in the state of São Paulo. However, it should be noted that research concentration in the State of São Paulo is proportionally greater the than economic concentration. While São Paulo accounts for approximately 40% of the Brazilian manufacturing industry value added, researchers working in universities and labs located in the state account for 50% of the scientific output (publications) (FAPESP, 2005).

Institutional concentration is even more pronounced. Out of the 265 RGs mapped out, 148 RGs (56%) belong to only 6 outstanding and leading research institutions, which accounted for 10 or more RGs each: the 3 São Paulo state universities (USP-São Paulo University, UNICAMP-Campinas University and UNESP-Paulista University), the Federal University of Santa Catarina, the Federal University of São Carlos and the Federal University of Rio de Janeiro. The average number of 25 RGs per institution in this elite group of universities is remarkably contrasting with the average of 2,5 RGs per institution in the remaining institutions. Even taking into account the bias related to data collection being centered in the State of São Paulo, these figures reflect the concentration and control of research in Brazil by few institutions, which has been pointed out by recent S&T indicators (FAPESP, 2005).

As one could have expected, the patenting activity of Brazilian RGs is quite timid, even though this has somehow changed in recent years, particularly in the elite group of institutions. The total number of patent submissions identified in data collection is 256, which leads to an average of less than 1 patent per group. The technological field of Materials presents an average which is double the general average of patents per group. In Materials, half the RGs own at least 1 patent. (Table 4). In line with the concentration of RGs, the same

6 elite universities account for the largest share of patents. Three federal labs – INT (National Institute of Technology) and CTA/ITA (Centro Tecnológico Aeroespacial/Instituto Tecnológico da Aeronáutica) – are the only non-university institutions which have submitted patent applications to the Brazilian federal patent office.

TABLE 4
Database overview: Frequency of patent owner groups and of patents by major technological field

Technology	Total of Research Groups	Patent Owner Groups	Patents	% of Owner Groups
Materials	50	26	100	52
Powertrains and Fuels	53	22	37	42
Manufacturing	73	18	48	24
On-board Electronics	63	22	45	33
Ergonomics	26	8	26	31
Total	**265**	**96**	**256**	**36**

Source: fieldwork

Results of the investigation of RGs also revealed that the frequency of contacts and contracts between firms and RGs and their research institutions/RI, which are related to the outsourcing of R&D and services, is much larger than usually acknowledged (Table 5) and even more so in regard to the automotive industry. The database has identified more than 400 service contracts and 360 research contracts between RGs and manufacturing or services business firms, considering the period 2000/2005. As most of these contracts have been funded by firms'own resources (and not by government sources), they may prefer to keep this type of information non-disclosed. Certainly, the fact that the focus of our research and of the methodology of peer recommendation was the applicability of competencies and technologies to the auto industry has introduced a major bias in results in favour of contracts with the auto industry: 31% of service contracts and 18% of research contracts. This is why we cannot compare frequencies between industrial sectors. However, it is interesting to notice that frequencies are relatively high in industries other than the automobile, such as the oil industry, steel and aluminum, the chemical, the aircraft and the food industries. The fragility in the links between firms and RI seems to be rather in the intensity and continuity of the link than in the frequency of links.

The first sign of the latter point is that the overall frequency of services contracts is much higher than that of research contracts. This is even more pronounced in contracts with the automotive sector: service contracts are almost the double of research contracts. Secondly, the continuity of research funded by a firm is rare. There are few contracts for research continuing beyond two years. Moreover, in the case of assemblers, we have spotted at least three cases of 2/3 year research projects which have been discontinued (and have not rendered applications).

It is interesting to notice that the overall distribution shows equilibrium between assemblers and suppliers in terms of the total number of contracts of RGs with the automotive industry. There is some concentration of such contracts in the fields of Powertrains and fuels and Manufacturing technologies. While RGs working in Materials are more demanded by suppliers, assemblers are rather ore interested in research on Ergonomics. The less demanded RGs are the ones working on On-board electronics in Brazil. This seems to be the result of the combination of two determinants. On the one hand, as this is a less consolidated and perhaps more strategic area of research, there is a tendency for greater concentration of electronics-related research in the headquarters and major international R&D centres of corporations in

the automotive business. On the other hand, it also may reveal the fact that Brazilian research in electronics is less known by firms. However, considering the total number of contracts in all industries, the RGs in On-board electronics are the ones more demanded for research contracts as compared to services contracts, which seems to indicate a potential for further contribution of these groups for innovation in the auto industry.

TABLE 5
Frequency of Research/Development contracts outsourced by assemblers/suppliers (and total contracts) to Brazilian Research Groups by major technological field[1] (2000/2005)

Technologies	Assemblers		Suppliers		Automotive total		Total contracts	
	S_2	R_2	S	R	S	R	S	R
Materials	7	4	19	10	26	14	85	61
Powertrains and Fuels	21	12	21	12	42	24	85	64
Manufacturing	18	11	16	9	34	20	74	104
On-board Electronics	6	1	2	5	8	6	62	116
Ergonomics	14	4	3	0	17	4	101	17
Total	**66**	**32**	**61**	**36**	**127**	**68**	**407**	**362**

Source: fieldwork
1. Refer to contract frequency and not the number of firms.
2. R: research; S: service

We conclude this section with an illustration of the content of the contracts RGs have declared to have (or have had) with assembler and supplier corporations, by showing the declared subject of part of the contracts in the field of Materials. Even tough the number of contracts involving assemblers is smaller than the frequency among auto-parts firms, the assemblers' experience is quite revealing. Indeed, longer term and less immediately applicable research outsourced by assemblers have been rare and entirely related to experiments with biomaterials (Table 6). However, it is interesting to note that services refer rather to advanced engineering services or developments, than short term outplacement of small services, like testing. Two examples underline this argument: the development of safety under-rides for trucks, which is a major line of development of a research group at UNICAMP and the development of a corrosion inhibitor powder.

TABLE 6
Research/Development contracts outsourced by assemblers to Brazilian Research Groups

Firm	Technology/Content of project	Functional area	Type of project
General Motors	Composites based on biomaterials	Weight reduction; environment	Research (2 years)
	Development of engine components using sinterizing technology	Durability	Research
	Simulation of mechanical fracture and fatigue	Durability	Service (2 years)
	Under-ride truck guards	Safety	Service (2 years)
Volkswagen	Carburator corrosion	Durability	Service
	Corrosion inhibitor	Durability	Service
	Biodegradable polymer	Environment	Research (3 years)
Daimler Chrysler	Composites based on biomaterials	Weight reduction; environment	Research
	Under ride truck guards	Safety	Service (2 years)

Source: fieldwork

The diversity of contracts, areas of outsourcing and even in research outsourcing presents higher profile as regards suppliers (Table 7). Starting with the latter point, research outsourcing from suppliers goes beyond biomaterials, to include the development of new metal alloys, major changes in manufacturing processes and corrosion control technologies. There are two cases of outsourced research which have received support from Brazilian S&T funds: the Pematech-UNESP project on biomaterials and the Agrostahl-USP project on new Ni alloys. These are recent projects which are revealing of an emerging good-will and interest in Brazilian automobile firms and RI to increase outsourcing (if not technological cooperation). In both cases, projects are supported by new Brazilian S&T institutions and funds (eg. the FundoVerde-Amarelo) which have given priority to technological, industrial applied research. The case of Pematech interesting also because it involves an indirect participation of VW – VolksWagen do Brasil and the support of FINEP – Financiadora de Estudos e Projetos, the main federal agency for funding applied research in firms. Pematech has developed curauá fiber based fillings for the interior of the VW Fox. The application technology and fiber production requirements led Pematech to establish a partneship with a major research group at UNESP (in the state of São Paulo), which specialises in natural fiber agriculture and industrial its application. The project received considerable support from FINEP, to fund the university part of the development, in addition to the investment made by Pematech.

TABLE 7
Research/Development contracts outsourced by suppliers to Brazilian Research Institutions

Firm	Technology/Content of project	Functional area	Type of project
Eaton	Ultra-fine grain steel - application	Weight reduction	Service
	Plasma nitritation in metals	Durability	Service
	Adhesive development	Durability	Service
Pirelli	Modification in copper wire manufacturing	Weight reduction,cost	Research (2 years)
	Analysis of corrosion in components	Durability	Service
Bosch	New types of fuels	CO2 reduction-	Service
Sabó	Development of innovations in high performance elastomers	Durability	Research
Agrostahl (*)	New NiCrAlC alloys	Durability	Research (2 years)
	Surface treatment – friction reduction	Durability, cost	Service
Pematech	Biomaterial composite development	Environment, weight reduction	Research (2 years)
Teksid	Simulation of mechanical fatigue-fracture	Durability	Service
Tupy-FrasLe	Characterization of wearing factors (metals)	Durability	Service
Sifco	Ultra-fine grain steel - application	Weight reduction	Service
Mangels	Quality in casting	Cost, durability	Service
Mahle-Cofap	Analysis of corrosion	Durability	Service
Toro	Biomaterial composite development	Environment, weight reduction	Research
Lord	Adhesives for aluminum	Safety	Service
Ourofino	Manufacturing of under-ride truck guard	Safety	Service
Non-disclosed	Metal casting and solidification development	Weight reduction	Service
Non-disclosed	Equipment development for corrosion control	Durability	Research (3 years)

Source: fieldwork

Service outsourcing contracts to Brazilian RG also present larger diversity amongst suppliers than assemblers. It is important to emphasise, again, that services here are generally related to what could be called engineering with science fundamentals, rather than short term, testing-like services. The typical situation is one in which the adaptation or even an improvement in a given component requires materials technology knowledge, which is beyond the capabilities of the firm's Brazilian product development team (usually in a multinational corporation). Thus, in such contracts, the Brazilian RG works as if it was a replacement for the central R&D corporation lab, supplying solutions to the Brazilian engineering team. This is so for various reasons, some of them have been discussed recently by the authors with supplier product development engineers. First, there are specificities of applications, cost parameters, and implications of distinct weather and temperature in Brazil, all of them with implications for materials technology, which make it difficult and costly for central labs to provide prompt and efficient solutions. Secondly, usually central labs are too busy attending the corporation's priorities and can not afford dedicating the time the Brazilian subsidiary requires. In the case of Brazilian national suppliers, the explanation is similar, with the difference that there is no central lab to turn to and problems arise either from the adaptation of licensed technologies or from new technology development, as in the case of Pematech.

5. Conclusions

This paper has drawn on the methodological developments and implementation results of an applied research carried out by the authors for the Technocentre of Renault Sas. It has tacked an important problem faced by the assembler regarding the implementation of the recently adopted policy of increasing the outsourcing and off-shoring of R&D, including emerging country research institutions s possible partners. The question posed to Renault is similar to the ones we presented in section 2: how to manage the search of eternal partners for R&D? How to prospect and qualify potential partners?

The methodology developed and implemented by the authors is a response to these questions which is intended to allow a strategic search by the corporation, as the database produced presents features that seem to assure this intent. First, it is oriented towards the technologies which are considered relevant for the corporation's innovation objectives. Second, it is comprehensive and representative of the major technological fields to which such technologies belong. Third, the scope and methods of data collection allow for emerging, not-yet-known technological opportunities to be mapped and influence the definition of strategic R&D objectives. Fourth, the methodology can be reproduced and transferred to other countries and even lead to other surveys for the updating of the database.

Even though the content of the survey carried out for Renault is very industry specific, we suggest that the lessons and procedures learned in the development of this methodology can be applied in mapping out technological research competencies in other business contexts. The most relevant lessons are as follows:

1. It is very important to start by deciding on the critical dimensions of the search: scope of the search, concepts and indicators for operationalizing the relevant dimensions of search (for instance: a clear operationalization of the term competencies), strategy of data collection and unit of investigation;

2. The phase of identification of partners (either RGs, researchers or institutions) requires good knowledge of the research environment and of S&T institutions, which will allow for the definition of procedures which can assure the comprehensiveness and representativeness of identification;
3. The phase of approaching partners and collecting information requires good communication skills and infra-structure, a lot of patience and persistence, in addition to good planning and well organized follow-up;
4. The organization and tabulation of data (the database) should be kept as simple as possible; retrieving simple reports rather than complicated cross tabulations is what fits better the process of learning how to use such tools;
5. Finally, it is important to validate the results of the implementation of the methodology, that is, to demonstrate the comprehensiveness and representativeness of such results, so that the users of the tool will be confident in using it.

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[i] This is the project "Capabilities and opportunities involving technologies applicable to the automotive sector mapping out of the Brazilian research institutions".
[ii] Data was collected from 2004 to 2006 by means of a questionnaire sent to approximately 570 research groups, out of which we have obtained 287 replies.
[iii] The Ministry of Education's Committee for Post-graduation Policies.