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Adapting the roadmapping approach to science-intensive organizations: Lessons from a drug development program for neglected diseases

Jonathan Simões Freitas[a,*], Raoni Barros Bagno[b], Caryne Margotto Bertollo[c], Tânia Maria de Almeida Alves[d], Carlos Leomar Zani[d], Lin Chih Cheng[b], Carlos Alberto Gonçalves[a]

[a] Departamento de Ciências Administrativas, Faculdade de Ciências Econômicas, Universidade Federal de Minas Gerais (UFMG), Antônio Carlos Avenue, 6627, Pampulha, Belo Horizonte, Minas Gerais, 31270-901, Brazil
[b] Departamento de Engenharia de Produção, Escola de Engenharia, Universidade Federal de Minas Gerais (UFMG), Antônio Carlos Avenue, 6627, Pampulha, Belo Horizonte, Minas Gerais, 31270-901, Brazil
[c] Departamento de Produtos Farmacêuticos, Faculdade de Farmácia, Universidade Federal de Minas Gerais (UFMG), Antônio Carlos Avenue, 6627, Pampulha, Belo Horizonte, Minas Gerais, 31270-901, Brazil
[d] Instituto René Rachou, Fundação Oswaldo Cruz, Augusto de Lima Avenue, 1715, Barro Preto, Belo Horizonte, Minas Gerais, 30.190-002, Brazil

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ABSTRACT

This paper discusses a roadmapping approach (RMA) adopted on a program on drug discovery and development for neglected diseases. This experience led to changes in traditional RMA that revealed special potential for science-intensive environments: (i) conduct the roadmapping process in parallel for alternative areas of interest; (ii) start the roadmapping process by focusing on the consolidated technological paths; (iii) construct roadmaps to highlight organizational strengths and weaknesses; and (iv) consider the sectoral contingencies to enhance the managerial approaches. Among the implications, some literature paradigms are contrasted by contingency adapting RMA, changing workshop dynamics; and adopting a slow inside-out strategizing approach.

1. Introduction

Opportunities are usually seen as positive strategic factors external to the firm (Short et al., 2010). Identifying them is considered the first step of the entrepreneurial process (Shane and Venkataraman, 2000) and a fundamental part of any strategic analysis (Hutzschenreuter and Kleindienst, 2006). Indeed, opportunity identification (OI) is a widespread practice among both entrepreneurs and managers (*c.f.* Alvarez et al., 2013).

Many approaches that support OI have been developed over recent years (e.g. SWOT[1] analysis; PESTLE[2] analysis; Porter's five forces; Ansoff's product/market matrix; perceptual mapping etc.). More specifically, visual practices have been increasingly incorporated to better tackle various cognitive, social and emotional challenges that arise in strategizing (Eppler and Platts, 2009). In

* Corresponding author.
E-mail addresses: jonathansf@face.ufmg.br (J.S. Freitas), rbagno@dep.ufmg.br (R.B. Bagno), cmbertollo@farmacia.ufmg.br (C.M. Bertollo), tania@cpqrr.fiocruz.br (T.M.d.A. Alves), zani@cpqrr.fiocruz.br (C.L. Zani), lincheng@dep.ufmg.br (L.C. Cheng), carlos@face.ufmg.br (C.A. Gonçalves).

[1] i.e. Strengths, Weaknesses, Opportunities, and Threats.
[2] i.e. Political, Economic, Social, Technological, Legal and Environmental.

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this context, the roadmapping approach (henceforth, RMA) (Carvalho et al., 2013; Phaal et al., 2010) stands out for explicitly assigning a significant role to visualization in its workshop-based process (Phaal et al., 2009; Phaal and Muller, 2009) – which, in more strategic-oriented applications, is specifically aimed at the identification and initial exploration of opportunities (*c.f.* the "S-Plan" RMA version, in Phaal et al., 2007, 2010).

Nevertheless, roadmapping for opportunity identification may still be enriched. For instance, the S-Plan standard (Phaal et al., 2007, 2010) assumes that a single "area of interest" will be chosen in the "planning stage" for subsequent roadmap-based OI. Yet, in complex problematical situations, this limitation to only one analytical focus may not be possible or even desirable (*c.f.* Rosenhead and Mingers, 2001). In fact, in many cases, participants may want to analyze multiple areas of interest in parallel.

Furthermore, S-Plan defines the sequence of roadmapping stages according, primarily, to the scope being explored. Initially, the full scope of the selected area of interest is considered (i.e. the "strategic landscape" stage). Then, the specific scope (i.e. a "topic roadmap") of a "priority opportunity" is brought to the forefront (Phaal et al., 2007, 2010). However, this scope-based sequencing may cognitively overwhelm participants. After all, in each of the roadmapping stages, they will need to construct a complete roadmap at once, having to simultaneously fill in and align multiple layers of information over a time axis (*c.f.* Phaal and Muller, 2009). The complexity of this task may negatively affect the quality of the resultant maps and undermine participants' engagement with the process.

Following previous RMA standards (e.g. "T-Plan" – Phaal et al., 2001, 2004), each S-Plan roadmapping stage could itself be sequenced according to roadmap layers. That is, both in the "strategic landscape" and in the "topic roadmap" stages, participants could be instructed to firstly focus on "market" information; then, on "product"; then, on "technology"; and, only then, on an integrative "charting" synthesis. This layer-oriented sequencing may prevent information overload in the first steps of the process, by considering only one layer at a time. However, it can hinder consistent longitudinal cross-layer alignment in the final charting stage. Therefore, this alternative roadmapping sequencing may not help overcome the traditional lack of integration and synchronization between initiatives from different departments.

Moreover, the S-Plan roadmapping approach is currently focused on the identification (and initial exploration) of opportunities, seen as external strategic factors (*c.f.* Phaal et al., 2007, 2010). Thus, internal strategic factors that could be decisive to strategy formulation – e.g. organizational strengths and weaknesses – may be overlooked during the process, favoring an unbalanced outside-in rationale (*c.f.* Khalifa, 2008).

These challenges may be well addressed by contingency adaptations, *i.e.*, approaches that include aspects (e.g. industrial sector, size, region) that could shape the original propositions of some management theories (e.g. tools, methods), enhancing their potential and making them more suitable to contexts that significantly differ from those in which such theories emerged. In the innovation management field, researchers have focused mostly on large companies that have resources in their formal budgets, well-structured innovation processes and business-to-consumer operations (Bagno et al., 2017). As Cheng (2003, p. 108) states, every method or tool is a product of its context. They are "developed for particular aims, under certain orientation, to obtain specific outcomes, and have underlying assumptions". Regarding RMA, Tierney et al. (2013) affirm that previous generations of roadmapping techniques are echoes of the innovations and products they were first intended to support. Finally, Carvalho et al. (2013) alert for the lack of evidence of how variables such as industrial sector and firm size might moderate the success of RMA approaches. In sum, although RMA holds great potential to help strategists, its application needs improvements to better deal with important complexities involved in this process.

Therefore, the purpose of the research reported in this paper was to design and implement an alternative RMA able to satisfactorily support OI in an extremely complex strategizing situation, notably different from the typical industrial environments approached by the dominant literature, despite its high relevance. This extreme case was found in a technical-scientific unit – a R&D institution of the Brazilian Ministry of Health. After all, while this division intended to identify opportunities for discovering and developing drugs for neglected diseases, its sectoral, organizational and program-specific context imposed many puzzling complexities on achieving this goal. More generally, this organization embodied many of the typical challenges imposed by the sectoral characteristics of the pharmaceutical industry (*c.f.* Pavitt, 1984). The central role of scientific activities performed by the companies immersed in this context provides peculiar challenges for some traditional RMA prescriptions. Such an environment is prolific to the study of contingency adapted approaches that better cope with the nature of the learning processes, technological accumulation paths and other organizational constraints that distinguish the strategizing challenge and the management of technology in science-intensive organizations.

Hence, an action research project focused on this problematical situation was carried out. It lasted 6 months, encompassed 10 workshops, involved more than 20 people from 3 organizations, and had positive repercussions both internally and externally.

2. Theory

In this section, we initially review the main developments in RMA for OI. Then, given the technological and managerial complexities imposed by the science-intensive organizational environments, we present the main sectoral contingencies of the pharmaceutical industry, converging to the roles assigned to public research institutes in developing countries, which was the focus of the field research.

2.1. Roadmapping for opportunity identification

The concept of "opportunity" has received a lot of attention from many research strands and is considered the focus of the

increasingly influential entrepreneurship field of study (Alvarez et al., 2013; Shane and Venkataraman, 2000; Short et al., 2010). Over the last years, this concept has been defined in various ways, each of them emphasizing distinct aspects of this multifaceted phenomenon (Alvarez et al., 2013; Short et al., 2010). However, the notion of "opportunity" as a strategic factor that is both external and positive to the firm remained considerably stable over time (Short et al., 2010). This shared understanding of the basic concept can be traced back, for instance, to the widespread SWOT matrix and its underlying view of opportunities as not "negative" – in opposition to threats and weaknesses – and not "internal" – in opposition to weaknesses and strengths.

A critical task, in this context, however, is to identify these opportunities. Most of OI methods and techniques were not explicitly designed to tackle the cognitive, emotional and – mainly – social challenges that may arise in a group-based entrepreneuring or strategizing situation (Eppler and Platts, 2009). More recently, though, some advances have been obtained in this regard. As visual templates can bring structure into a conversation and help not to mislead the discussion, some attempts have been made to integrate them into OI practices (Eppler and Platts, 2009). Among these attempts, RMA emerged as a prominent alternative, due to its explicit and consistent use of visualization during its workshop-based process.

RMA is currently seen as an approach to identify and initially explore strategic issues and opportunities (*c.f.* Phaal et al., 2007, 2010) – usually those related to strategic technology management (e.g. Möhrle et al., 2013; Phaal et al., 2012). As such, it focuses on the firm's external environment, from which it identifies and characterizes strategic factors.

To do so, the approach is based on workshops dedicated to building a "strategic landscape" of the environment under analysis and, then, identifying and exploring "priority opportunities" and their implications for internal action (*c.f.* the "S-Plan" standard Phaal et al., 2007, 2010). This workshop process is preceded by a planning stage and followed by a final review of the experience (Phaal et al., 2007, 2010). In the former, a single area of interest is chosen to be explored and workshops are prepared. In the latter, learning is reported, and participants revise the needed actions to take the initiative forward. During the workshops, market, product and technology issues are usually explored in this order (Phaal et al., 2001, 2004, 2010).

These RMA workshops make extensive use of visualization, guided by the collective construction of "roadmaps" (Phaal and Muller, 2009). These visual templates can have various formats, but are usually represented by multiple layers aligned in relation to a time axis (Phaal et al., 2009). Each layer must represent a distinct aspect of the system under analysis (e.g. an industrial sector) and the main goal is to discuss connections, over time, between elements from different layers (Phaal and Muller, 2009). The assumption is that this debate may foster convergence between previously divergent perspectives held by workshop participants.

Nevertheless, the current RMA format goes beyond previous roadmapping proposals – e.g the well-known "T-Plan" standard (Phaal et al., 2001, 2004, 2010) – both in its purpose and in the way to build the map. While T-Plan, for instance, focuses specifically on the alignment of product-technology development plans with market-business trends over time (Probert et al., 2003), RMA currently aims, more broadly, at the identification of innovation opportunities from an overview scanning of the environment (Phaal et al., 2007, 2010). Moreover, while T-Plan proposes a different workshop for each layer (Phaal et al., 2002; Phaal et al., 2001, 2004), the current RMA process is primarily sequenced according to the scope of the analysis – firstly, a broad area of interest; then, just the scope relevant to a priority opportunity. Hence, the current RMA is usually seen as a high-level, strategic planning of innovation, to be followed by previous roadmapping proposals, in their further exploration of product-technology development implications (Phaal et al., 2007, 2010; Phaal et al., 2012).

These contrasts are based on the standard roadmapping "fast-start methods": T-Plan, for product-technology planning; and S-Plan, for innovation-related opportunity identification (Phaal et al., 2001, 2004, 2007, 2010). Although other roadmapping proposals exist (specially, for product-technology planning, e.g. Albright and Kappel, 2003; Groenveld, 2007), T-Plan and S-Plan are widely spread among organizations and provide the main characteristics of these two basic types of RMA (Phaal et al., 2010).

Nonetheless, literature on roadmapping is still evolving and several recent efforts have been made to refine practical applications. To cite some, Geum et al. (2015) alert for the lack of a dependency measure that can be used between layers of technology roadmaps and suggest an "association rule mining" (ARM)-based technology roadmap to identify such a relationship between different layers. Oliveira and Fleury (2015) offer a framework for examining roadmaps using three performance indicators: information gathering, layers integration and forecasting. By turn, Freitas et al. (2017) combine the development of roadmaps with other strategy and innovation tools to propose an integrated approach to strategic management and innovation-related processes.

Moreover, new approaches and adaptations of RMA tend to arise, mainly due to sectoral-technological and organizational specificities. For instance, Huang et al. (2014) propose a roadmap-based and bibliometric-integrated industry S&T planning framework, directed toward four dimensions (nation, technology, industry, risks and impacts). The study was intended mainly for the industry level of analysis and took China's solar cell industry as the case study. Jeong and Yoon (2015) suggest the concept and process of a patent roadmap, based on technology roadmap and patterns of patent development. The example of a transparent Active-Matrix Organic Light Emitting Diode illustrates the process. Lastly, Tierney et al. (2013) proposed the Technology Landscaping as a new roadmapping technique, intended to cope with differences in today's use of technology and related constraints, technology-triggered new business models, and the role of innovation drivers. The authors tested their model in the pharmaceutical industry.

The bibliometric analysis of Carvalho et al. (2013) points to an increasing interest in the "roadmap" topic. From a total of 79 articles considered (38 dedicated to strategy and business level of analysis and 41 to innovation and new product development), the last 5 years of research covered by the study (2007–2011) were more productive than the whole of the previous decade. Some sectors of application stand out among the documented roadmap studies: mobile communications, automotive and energy, chemical products, software, nanotechnology, mining, police, construction, medicine, academic services, hydrogen, and telecommunications. Among the main trends that Carvalho et al. (2013) identify, two deserve special mention due to the close links to the present study: (i) a strong interest in identifying the critical success factors of RMA (despite a lack of evidence of how variables such as industrial sector and firm size might moderate the effect of these factors); and (ii) further exploration of the interface between roadmapping and

innovation/corporate strategy, primarily by looking carefully at real-world experiences.

2.2. Pharmaceutical industry: new contingencies for RMA

According to McKelvey and Orsenigo (2001, p.1), the pharmaceutical sector is a "large, high-growth, globalized, and innovation intensive industry". The authors argue that health care and therapeutics are of utmost importance for the welfare and democracy in contemporary society.

The application and contingency adaptation of management approaches such as the roadmapping is expected to differ among organizations, not just because of their individual aspects, but also due to the differences in the technological dynamics that underlie business sectors and trajectories. According to Pavitt (1984), the pharmaceutical industry is the typical example of a science-based industry, hence many of the innovations in this sector stem from technological and scientific efforts, normally as a direct result of R&D.

Figueiredo (2002) shows how the learning processes influence inter-firm differences in technological capability accumulation paths. Technological capabilities can be defined as the technical, managerial or organizational skills which firms need in order to efficiently utilize the hardware and software of technology (i.e. equipment and information) and they are typically accumulated over time (Bell and Pavitt, 1995; Morrison et al., 2008). The pace of the technological capability accumulation, whether of an industry or an individual company, strongly depends on the nature of the learning processes. Therefore, efforts on knowledge-acquisition and knowledge-conversion processes could catalyze the technological capability accumulation (Figueiredo, 2002).

Showalter and Denny (2008) argue that drug discovery and development is complex, expensive and requires many years and resources. This process, on average, ranges from 12 to 15 years depending on the disease area and the treatment approach. According to Torres and Hasenclever (2016), basic research is among the utmost technological capabilities in the pharmaceutical industry. In short, this capability involves the identification of new molecules of therapeutic potential, propelling the identification of innovation opportunities. Throughout the journey from the bench work to the market, three groups of technologies deserve special mention: pharmacochemistry, biotechnology and pharmaceutics, each one with its own knowledge base and high technological complexity (Torres and Hasenclever, 2016). Thus, heavy and highly specialized academic education marks the profile of people employed in basic research. In a similar context, Butler (2008, p.841) adds that the "basic biomedical research enterprise has now evolved its own dynamic, with promotions and grants based largely on the papers scientists have published in top journals, not on how much they have advanced medicine".

The history of world's pharmaceutical industry reveals substantial changes in the main technological paradigms related to new drug discovery: from chemistry to biology and from random research to the rational design of molecules. Mckelvey and Orsenigo (2001) underline the advents of the so called molecular biology revolution and biotechnology as strong drivers for changes in drug discovery processes. Such changes highly influenced the companies' technological paths in the late 20th century (Mckelvey and Orsenigo, 2001; Tierney et al., 2013).

Nonetheless, these paradigm breaks did not seem to be enough to generate a creative destruction (in the sense proposed by Schumpeter, 1934), as one might expect. Instead, in most cases, complementary assets (Teece, 1986) – hard to be acquired or developed by newcomers – made the accumulation of knowledge not just an important success factor, but also a great barrier to market entry. This aspect is even more intensified if we consider the role assigned to patents in protecting the technical knowledge in the pharmaceutical industry. McKelvey and Orsenigo (2001, p.10) emphasize that this sector is one of the main environments where patents represent a strong knowledge protection: "because small variants in a molecule's structure can drastically alter its pharmacological properties, potential imitators often find it hard to work around the patent".

Despite the central role played by scientific knowledge in this industry, increasing investments in pharmaceutical R&D did not mean more drugs introduced in the market (Butler, 2008; Mccarthy, 2003). Among the potential causes for this apparent performance mismatch, figures not just the unpredictable complexity of biological systems, but also a lack of organizational approaches that help to make appropriate investments in technological areas that could lead to better numbers in terms of research productivity. Mccarthy (2003) also reinforces that roadmapping is an essential approach for the drug discovery process since it directly ties technology to business needs by using simple visual charts. In fact, the nature of many pharmaceutical innovations varies greatly from the architecturally stable product/technology platforms assumed in typical RMAs. Therefore, to some extent, it is difficult to apply some largely accepted roadmapping prescriptions to this context (Tierney et al., 2013).

Tierney et al. (2013) list a number of specificities associated with pharmaceutical innovations that increase the roadmapping complexity and motivate reflections to guide new experiences. For the purposes of the present study, we highlight three of them: (i) pharmaceutical innovations normally result from multiple root technologies and their interfaces. This is a strong challenge to the typical application of RMA, which recommends designating a single technology as the most important to an innovation; (ii) there is no dominant unit cell (as the transistor does for semiconductors), which usually nurtures the Y axis of the traditional RMA; (iii) there is no unique critical dimension for most new pharmaceutical innovations (as is the number of transistors for a given silicon area). Pharmaceutical innovations often require the technologies to improve on multiple dimensions. Sommer and Loch (2004, p.32) recognize the pharmaceutical industry as a typical example of a "selectionist" when "investing in back-up molecules for the same target indication to provide insurance if the lead molecule fails". The concept of "selectionism" is used in the literature to refer to parallel trials of multiple approaches, choosing the best one ex post based on the knowledge obtained from the first efforts (Sommer and Loch, 2004).

The pharmaceutical ecosystem comprises many different, increasingly interdependent agents (different types of firms, universities, public and private research centers, financial institutions, regulatory authorities, and so on). For instance, Butler (2008)

raises special expectations for public research centers to help cross the huge gap that has been advancing between biomedical researchers and the real clients of the discoveries. Public research centers may arise as fundamental agents, but especially for developing countries in the face of neglected diseases. Once these are not attractive markets for private companies, they represent an arena where public research can effectively reduce the distances between science and the local industry (Foladori, 2003; Trouiller et al., 2002).

3. Methodological considerations

The research method was action research (AR). In order to design and implement an alternative RMA, an AR project was conducted at René Rachou Research Center (CPqRR), a technical-scientific unit of Oswaldo Cruz Foundation (Fiocruz) – a R&D institution of the Brazilian Ministry of Health. This unit was founded in 1955 and has focused its R&D within the context of national public health, promoting improvements in diagnosis, treatment and control of numerous diseases.

AR is a research method for tackling problematical situations in which local actors work together with researchers to interactively make sense of perceived problems and search for adequate contextual solutions in non-controlled settings (Checkland and Holwell, 1998; Eden and Huxham, 1996). Therefore, differently from other research methods, AR emphasizes the collaboration between insiders (i.e. actors) and outside facilitators (i.e. researchers) in dealing with a real-world problem (Riordan, 1995). In this sense, AR is "research *in* action, rather than research *about* action" (Coughlan and Coghlan, 2002, p. 222).

The research reported in this paper was born and pulled from a real demand of – and to solve real problems faced by – the scientific institute. This was a special opportunity to study RMA in a new and complex setting. Despite that, the action research here reported is not similar to consultancy projects in, at least, these four aspects: (i) the greater rigor applied to investigation and documentation; (ii) the search for theoretical explanations for the events observed; (iii) the fewer constraints imposed in terms of time and budget; and (iv) the cyclical nature that characterized the research, instead of the linear nature of consultancy (Coughlan and Coghlan, 2002; Gummesson, 2000). Hence, action research cannot be reduced to action, because its conscious use explicitly implies the intention to refine knowledge by theoretically reflecting upon action – i.e. its process and results (Riordan, 1995).

Moreover, action research has been pointed as a research method particularly suitable to the study of strategizing processes (Balogun et al., 2003). Indeed, AR has also been successfully applied as the research approach for the development of roadmapping in other studies (e.g. Caetano and Amaral, 2011; Phaal et al., 2004, 2007, 2010). The richer in-loco information provided by immersion in a research context, direct observation and collaboratively planned actions also helped to overcome some barriers of a typical retrospective case-study, viz, the initial challenge in identifying an adequate case for the study, the problem with secondary data (both in terms of permission to access and of quality of the available documents), the interviewees' biases and distortions about what happened in the past and even their availability to the research purposes (Eisenhardt and Graebner, 2007).

The problematical situation that motivated the action research project was the need to identify opportunities for the nascent "Drug Discovery and Development Program" (P3D), which was exclusively focused on neglected diseases. The first milestone to implement this program was the proposal of the P3D "Structuring Project" (SP). This project was specifically aimed at identifying opportunities to define a long-term vision for P3D and an initial portfolio of relevant R&D project ideas that could serve as guidelines for future cooperative R&D efforts at CPqRR.

However, SP coordinators foresaw many challenges to the accomplishment of this preliminary objective. After all, the project would directly involve more than 15 experienced researchers from different fields – i.e. with different research trajectories and interests. Moreover, they were spread over many laboratories of this highly departmentalized institution. Most of them were specialized in a single disease and, thus, many of them had never worked together in a common project. In addition, the academic mindset prevailed at the center, with the publish-or-perish drive hindering collective efforts that would not clearly contribute to build up one's publication list.

In this context, a main expected effect of the P3D program was to promote research synergy to obtain R&D results that would transcend the boundaries of laboratories and represent institutional outcomes, tangible for the neglected diseases market. This intention is reflected in the program's mission, initially formulated as: to contribute to drug discovery and development, bringing together intra and extra institutional competencies through integrated research activities, in order to be recognized as a program of excellence, with a portfolio of projects ranging from the early stages of basic research to clinical trials.

However, how can one facilitate communication and foster this collaboration among participants in such a way that convergence around a shared vision could be achieved, aligning individual motivations? Help was needed and, thus, SP coordinators looked for expert support and an action research project was jointly conducted for 6 months.

RMA was considered an appropriate type of approach to tackle this problem. After all, its visual nature could contribute to establish a common language among participants, in such a way that workshops could serve as effective communication channels between previously irreconcilable perspectives. Moreover, its focus on opportunity identification had a perfect fit to SP's specific goal. Given the strategic importance ascribed to SP, the Center's director, one of its top managers and a key middle manager were the leaders (hereafter called "coordination team") of the project, alongside more than 15 research experts from CPqRR directly involved in neglected diseases.

After defining the team (both the research and organization teams) and the first alignments were set, a research diary and constant collective reflection were maintained to keep track of the learning process. More important, however, was the fact that the research process was collaborative from beginning to end (*c.f.* Balogun et al., 2003). In this regard, for example, a common practice was to hold pre-workshop simulations with key coordinators. In these preliminary pilot sessions, the feasibility of the proposed tasks

could be pre-tested and refinements introduced, helping to prevent frustrating workshop experiences. Indeed, even *a post-* assessment of workshop results was always done together with the local actors – eventually leading to process adjustments.

This action research project lasted 6 months, encompassed 10 workshops, involved more than 20 people from 3 organizations, and had positive repercussions both internally and externally. The next section presents the results of this collaborative work and provides an additional description of the intervention steps.

4. Case description and results

In this section, we present some details of the actions and the main results of the action research project conducted in CPqRR. They are categorized as "process" (i.e. the roadmapping effort and its associations to the organizational elements), "outcome" (i.e. the roadmaps as the objective deliverables of RMA, including other outcomes such as decisions made and action plans) and the "assessment" results (i.e. measurable impacts of AR in organization). The first two categories regard the nature of RMA itself as discussed in theoretical section as the central object of the research. This covers other observations made along the AR project from data collection to implementation. The last one regard the fact that AR is fundamentally about change and the "assessment" characterizes the last recommended phase of an AR project (Coughlan and Coghlan, 2002)

4.1. The approach's process

In general, RMA starts by the identification of a single area of interest for roadmap-based exploration. However, in P3D, the coordinators could not preliminarily find a would-be broadly accepted area of interest. They considered it unfeasible to select a single neglected disease without losing the commitment of key participants. In fact, they saw the possibility of conducting parallel roadmapping processes for the main diseases of interest as a desirable collective learning experience on its own. Thus, they chose four diseases to be explored simultaneously: Chagas disease; leishmaniasis; schistosomiasis; and dengue. In the context of neglected diseases, this choice is also justified by the associated public health statistics, which is a strong driver for the strategy of a public research unit, instead of just considering "market" or "target-niches" (Foladori, 2003).

After all, to explore the full scope of an area of interest at once would be unfeasible, since even the specific scope of activity of the participants representing each of the main technical-scientific fields was not clearly known by the other participants yet. In addition, much information needed to ground a well-informed discussion of R&D "roads" to follow was not readily available. In fact, a systematic external analysis regarding each neglected disease (i.e. patents, clinical trials, trends etc.) was considered necessary before discussing ways forward for P3D-related R&D, a problem also recognized by Tierney et al. (2013).

Another crucial aspect was observed when asking participants to plot these future paths on the roadmap at the same time they plotted their past trajectories and present states – as well as align them with the stories of others and of the organization itself. Participants were not used to the roadmapping visual language yet. Thus, asking them to represent (all at once) multiple layers of interconnected information over a time axis would be a naive oversimplification of an undeniably complex task for that context. Hence, the general feeling among coordinators was that exploring the full scope of each area of interest all at once would be overwhelming and, as such, would possibly impair the quality of roadmaps and the engagement of participants with subsequent activities. Therefore, an alternative way of sequencing the overall roadmapping process was designed, arranging roadmapping stages according with the main time intervals of the roadmap. (Fig. 1).

At first, participants should focus exclusively on past-to-present issues. By doing so, they could, firstly, learn more of the visualization process by dealing, mainly, with already known content. Then, once they got used to roadmap-based representations, the second roadmapping stage should focus on present-to-future discussions. At this point, the obtainment and social construction of new content using the visual language would, finally, be the emphasis.

In short, participants dealt with multiple layers but with only a single time column at a time. Thus, they were meant to think of layers in an integrated manner, so their plotted stories were meaningful (i.e. explicit connections between know-why, –what and –how). Nevertheless, they did not need to represent the overall picture at once; they could separate focus, initially, on what was already consolidated history before embarking on prospective path creation. This was in alignment with the complexity represented by capabilities accumulation paths that mark the organizational level, but also the people/team level of analysis, once, as mentioned, highly specialized education and individualized work were prominent characteristics of that environment.

Once the complete roadmaps (i.e. past-to-future) were obtained, participants should consolidate a portfolio of the opportunities identified during the roadmapping workshops (Oliveira and Rozenfeld, 2010). Based on these results (i.e. maps and portfolios), they should finally choose a single area of interest in which P3D should focus the most – considering its limited availability of resources.

In order to better design the workshop dynamics, a simulation of roadmapping processes was previously done with the main coordinators of the program. From this experience, it became clear that mapping activities should begin by groups of researchers sharing similar expertise (i.e. biological tests; chemistry; genomics; immunology). Then, after each group had consolidated their own perspective, they would be able to compare their maps and integrate the main points in a single program-level roadmap for each neglected disease. Therefore, both in the past-to-present workshops and in the present-to-future ones, participants would firstly build their research group perspective roadmap to subsequently discuss and articulate it with the maps from other groups.

For example, in the present-to-future roadmapping stage, participants were initially asked to represent the possible future paths of their research groups in the roadmap structure – in light of past trajectories and of the preliminary external analysis done. Then, these

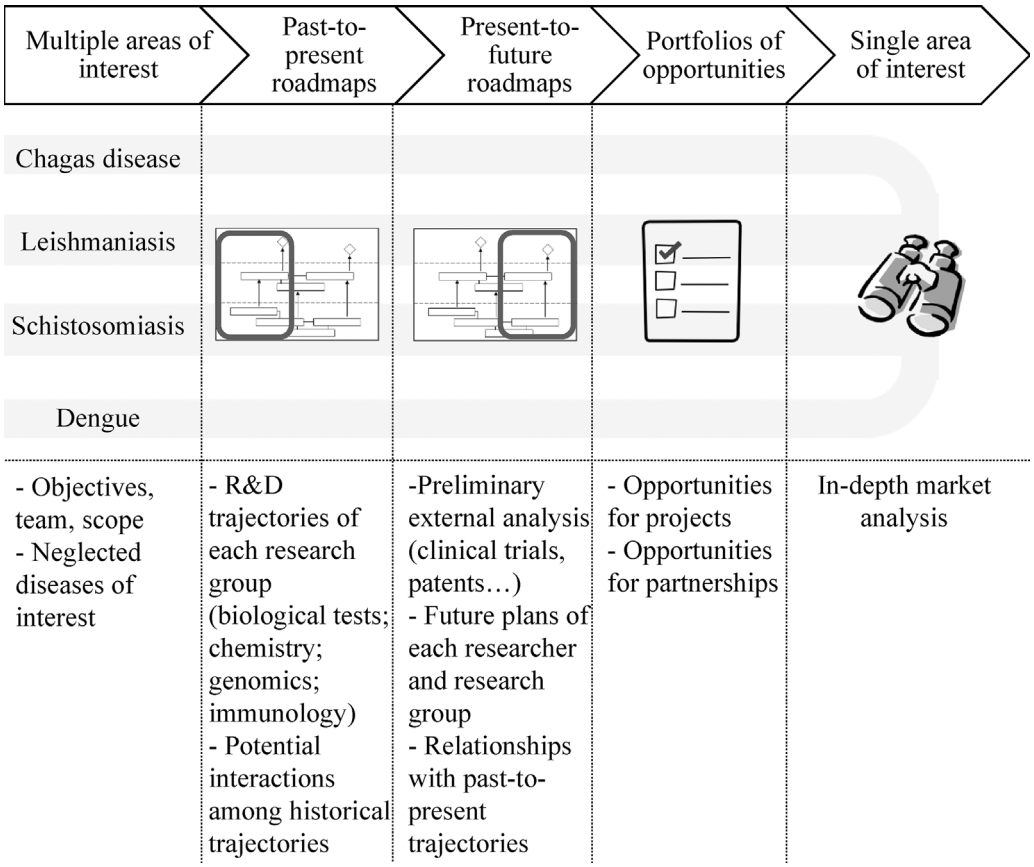

Fig. 1. Stages and main results of the roadmapping process. Elaborated by the authors.

roadmaps served as an input for each disease-oriented workshop, in which groups needed to discuss their perspectives in order to integrate a common way forward, for each specific neglected disease.[3]

4.2. The outcomes of the approach

"Outcomes" refer to all the results that were obtained as products of the roadmapping process. Besides the roadmaps themselves, these results include the choice of one area of interest to focus on and the constitution of a portfolio of opportunities for each neglected disease.

4.2.1. Roadmaps

The 10 workshops resulted in 19 roadmaps – 11 focused on past-to-present and 8 on present-to-future. Maps were constructed for: each neglected disease (past-to-present and present-to-future); and each research group, in more detail. Fig. 2 shows an example of one of a past-to-present map.

The temporal dimension of the roadmaps was divided into past, past-present and future. This division considered the possibility that some projects that were no longer in execution (i.e. past) could influence the present and future innovation strategy of the CPqRR – and, perhaps, should be restarted. It also reflected the fact that several ongoing projects had started in the past or were related to past projects (i.e. past-present). Furthermore, future innovation "roads" should be related to present and past efforts (i.e. path-dependent future), in opposition to a common RMA bias that external information is privileged in strategizing process and recognizing the capabilities accumulated through past experiences as a counter-balance argument.

Layers were divided as follows: the upper layer encompassed the external environment (i.e. market and institutional factors); the lower layer, the internal environment (i.e. resources); and the middle layer, the value delivered by the organization – which, in the case of the organization under analysis (i.e. a R&D institution), was represented by technologies (not products).

The upper layer was further subdivided into three sublayers. The "macro environment" sublayer contained information which could impact the whole health sector, such as: trends and drivers of international basic research; renewed interest in natural products; and development of molecular tools, among others. The "market" sublayer referred to the health sector itself – e.g. information

[3] In all workshops, the traditional post-it-based process of roadmap construction (*c.f.* Phaal et al., 2010) was adopted.

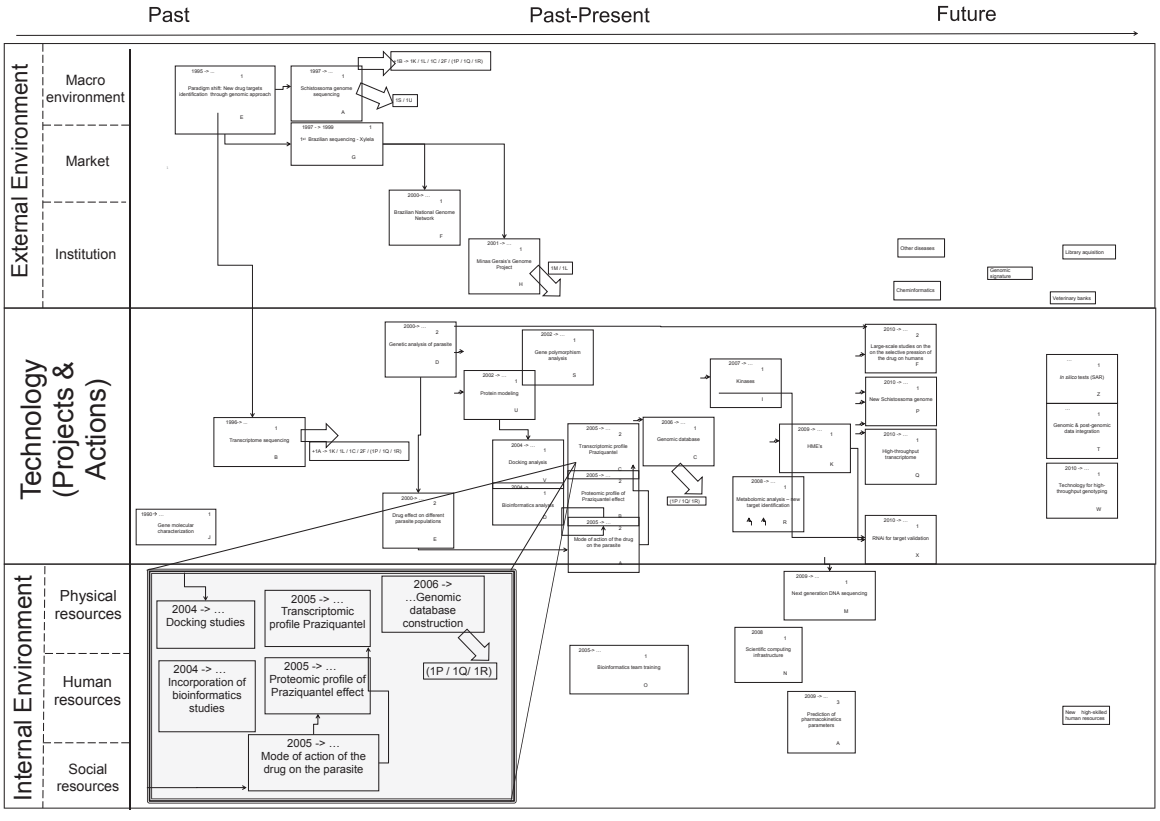

Fig. 2. A past-to-present roadmap. (Due to its illustrative purpose, only a small subset of the roadmap'selements is made readable − i.e. the lower left-side.) Elaborated by the authors.

regarding investment of the pharmaceutical industry on specific diseases and lack of infant formulation for some diseases. Finally, the "institution" sublayer encompassed broad strategic drivers of Fiocruz (e.g. work policies; guideline for bioinformatics). Similarly, "internal environment" was further subdivided into the three types of resources considered critical by P3D team coordinators: physical (i.e. equipment), human (i.e. hiring needs) and social (i.e. partnerships). Important to note partnerships in this context as an advent primarily influenced by social interactions rather than institutional efforts.

In the future-oriented roadmaps, the technology layer was further subdivided into the following sublayers, concerning the main stages of drug R&D: target to hit; hit to lead; lead optimization; preclinical; and phase I, II and III of clinical trials. This division was done to identify on which stages the institution's R&D projects were concentrated. Connections with past-to-present roadmap elements were depicted in the first column. Moreover, in these maps, the time horizon was further subdivided into: "next steps", representing the near future; and "vision", related to a long-term perspective (e.g. Fig. 3, focused on the central technology layer of a future-oriented roadmap).

Due to the construction of the 19 roadmaps, one of the most important outcomes of the roadmapping initiative in P3D was the recognition, by participants, of previously overlooked organizational strengths and weaknesses. Some competence gaps in the institution, for example, were not acknowledged until they became explicit by the concentration of project proposals in a relatively small subset of the R&D-related layers of future-oriented roadmaps (i.e. from target to lead optimization – see Fig. 3). Similarly, collective awareness of some important resources and research results achieved by participants did not emerge until past trajectories were presented and discussed in the retrospective workshops. Indeed, these new perceptions turned out to play a central role in the assessment of the fitness of opportunities to organizational capabilities, as well as in the suggestion of many previously unthinkable opportunities.

4.2.2. Choice of an area of interest

Participants could achieve a satisfactory consensus about which neglected disease to prioritize after they saw the results of the concomitant construction of roadmaps. Based on the resultant maps, participants of all workshops were asked to individually write down which disease they would choose and why they would not choose the others. A total of 80% of 15 respondents chose leishmaniasis. All the "generalists" (i.e. researchers involved with all four diseases, representing 46.67% of total) were included in this percentage, as well as many of the specialists in the other diseases. Moreover, in all six broad criteria derived from the answers (i.e. relevance to the market; technical considerations; installed capacity; structuring/integrating character; involvement of P3D team; opportunities for partnership), leishmaniasis was the only disease which had many strong arguments in its favor (e.g. availability of

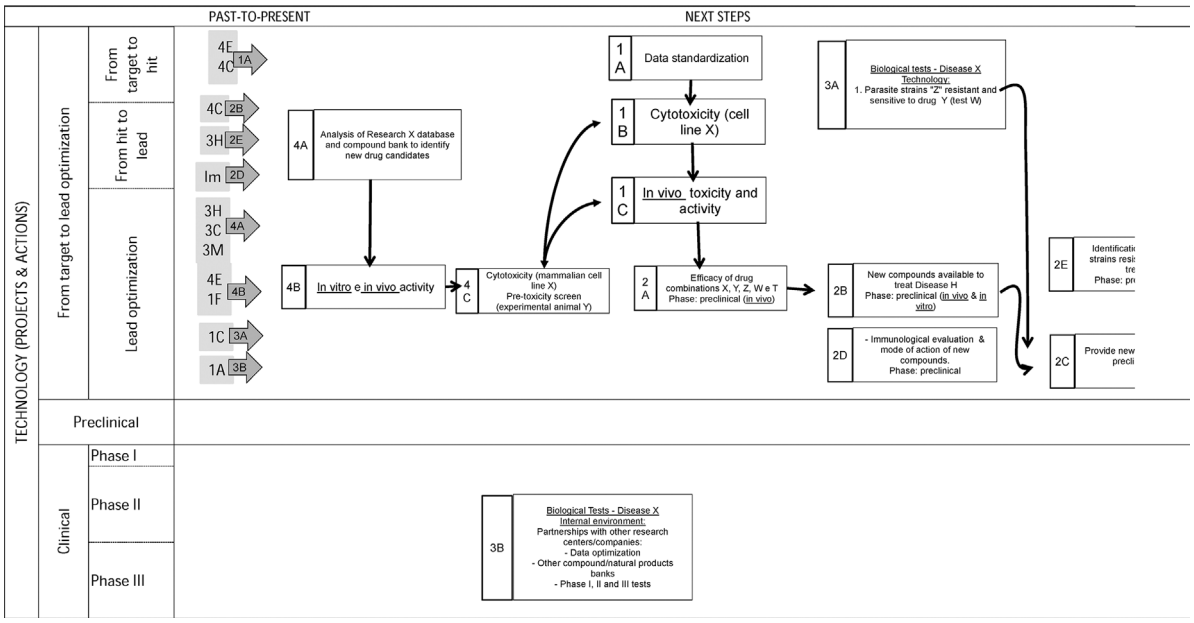

Fig. 3. The technology layer of a future-oriented roadmap. Elaborated by the authors.

human and technical resources for R&D in the institution; possibility of integration between experts from different areas) and just a few – and weak – ones against it.

Based on the presentation of these results, it was consensual that this disease should be prioritized. Hence, the simultaneous consideration of multiple areas of interest helped initially irreconcilable opinions to converge, keeping P3D members engaged with the program even after a single disease was selected to be its focus. Indeed, after the selection of leishmaniasis as the target disease, a comprehensive analysis of the external environment related to this neglected disease was carried out.

4.2.3. Portfolios of opportunities

For each of the four neglected diseases, an initial portfolio of opportunities was set up, based on the roadmaps. Participants classified each opportunity as "project" or "partnership" (Table 1).

In total, participants agreed upon 81 opportunities. It was surprising that, for all neglected diseases, the final portfolio of opportunities resulted, to a great extent, from new combinations of either a strength–strength or a strength-weakness nature (i.e. with no external factors). In the former, a desirable "synergistic" effect was envisaged if the link could be established. In the latter, a strengthening of the weakness by the existing strength (i.e. a "monergistic" effect) was expected. Thus, enhancements in the overall organizational performance were expected from internal combinations of research groups – if they prove to be viable.

4.3. The assessments and feedback of the approach

A RMA is typically an initiative aimed at long-term outcomes and so are its measurable impacts on organizational performance. Objective results depend on strong commitment to the actions outlined over time by managers. Also, RMA is not designed to be a punctual experiment, but rather a discipline in the organizational environment. Meanwhile, since the main value of RMA may really come from the "roadmapping" rather than "the roadmap" itself, and in order to assess whether the designed RMA was considered able to satisfactorily support OI in P3D, SP group leaders were asked to answer a questionnaire. Due to its focus on the assessment of

Table 1
Part of the portfolio of opportunities for projects and partnerships. Elaborated by the authors.

Neglected disease	Category	Description
Chagas disease	Partnership	Tridimensional structures (crystallography)
Chagas disease	Project	Analysis of the proteomics and transcriptomics data bank
Leishmaniasis	Project	Development of fluorescent leishmanias
Leishmaniasis	Project	Development of ADMET tests *in silico*
Schistosomiasis	Partnership	Intravital microscopy
Schistosomiasis	Project	Citofluorimetry tests with fluorescent microspheres
Dengue	Project	Chemoinformatics to identify immunomodulators
Dengue	Partnership	Serum and cell banks

Table 2
Percentage of respondents per degree of agreement with Eppler and Platts's questionnaire items (Eppler and Platts, 2009), omitting values equal to 0.00%. Total of 13 respondents. Elaborated by the authors.

	Degree of agreement				
	Completely disagree	Mostly disagree	Mostly agree	Completely agree	Unable to assess yet
Availability of information: information gathering for roadmapping was viable			7.69%	84.62%	7.69%
Timing: workshops' agendas were appropriate			30.77%	61.54%	7.69%
Participation: all workshop attendants had the opportunity to participate		7.69%	30.77%	53.85%	7.69%
Clarity: the roadmapping process was clear			7.69%	92.31%	
Ease of use: it was easy to perform the roadmapping process			46.15%	46.15%	7.69%
Appropriateness: the designed process fitted the specific context			15.38%	69.23%	15.38%
Relevance: the roadmapping process and the constructed roadmaps were relevant		15.38%	15.38%	61.54%	7.69%
Usefulness: the roadmapping process and the constructed roadmaps will be useful			23.08%	61.54%	15.38%
Facilitation: process facilitation by outsiders was useful			7.69%	84.62%	7.69%

visualization practices in strategizing processes, Eppler and Plattsö (2009) questionnaire was used in an adapted version. Results are shown in Table 2.

In general, the RMA got highly positive feedbacks. In all items, most of the answers corresponded to the option "completely agree". This strong agreement among P3D participants shows that the designed RMA was perceived as satisfactorily fulfilling its purpose in all aspects considered. "Ease of use" was the only item for which the answers in the "completely agree" was lower than 50%. This evidence points to the need to further simplify the approach to better introduce it into new contexts. "Time" and "participation" items also presented relatively high percentage of answers in the "mostly agree" category. This reflects the fact that, in the first two workshops, the proposed agenda limited available time and opportunity for participation during the presentation and discussion of roadmaps – a problem solved in the subsequent workshops. Finally, there were many "unable to assess yet" responses, with regard to the "appropriateness" and "usefulness". This was an expected result, since the pursuing of the identified opportunities was still to be proven over time through concrete exploitation actions.

Some examples of written comments reinforce the perceived benefits of RMA for the organization: "We are enjoying the process, because it is binding us together", "The work was well planned, and the discussions were stimulating and productive", "It was an extremely rich moment for group self-knowledge. Process dynamics were very useful. Facilitators' ability to listen and synthesize ideas was remarkable". Furthermore, other internal repercussions after the completion of the AR project corroborate the above-mentioned perceptions. For instance, a P3D-dedicated project management group was created by participants to provide guidelines for project submission, aligned with R&D finance function. In addition, new R&D internal partnerships were established between the research groups of bioinformatics and chemistry of natural products and between the latter and the groups that develop research projects regarding dengue virus and yellow fever virus. Finally, SP was presented by P3D coordinators as an exemplary success case in a workshop at Fiocruz headquarters, which involved many leaders from other major divisions of the institution.

5. Discussion and implications for theory and practice in innovation management

The first three topics of this section, discusses the main inferences that can be drawn from the evidence and their direct implications for RMA applications. After, more broad implications for the theory and practice of innovation management and its underlying methods and techniques are brought.

5.1. Alternative areas of interest

The current format of RMA assumes that the owners of a roadmapping initiative will select only one area of interest at a time (Phaal et al., 2007, 2010). However, as the case illustrates, this assumption may need to be abandoned when dealing with complex strategizing situations, as observed in the pharmaceutical industry (Mccarthy, 2003; Showalter and Denny, 2008; Tierney et al., 2013).

In this context, agreements about which area to select for further identification and exploration of opportunities can be specially challenging and are potentially associated with conflicts concerning resource allocation. Poor results of a quick iteration, instead of facilitating the introduction of roadmapping in a given context, represent another potential problem. After all, in the absence of a clear set of objective criteria to assess collective investment options, the simultaneous construction of roadmaps representing each alternative provided a common ground for achieving a reasonably consensual agreement among decision-makers and – even in the case of no agreement at this step, the execution of parallel maps may strongly support "selectionist strategies" often applied in pharmaceutic environments (Sommer and Loch, 2004). Obviously, the reported case may represent a relatively lengthy and resource-

intensive consensus-seeking initiative. A quicker and lighter version of the process may be desirable in other applications.

5.2. Timeframe-based process

The reported experience proposes a timeframe-based process. It proved to be beneficial in many specific ways. Firstly, it indeed facilitated the introduction of roadmapping in P3D. Thus, the proposed process played helped to overcome common challenges imposed on the first roadmap-based intervention in an organization (*c.f.* Phaal et al., 2010).

Additionally, sequencing roadmapping stages according with a roadmap time axis provided, not only a quicker way to grasp the visual language, but also the attainment of high-quality outcomes at each stage. Having a part of the process exclusively focused on past-to-present issues helped participants to better appreciate the organizational background and path dependencies (Bell and Pavitt, 1995; Figueiredo, 2002) before launching themselves into future-oriented discussions (*c.f.* Freitas et al., 2013). Moreover, in assigning the same weight to past and future, it allowed participants to appropriately identify points of alignment between their stories much earlier in the process, leading to the construction of past-oriented roadmaps that were solid enough to be seen as a valuable result on their own (see Fig. 2).

Finally, the timeframe-based process neither imposed on participants the possibly overwhelming demand to construct a complete roadmap at once nor left them with multiple separately filled layers to be consistently aligned in one final charting step – as emphasized by Geum et al. (2015). By treating each main time interval separately and approaching layers in an integrated manner in each stage, this alternative proposal helped to tackle complexities associated with the scope-based and layer-based sequences, respectively.

Nevertheless, it may be argued that this arrangement of the process – first, past; then, future – can hinder the ideation of radical innovations. Although we recognize this as valid tension, the associated concerns should be lightened in environments where innovation is predominantly a result of codified scientific and technical knowledge. Thus, past trajectories must be considered (among other inputs) in suggesting collectively meaningful paths forward.

5.3. Overlooked organizational strengths and weaknesses

The current RMA emphasis on “opportunity” as an external element may hinder a deeper appreciation of internal strategic factors and relevant inside-out strategies. Therefore, we propose a broader recognition of strengths and weaknesses during roadmapping. In the case here reported, constructing roadmaps was strongly helpful in highlighting organizational strengths and weaknesses, which were previously unacknowledged due to the complexity of the technological dynamics and the rigid internal boundaries of the scientific unit. Thus, designing the structure of roadmaps in a way that may visually indicate “where” the organization is can also be helpful (Fig. 3). Therefore, given its potential benefits, investing more on the “inside and backwards” logic in roadmap-based explorations is neither a possible distraction nor a loss of time.

5.4. Sectoral contingencies and the refinement of management methods and tools

Since every method or tool is a product of its context (Cheng, 2003), research advances in new managerial approaches intended to support innovative efforts in organizations (such as the RMA) must carefully consider the exploitation of sectoral contingencies for guiding (and evaluating) refinements or even support new propositions. In the present research, such a possibility arose as a relevant strategy to unwrap assumptions that characterize the classical RMA, discuss its prescriptions in the light of new contingencies and test new ways to adapt and improve current theory. So, findings about the limitations and potentialities of the approach become better grounded. In the case reported, this rationale allowed the research team to explore the RMA flexibility without loosing its structured character.

Additionally, throughout this AR project, much of what the research team initially interpreted as new insights that emerged from the field, were, in fact, predictable manifestations of sectoral contingencies in the specific organizational set. These contingencies, if first scrutinized and leveled among the participants could lead to a more efficient learning process and decision making. Conversely, reflections motivated by such contingencies seem to be helpful in dealing with the typical generalization problems of single-case research.

5.5. Implications for current paradigms in innovation management

At first sight, conducting roadmapping in a time-frame basis or mapping multiple areas of interest instead of just one – among other particularities of this study – may sound just as obvious, although unexplored, options. Nonetheless, these aspects fostered reflections on method and its basic assumptions as well as the application in the given context. The following topics explore these implications, detailing in which ways the study contrasts to the dominant literature.

i Conducting roadmapping in a time-frame basis dramatically changes the workshop dynamics, as so as the mediation skills required from RMA specialists. Taking the case here reported, science-intensive organizations are characterized by poorly integrated structures and weak communication among departments or even among R&D people from different disciplines. Each “micro organization” has its own language and way to measure its advances. Thus, challenges concerning the collaborative setting of common goals are intensified. A typical pharmaceutical organization deal with long development times (central layers),

challenging social demands and regulatory protocols (layers above); and complex funding structures, networks and technological infrastructure (layers below). Our proposal directly tackles with this challenge by using the time-frame basis as a robust integration approach.

ii Technical-scientific advances can trigger multiple opportunities in different fields of application, which has no parallels in cases in which the product architectures are more stable (e.g. automobiles or electronic devices). Thus, slow planning, one step at a time, can be preferable to roadmapping faster. Like a chess game, the full potential of each movement is not clear before we simulate many possibilities forward. Moreover, some sectors like the pharmaceutical face a mad-race among substitute (sometimes complementary) solutions for the same problems. Medicines, medical devices, various alternative therapies, preventive actions of a social nature (especially in the case of zoonoses), among others require constant monitoring since they can strongly impact on the strategic decisions in OI.

iii Contingency adaptation of tools, methods and other management approaches is a prominent – if not urgent – alternative in innovation research. The generalist pretension of typical managerial approaches after successful applications in their original environments often falls in the face of the challenges imposed by new organizational contexts. As a consequence, methods of great prominence seem to get old, whilst new “one fits all” promises come to be the new management fashion (e.g. design thinking, lean startup). Contingency adaptations of well-known methods (e.g. RMA, QFD), or even of the new ones, go against this way by taking advantage of consolidated knowledge, but deeply exploring its limits and subjacent assumptions. Studies like Shenhar and Dvir (2007); Salerno et al. (2015) (in project management and innovation processes fields respectively) illustrate this effort.

iv By building past and past-to-present roadmaps we contrast the dominant approach of outside-in to OI, that reinforces the notion that true innovations always come from punctual revolutions. At least for an organizational perspective, an inside-out rationale is especially required by certain types of companies and sectors that are strongly path-dependent. As the present case confirms, some innovations results from mature technological capability, built upon decades of experience, acquisition of specialized assets and learning processes. This environment claims for adapted approaches to innovation management such as RMA.

6. Conclusions

This paper reports an action research project conducted to design and implement an alternative roadmapping approach, in an attempt to adapt RMA in its capacity to tackle opportunity identification problems in an extremely complex strategizing situation found in pharmaceutics, a typical example of a science-intensive sector (Pavitt, 1984). The research setting was a R&D institution – a major technical-scientific unit of the Brazilian Ministry of Health, where many contextual factors made the need to identify opportunities for drug discovery and development for neglected diseases an amazingly entangled challenge.

Results suggest that the designed RMA could satisfactorily support OI in this situation. Moreover, the analysis of these results led to discussions that may be valuable to the development of roadmapping practices and other managerial approaches intended to support innovation management in organizations.

Important sectoral contingencies of the pharmaceutical industry could be observed and influenced many decisions made during research, raising considerations on how such contingencies may fuel research in management topics. In relation to the roadmapping literature, this paper adds an alternative proposal on how to conduct the roadmap construction process, namely: by considering multiple areas of interest in parallel and sequencing the stages according to the roadmap time axis. Potential benefits of these methodological shifts were presented, based on the AR project evidence. In addition, the ability of this new RMA to highlight previously unacknowledged organizational strengths and weaknesses was stressed in contrast to the potential bias of the original approach towards external strategic factors.

Therefore, summing up with other recent reported experiences with RMA, this research is connected to the new generation of studies in this field, as well as with research demands. The present contributions also inspire future work at least in the following topics (i) working on the refinement of practical applications to establish innovation-related approaches as systematized disciplines (including the integration of tools and methods into innovation management systems, aiming at consolidating innovation as a routine in organizations); (ii) integrating sectoral-technological and organizational specificities to the analysis to support roadmapping in industry level, especially for emergent complex chains such as nanotechnology or internet of things; (iii) exploring the interface between roadmapping and innovation/corporate strategy for high dynamic sectors; and (iv) proposing new contingency adaptations for consolidated tools and methods, expanding their potential to support innovation initiatives and organizational integration. We hope that this accumulation of case studies and action research interventions in diverse contexts contribute to the development of new concepts, theories and practices related to roadmapping and innovation management.

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