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Proposition of a dynamic approach for a technology roadmap

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1. STATEMENT OF PROBLEM

The academic spin-offs may face highly mutant contexts, marked by unforeseeable uncertainties, which are related to the inability of articulating, in advance, all the variables relevant to business performance (SOMMER; LOCH, 2004) and the complexity, which consists in the difficulty of mapping the variables and their functional relationships (SOMMER; LOCH, 2004), the emergence of events, the ambiguity and the non-linearity in the development course of the new venture (BORGATTI, 2008; DEMO, 2002; AUTIO, 1997). In such contexts, the survival of an academic spin-off is directly related to the ability of entrepreneurs to restructure the business in face of the emergence of unforeseeable uncertainties and complexity (SOMMER; LOCH; DONG, 2009), learning and unlearning with the new (VOHORA *et al*., 2002), which may require new approaches to management (PICH; LOCH; MEYER, 2002). Based on literature review, on an intervention in the light of action research and on three case studies, this article will propose a dynamic approach that seeks to integrate two processes: the roadmapping and the implementation of the technology roadmap.

Technology Roadmapping method has been spreading and consolidating as one of the most recognized management techniques to support innovation and strategy for firms and industry (PHAAL; MULLER, 2009; LEE *et al.*, 2009; PHAAL *et al.*, 2004). The method has been used to design policies and develop strategic plans for innovation and development of sectors. It has been used to support in forecasting the evolution of a technological trajectory (PHAAL *et al*., 2004). For example, roadmaps designed by the semiconductor industry in the United States to understand the evolution of semiconductors and to align efforts among the various actors involved, such as companies, universities and research institutes. In the context of firms, the method has been used to assist firms on the challenge of dealing with the evolution and revolutions

caused by radical innovations (VOJAK; CHAMBER, 2004), generating as main benefit an improvement on communication (usually graphical) throughout the organization, aligning different perspectives such as technological and commercial, allowing a better balance between technology push and market pull (PHAAL; MULLER, 2009; PHAAL *et al.*, 2004).

Despite the growing number of publications on the TRM, there are few studies dealing with its application in the context of academic spin-offs. Which is impressive, after all one of the central problems in this kind of venture is precisely the technological planning activity, seeking to assist the transition of technology from the academic world to the market world (ROBERTS, 1991; SHANE, 2004). In the context of spin-offs, the TRM method would allow entrepreneurs to better understand the possible unfoldments of a technology and emerging technological trajectory, seeking to identify new products and services that could be offered to the market.

The academic spin-offs can be defined as organizations created in order to allow a formal or informal transfer of technology and knowledge generated in institutions of science and technology (universities, research centers, etc.) by launching products and services on the market (HEIRMAN; CLARYSSE, 2007; SHANE, 2004; ROBERTS, 1991). This kind of firm has attracted the attention of academic and policy communities over the last two decades due to the possibility of generating wealth from the results of academic research (MUSTAR *et al*., 2005).

One of the major problems in supporting the creation and management of this kind of firm is that much of the management literature is still predominantly focused on assisting managers at established and stable sectors, industries, markets or niches (SARASVATHY, 2001). Traditional methods of planning, including the Technology Roadmap in its original conception (PHAAL *et al*., 2004), are better suited to analyze

existing contexts in which products, customers and competitors are known (SARASVATHY, 2001; DAY *et al.*, 2000). The creation of new markets through the introduction and commercialization of radical innovations, as is the case and the purpose of creating an academic spin-off, requires new management approaches (see BIAZZO, 2009; PHILLIPS *et al*., 2006; O'CONNOR, 1998; 2005; DAY *et al*., 2000), even for the planning process (SOMMER; LOCH, 2004; COURTNEY, *et al*., 1997) and therefore the technology planning.

These new management approaches aim to deal with the unforeseeable uncertainty and the complexity present at birth or in the formation of a sector, industry, market or niche. Phaal *et al*. (2004) suggests that the TRM can be applied in turbulent and dynamic contexts, but these researchers address only the foreseeable uncertainty (being aligned with the authors of the traditional risk management). Phaal et al. does not suggest how unforeseeable uncertainty and complexity should be managed. This paper aims to fill this gap by proposing a new process of roadmapping, more suitable for academic spin-offs.

In this sense, this work has three contributions. The first consists in proposing a new process to facilitate the application of the technology roadmap (TRM) in the context of an academic spin-off, according to its characteristics, such as being born in a non-commercial environment, the transition it goes through from the world of science to the market and the lack or scarcity of resources it presents. The proposed road mapping is different from the T-Plan, intended to serve as a reference for companies without experience in the technique (PHAAL *et al*., 2004). The T-Plan consists in a guide structured in four workshops, which aims to quickly start TRM method. However, the T-Plan appears more suitable for firms established in more mature contexts or markets. Furthermore, the roadmapping is a further step of strategic planning, being fed of its

decisions. The second contribution of this work is to incorporate the strategic planning to roadmapping. The results obtained in field research suggest that the roadmapping is a simultaneous process to strategic planning. These results indicate that strategic planning does not follow the logic of one type fits all. Because of the uncertainty and complexity, the formation of the new venture strategy combines both deliberate and emergent strategies (MINTZBERG, 2004), modifying and being modified by the emergence of new events, information and learning throughout the development of the enterprise. The third contribution is to propose the integration between the development and implementation of TRM, treated separately in the literature.

In order to achieve the intended objectives, the article was organized in four parts. The first provides a review of the literature on the technology roadmapping method, complex thinking and paradigm of complexity, and new management approaches. The second stage presents the definition and description of the methodological strategies. On the third stage it is carried out an analysis of the results obtained in the field and it is suggested an improvement on the practice of technology roadmapping method, employing a dynamic approach.

2. METHODOLOGICAL BACKGROUND

This paper is aligned with a recent effort of the management literature, particularly of the strategy, to understand the practice of the use of methods, techniques and concepts. In this sense, this paper combines two strategies: three case studies and action research.

Through the employment of case studies methodology, it was possible to understand the whole process of application and adaptation of the technology roadmapping method to assist the processes of the strategic and technological planning

of an academic spin-off. The methodological framework that assisted the structuring of the case study is based on Eisenhardt (1989) and Voss *et al.* (2002).

Based on lessons learned in the case study, we designed a structured guide to assist in strategic and technological planning of a spin-off. This step contributes to practice, while trying to solve a real problem, and to theory, allowing the proposal a new structured process of technology roadmapping elaboration and implementation. To outline the methodological background for action research, this work was inspired by the framework proposed by Miguel (2009): Eden and Huxham (1996), Thiollent (1997), Checkland and Holwell (1998), Coughlan and Coghlan (2002).

2.1. Case Study background

Voss *et al*. (2002) argue that the methodology of case study is particularly useful when the goal of a research is to attain a deep understanding of a phenomenon (or method), in order to propose a new model or a new theory (EISENHARDT, 1989). This is consistent with the purpose of the research, to propose a dynamic approach to technology roadmapping method for academic spin-offs. This study will seek to understand which are the process variables in the context of academic spin-offs and relationships between them.

To meet the goals of this research, field research was structured as follows: i-drafting of protocols and research tools ii-definition of an universe of criteria for defining potential cases to be investigated; iii-selection of cases, iv-conduction of field research, and v- the model proposition.

Voss *et al.* (2002) point out that the validity of the results obtained in a case study depends on the rigor of the design of the protocols and research tools. The protocols were developed from the review of the literature on strategic planning,

technology roadmap and academic spin-offs. These protocols correspond to the key questions that guided the preparation of questionnaires that were applied in the cases.

The approach chosen for the selection of cases was intentional or theoretical, which is appropriate when the objective of the research is to propose or develop a new theory or model (EISENHARDT, 1988). A list of ten potential spin-offs that could be studied was elaborated. For the selection of cases to be investigated, three criteria were analyzed: i- relevance ii- being born to exploit a radical innovation, and iii- having applied the method to support the strategic and technological planning. Three of the ten spin-offs from the original list have met the above criteria: spin-off (A), spin-off (C) and spin-off (D),

The spin-off A was investigated for 12 months, which allowed us to accompany the evolution of the undertaking, the issues that arose for its viability and the process of elaboration and implementation of the technology roadmapping. For that, we interviewed all the spin-off's founders (i.e. 100% of human resource development). The spin-off C and D were investigated for 3 months. We interviewed all the spin-offs founders.

The results of this phase of research contributed to the construction of a dynamic approach for technology roadmapping. This approach was applied in the light of action research.

2.2. Action Research background

Action research is an empirical methodology dedicated to the intervention in a real organizational context, with the purpose of resolving a problem or a problematic situation with the involvement of researchers and participants representing the context (THIOLLENT, 1997). Action research is a methodology focused on social situations that deal with subjective aspects such as world views, political and cultural aspects

(CHECKLAND; HOLWEEL, 1981). The scholars of this methodology do not make assumptions, but act on problems and challenges of an organizational nature (MIGUEL, 2009).

Coughlan and Coghlan (2002) enrich the understanding of this strategy research by proposing a set of characteristics, described in Table 1. These characteristics served to structure and organize the intervention.

Features	**The intervention made**
The researcher takes action (its role is not limited to an observer)	The researcher participated in weekly meetings with the entrepreneurs in order to apply and adapt the technology roadmapping method. This allowed us to attain a better understanding about the difficulties and about how the method was applied in practice.
Action research has two objectives: i-solve a problem; ii-contribute to science	The problem to be solved was the strategic and technological planning. The contribution to the literature is the proposition of a new approach to technology roadmapping, different from the current T-Plan approach (Phaal et al., 2004)
Action research is interactive (cooperation and interaction among stakeholders)	Miguel (2009) suggests two dimensions to measure the interactivity: the intensity (with stakeholders) and the extension. The intensity involves all the founding members of the company, while the extension consisted of weekly meetings of three hours over 28 weeks, in addition to several informal visits to the laboratory.
Action research aims to develop a holistic understanding	To carry out the strategic and technological planning of the venture it was required to carry out a broad theoretical study: i-literature of strategic planning of the traditional type Porter (1985) and Mintzberg (2004), ii-Technology Roadmappping literature iii-new management approaches, iv - complexity theory and complex thinking, and v-knowledge management. The study also had a large empirical scope involving interviews with the director of the incubator, investors, technology transfer offices, other entrepreneurs and businessmen, formal and informal visits to suppliers, etc..
Action research is fundamentally related to change	The spin-off is an undertaking that represents a transition (change) from an academic environment (not commercial) to a commercial and capitalist one. The intervention aimed to assist in this process of change.
Action research may include different methods and techniques of data collection (quantitative and qualitative)	The conduction of the research employed qualitative techniques for data collection as writing a board diary, minutes of meetings, elaboration of presentations for the team of entrepreneurs and other actions.

Action research should be conducted in real time (a case study "live")	The formal and informal contact with researchers for 28 weeks allowed us to monitor in real time all the dilemmas and problems involved with strategic planning and technological development (implementation) of business.
Action research requires its own criteria for quality evaluation.	The criteria developed to measure the quality of the intervention were feedback presentations to researchers on the planning of academic spin-offs, with entrepreneurs, consultants, and participating in events and presentations to investors.

Table 1 - Adapted from Miguel (2009)

Table 1 shows the relationship between the desired characteristics for carrying out a search in the light of action research and what was done in practice. The credibility and validity of a search increases with the accuracy of these characteristics. Besides, the research was also structured in the light of the research of Coughlan and Coghlan (2002), in three phases: preliminary study, driving cycle and a target phase.

3. BACKGROUND THEORETICAL

3.1. Technology Roadmapping

Since its initial development at Motorola in the 70's, the approach of Technology Roadmapping has undergone significant developments, carried out by researchers and practitioners of the method, especially from experiences in the context of established firms in different sectors such as automotive, internet, software, energy, etc. These developments are associated with a better understanding of the processes of roadmapping and customization of the roadmap (PHAAL *et al.,* 2004; PHAAL; MULLER, 2009; LEE; PARK, 2005), the employment other methods, tools and techniques, as scenario analyses (ROMMES; AMERICA, 2006), the Quality Function Deployment (MARTINICH, 1997) and the development of different approaches for the roadmapping, such as the technological (LEE *et al.,* 2009) and the market (PHAAL *et al.,* 2004).

There are several ways to prepare a roadmap, but for the quick start method, especially for cases in which practitioners are not familiar with the technique, Phaal *et al.* (2004) proposed the T-Plan, a guide on how to develop a technology roadmap based workshops (figure 1).

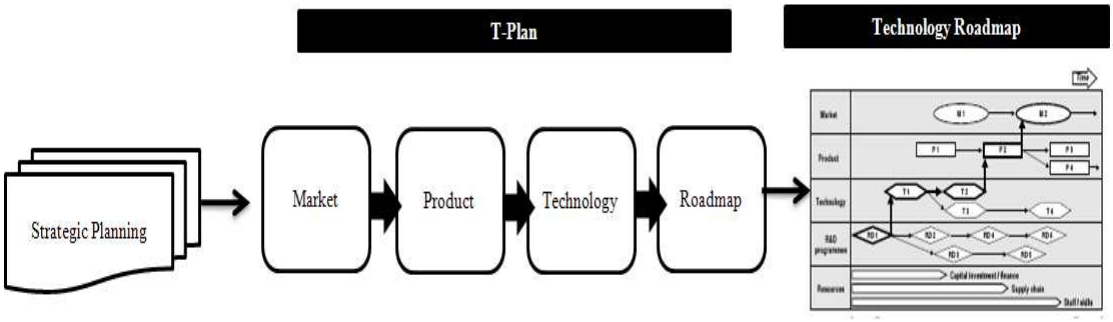

Figure 1 – Technology roadmap

Source: Adapted from Phaal *et al* (2004).

The T-Plan is a guide, structured around four workshops (market, product, technology and making the statement), the resulting document is the technology roadmap. The information and strategic guidelines used during the four workshops reflect the decisions from the Strategic Planning (PHAAL *et al*., 2005). From this perspective, the technology Roadmapping is a step in the strategic planning process that serves to capture and communicate its results.

According Phaal *et al.* (2005), companies can use an approach of Porter's (1985) kind to identify the five classes of competitive forces that impact on an organization, located in a particular industry, which will provide a deeper understanding of the context in which the roadmap will be developed. It can also be used in SWOT analysis technique, which analyzes the strengths and weaknesses of a firm relative to its external environment, thereby establishing a generic competitive strategy of the cost type or differentiation (PHAAL *et al*., 2004).

After the completion of the strategic planning and roadmapping, we obtain the first-curt technology roadmap (PHALL *et al.,* 2004). According to the authors, to

increase the benefits of the method, the company should undertake a process of customization, adapting the method to its context and its goal. Phaal *et al.* (2005) employ the concept of funnel strategy to understand the linkage between the strategic planning process, the roadmapping and the customization (figure 2).

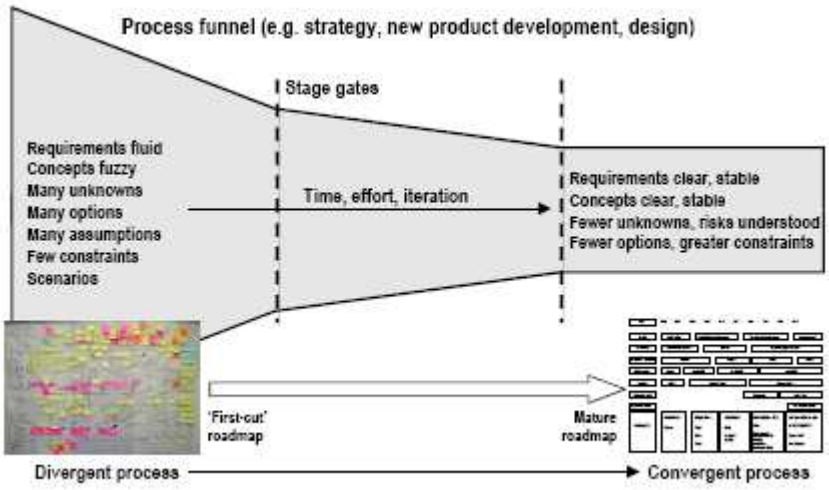

Figure 2- Business process and roadmapping

Source: Phaal *et al.*, (2005)

Phaal *et al*. (2005) describe that initially the requirements are fluid, the concepts are chaotic, and there are many uncertainties, many options, few restrictions and assumptions. After an iteration process, consuming effort, time and resources dedicated to improving the roadmap, there would be a stage in which the requirements are clear and stable, the concepts are fluid, and the uncertainties and risks are few (PHAAL *et al.*, 2005). After this iteration process, the TRM is "frozen" for its implementation.

In the context of academic spin-offs, it is necessary to conceive a new approach for the technology roadmapping method. First, because the approaches of strategic planning (PORTER, 1985) are more suitable for established firms in existing and more stable contexts, with established markets, consolidated production chains, customers and competitors known (TIDD *et al.*, 2005; MINTZBERG, 1994). Second, because the

T-Plan is a consolidation of the decisions taken in strategic planning (PHAAL *et al.*, 2004), while in an academic spin-off, the strategic planning involves the whole birth of the business. The unforeseeable uncertainties and complexity require an approach to planning different from the kind one fits all (GOMES; SALERNO, 2008; COURTNEY *et al.*, 1997; MINTZBERG, 1994). The traditional approach of technology roadmapping manages foreseeable uncertainties. For this kind of uncertainty, it could use traditional approaches of risk management (SOMMER; LOCH; 2004; PICH; LOCH; MEYER, 2002). Third, Phaal *et al.*, (2005) do not discuss how and what should be the effort and the iterative process to customize the technology roadmap to business context. Fourth, the roadmapping and customization process are not separated from the implementation of the technology roadmapping. In an academic spin-off there is no clear separation between the process of planning and implementation (GOMES; SALERNO, 2008). These two processes overlap and affect each other (GOMES, SALERNO, 2008), which requires an integration between the two. And sixth, the development of academic *spin-offs* may have a non-linear behavior, being subject to the emergency of events and sudden changes of direction (VOHORA *et al.*, 2004; AUTIO, 1997), it may require a new paradigm and a new way of thinking.

3.2. The paradigm of complexity

The paradigm of complexity has been developed as an attempt to address issues that the Cartesian paradigm and the systemic paradigm failed to address (BORGATTI, 2008). These issues are related to the properties of emergence, dynamics, nonlinearity, chaos and unpredictability of certain phenomena (BORGATTI, 2008). The scholars of the System Theory argue that complexity is conceptualized as a large set of variables on which it is not possible to map the number of variables and intensity of relations between them. From the perspective of theorists and thinkers of the complexity, the

complexity goes beyond the issue of set size and the functional relationships between variables. According to Demo (2002), the complexity involves, in addition to this characteristic, some others like:

- Dynamicity: it cannot be complex if it is not a field of opposing forces, in which any stability is always a temporary rearrangement, modified by endogenous and exogenous forces, emerging events, etc;
- Non-linearity: what is complex cannot be completely linear. It is important to note that part of reality follows a linear order and the other part follows a nonlinear behavior.
- Ambiguity: it is not complex if all the parts and the whole can be completely modeled and the relationships between them identified.

By adopting the perspective of the complexity paradigm to support a dynamic approach to the TRM, we do not intend to deny the important contribution made by the authors of Systems Theory and Systems Thinking. The goal is to add the issues addressed by researchers and theorists of complexity. Thus, this paper seeks to contribute in a major challenge for researchers and managers, which is to deal with complexity not only as a assumption of a social phenomenon (a problematic situation), but seek ways to operationalize the concept.

3.3 New approaches for managing uncertainty and complexity

In new contexts in which economic artifacts are created, such as firms, markets and industries, the agents have to play a different game (DAY *et al*., 2000), which is not based solely on the logic of causality, present in different methods of management (SARASVATHY, 2001).

In order to build a way of assisting decision makers to act in such contexts, Sarasvathy (2001) proposes the effectuation, which consists in a change in the logic of dealing with

the future: considering the means (which could be resources), the decision maker tries to control the possible effects. This logic is different from the causal model used by Porter (1985), in which, based on the desired effect (a general position in the industry) the means (e.g. products and services) to reach them (SARASVATHY, 2001) are defined. The effectuation is based on four principles:

1. Minimize the loss rather than maximize profits;
2. Strategic alliances rather than competitive analysis;
3. Exploration of contingencies rather than existing knowledge;
4. Control of an unpredictable future rather than a prediction.

There is another important set of papers that attempt to characterize and deal with the unpredictability of the future (PITCH; LOCH; MEYER 2002; SOMMER; LOCH, 2004; SOMMER; LOCH; DONG, 2009). For this set of authors, the approaches of traditional risk management are more focused on the foreseeable uncertainties. The unforeseeable uncertainties and complexity (in the systemic sense) require new approaches to management (PITCH; LOCH; MEYER 2002). To cope with unpredictable decisions under uncertainty and complexity, Sommer and Loch (2004) suggest two approaches to management: Learning and Selectionism. The Learning by trial and error can be defined as flexible planning, adjusting the goals and plans drawn up in accordance with the emergence of new information on the problem (SOMMER; LOCH, 2004). Selectionism refers to the conduction of different approaches independent of each other and with decision-making process ex post (SOMMER; LOCH, 2004).

The idea is that by handling the uncertainties (including unforeseeable) and complexity (in a complex sense), the roadmap can be reviewed and updated in a cyclic way, following the evolution of the business.

4. RESULTS

4.1. Proposition of a dynamic approach for Technology Roadmapping

The framework of the dynamic approach to the Technology Roadmapping is represented in Figure 4. The framework consists of three integrated parts. The first part is devoted to a cyclical process of roadmapping, in which the business model develops dynamically according to the treatment of unforeseeable uncertainty and complexity. The second part represents the technology roadmap, which changes dynamically, following the evolution of part I. And the third part corresponds to the business plan, it is no longer a result of the planning process, but a state of the planning process.

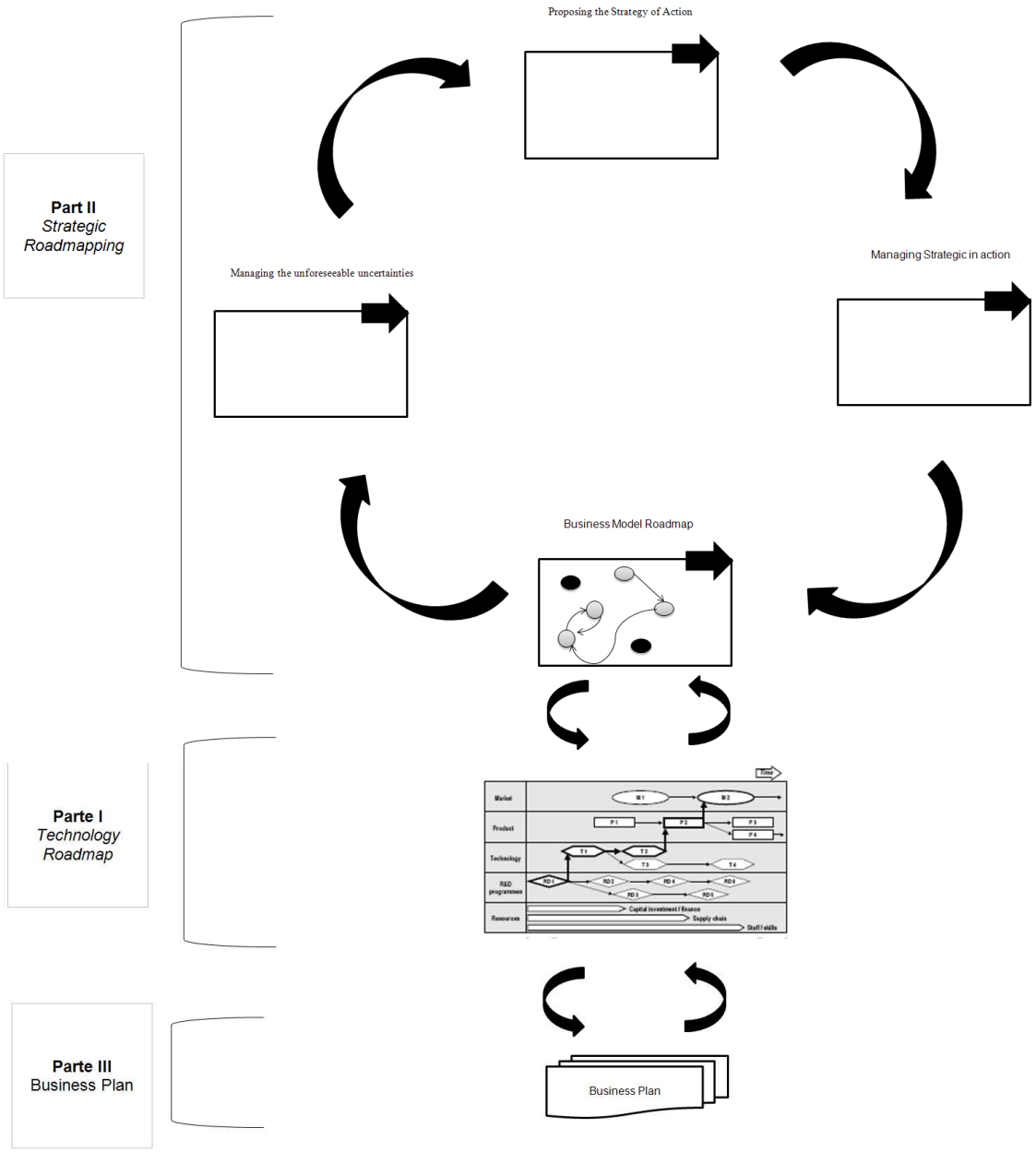

Figure 4- A dynamic approach for TRM

4.1.1 Part I - Developing the first version of the Technology Roadmap

The technology roadmap must be based on decisions previously made during the strategic planning of the firm (PHAAL *et al*., 2004). Which implies that the business strategy, in a deliberate sense, should be fully explained before starting the process of roadmapping. However, on the study case and the on the intervention, the strategic planning process was parallel to the *roadmapping*, not following a sequential and linear logic. In other words, modifications in strategy development, due to the emergence of

new information related to the market, led to a revision of the roadmap in a cyclical, dynamic and nonlinear process. The academic entrepreneurs of spin-off (A) and spin-off (D) initially sought to conduct a strategic planning as suggested by Porter (1985), adopting complementary techniques such as SWOT analysis (Strengths, Weaknesses, Opportunities and Threats), aiming to establish a strategic plan for the venture, but the lack of systematic data and information related to the degree of market development and technological uncertainties made it difficult to define a generic strategy (cost, differentiation and focus). The entrepreneurs of the spin-off (B) decided Porter's (1985) method would not be appropriate due to the lack of information and the uncertainties present in that stage of the business.

The entrepreneurship literature tends to relate the absence of a clear business strategy with the lack of managerial skills on the part of the entrepreneurs (e.g. ROBERTS, 1991; TIMONS, 1999), characterizing entrepreneurs as undisciplined and unfocused (DORNELLAS, 2001). This explanation can be partially minimized considering these four spin-offs. All projects were supported by management consultants specialized in techniques and methods at the management and planning for the spin-offs. The absence of a clear strategy can be best explained by considering the lack of information, the unforeseeable uncertainties and the complexity that were present in all decisions relevant to business performance, bringing direct consequences for roadmapping, especially for the application of T - Plan and its implementation.

In the four spin-offs, there were major difficulties in applying the T-Plan systematic guide for the elaboration of the first version of the roadmap. In the four spin-offs, entrepreneurs invested considerable time in understanding and applying the technique, but the lack of information, the unforeseeable uncertainties and the complexity hampered the application of the T-Plan (PHAAL *et al.*, 2004). After a

detailed study of what happened in the spin-off (A) and based on lessons learned in the spin-off (B), we identified the following alternative process to prepare the roadmap.

From the resources that the entrepreneurs had (the technology), the possible effects (products) were unfolded. In the second stage, the same process was conducted to determine possible markets for each product offered. It is important to note that throughout this process, entrepreneurs have identified and lived with various uncertainties and complexity.

Satasvathy (2001) emphasizes that the logic of "effectuation" is more appropriate to create artifacts such as new business and new markets, but he does not go into detail of the construction of the effects and does not mention how the treatment of uncertainties should be. In the intervention, even with the uncertainty, the entrepreneurs decided to use the result of "effectuation" to produce the first version of the technology roadmap and to structure the initial business model development. However, to cope with the uncertainty and the complexity raised initially in the roadmapping and in the definition of the business model, we developed an auxiliary process for handling uncertainty and complexity, as well as systematic search for information and events, which will be discussed in the next section.

4.1.2. Part II - Process of *roadmappping*

The literature interprets the business model as a set of decisions articulated in relations of cause and effect. In the three spin-offs (A, B and C) it was necessary to expand this vision to understand that the nature of the relations between decisions does not have always a linear chaining. Part of it is because there is not an explanation of how entrepreneurs choose a particular business model and how they articulate the decisions that constitute this business model.

The entrepreneurs of the spin-off (A) believed that they had three business model choices: to be a provider of specialized services, to be a developer of sensors for large companies and to be an integrator of technologies. These three business models would lead to different paths of development, with different resources, expertise and skills for each paths. Similarly, the spin-off (B) did not define what was the best development path: to become internationalized through a partnership with an outside laboratory or to be converted into the R&D department of its main supplier of raw material. Thus, the entrepreneurs of the four spin-offs had a difficulty in determining which business model to follow, and once defined the business model, they had to structure the decision as a linear causal chain of decisions: the technology "x" can be incorporated into the product "b", directed to the customer "e" on market "d", therefore "h" should be hired.

The initial expectation was that this process would follow a linear logic: first defining the business model, and then drawing the relevant set of decisions. What has happened in practice was that the two processes were mixed, presenting properties linked to complex thinking and complexity, as shown in Table 3.

Principles of the Complex Thinking	**Empirical analysis of the two conducted researches**
Systemic Principle	- The first question is to understand that the business model consists of two systems: a system that is in the business (eg, organizational structure, organization, production) that is being formed within another system (e.g. marketing and supply chain), both in stage of birth. Entrepreneurs could not explain precisely the relationship between these two systems dynamically over time, neither the process of organization between the two. - The entrepreneurs realized that the process of representing the two systems in a set of decisions, involved parties and cognitive strategies to deal with the issues of impoverishment and enrichment of any representation and organization process.
Principle hologramatic	The decisions that form a spin-off are, in theory, similar to any other new venture: what market: who is the client, what are the competitors, among others. Thus, the project carries the information of any other kind of business.

Principle recursive	There was not a linear causal sequence in the decisions that constituted the business. The relationship between market pull and technology push has always been complex. At times, it technology was pushing, and at times the market was pulling.
Principle of self-eco-organization	The emergence of new events and changes on the information required of entrepreneurs from both spin-offs on several occasions, to modify the relevant decisions of the business. In some instances, these new events required a significant change in business model and a redesign of the project.
Dialogical principle	The entrepreneurs had to live with paradoxical logics in the development of the business. One of the greatest paradoxes was the logic of non-linear development of science and the apparent linearity and control of the business logic. Moreover, for example, in spin-off (B), the entrepreneurs were living with paradoxical logics with regard to some principles and concepts of technology in development.
Principle of ecology action	This is the most adherent principle to both academic spin-offs. Once entrepreneurs have performed certain actions such as launching a prototype in the market or visit a potential client, these actions have produced unexpected effects, combining with other events. In the case of spin-off (B), a conversation with a potential supplier of raw materials has proved in fact a possibility of a new business model: to become its R&D laboratory. On the other hand, the bidder, aware of the technology, implemented actions to prevent the deal by imposing sanctions on the supplier. Spin-off (A) also feared that when their technology would get in touch with the market, it would suffer a process of imitation, which would lead to a loss of business competitiveness. Thus, rather than planning and executing, one of the most important activities of the entrepreneurs was to follow the evolution and effects of actions taken in the process that combined the search for new events, re-planning and gambling.

Table 3- Planning business model in light of complex thinking principles.

The table 3 illustrates briefly some aspects that show that complex thinking can be used to assist in planning and developing the business model of a spin-off, expanding the understanding of how entrepreneurs decide. The two researches indicate that planning and development of business model does not follow a linear causal sequence: nor the definition of which model should be developed and neither the articulation of the decisions of a given model. The business model of spin-off (B and C) contained decisions of different business models, even though these represented a logical paradox

or antagonist. For example, the entrepreneurs of spin-off (B) saw its provider as a client at the same time that they would see (and developed actions) it as a competitor.

The use of complex thinking to assist in the planning process and development of spin-offs expands the original proposal of Checkland (BORGATTI, 2008). Now, not only the world that is seen as complex, but also the way individuals think and act in this world.

4.1.2.1 Managing the unforeseeable uncertainties

This stage of the roadmap has been proposed to manage the unforeseeable uncertainty and the complexity in the present set of decisions of the business model and technology roadmap. Basically, the activities performed at this stage consist in:

1. The entrepreneurs must determine in what time they will take a certain decision. For example, the entrepreneurs of spin-off B have determined that the decision on starting the "production process design" should be taken only after the conceptual development of the product. Every decision must be ready in time;
2. For each decision, entrepreneurs must classify the type of uncertainty existent: foreseeable and unforeseeable. The entrepreneurs should also observe whether the decisions have properties of complexity: a large group of variables with a large number of relationships between these variables; ambiguity. Recalling that ambiguity is the difficulty in specifying the nature or behavior of the decision. For example in the spin-off (A), the decision on the role of a partner was ambiguous: at times it was represented as a client, at times as a competitor.
3. For each unpredictable uncertainty or complexity, entrepreneurs should classify them according to criteria of relevance, importance and priority. They should define at what point they will develop specific actions to address them. Notice that not only are the decisions that are prioritized, but also the uncertainties.

Entrepreneurs can use the structure of a roadmap to represent the uncertainties and complexity present in decisions over time.

4.1.2.2 Proposing the Strategy of Action

This step consists in assigning a management approach for each unforeseeable uncertainty or complexity. For each approach, planning, executing and controlling take different meanings, as shown in Table 4.

Management approach	Definition	Planning	Execution	Control and incentives
Expect a better moment	-The entrepreneurs decide to wait for the information to change and then they define a different approach to management.	- Plan only which resources or activities will be held until a date or a modification in particular information. - Search new information and events	- Implement the plans drawn up earlier	- The control is to wait for the advance of information. - The bonuses should be designed carefully. To encourage waiting for a change of the information can generate undesirable behaviors, leading to loss of business opportunities and risk rejection.
Big bets	Facing the impossibility of obtaining data to evaluate the options, entrepreneurs can set a direction or solution like a big bet.	- Plan all activities necessary to accomplish the bet. - Search for new information or events.	- Implement the plans drawn up earlier. - Search new information and events	- Watching the match between what was planned and what was executed. - This approach is of high risk. Usually occurs when there is little information to justify or support a decision. In case of failure, entrepreneurs should be aware of the risk they assumed when defining this

				approach.
Selecionism	Conducting various options in parallel in a decision-making process ex post.	- Plan to fully implement each of the options.	- Follow the plans drawn up.	- Since it was not possible to know in advance which options would champion, all involved in each of the options should receive the same incentives and bonus
Learning by Trial and error	Plan only until the next activity, remaining flexible to adapt to events.	- Plan only until the next task or decision point. - Search for new information or events.	- The entrepreneurs must carry out activities, always observing the emergence of new contingencies.	Encourage learning and experimentation. - Encourage risk and explore new options.

Table 4- Defining Strategies of Action

The treatment of uncertainty and complexity gives a dynamic character to the formation of the business model, evolving in the emergence of new events or information. This can be understood by observing how was the employment of management approaches throughout the development cycle of the business in spin-off (B) (VOHORA *et al*., 2004) as shown in Table 5.

Management approach	**Research**	**Recognition of opportunity**	**Pre-organization**	**Re-orientation**	**Sustainability**
Expect a better moment	19	14	9	11	**7**
Big bets	5	4	4	3	3
Selecionism	11	10	7	9	6
Learning by Trial and error	17	16	17	14	15

Table 5 - management approaches throughout the development of the spin-off

Table 5 shows the number of different decisions that are employed by the different approaches to management throughout the development of the business. The definition of these approaches followed the dynamic evolution of business development.

The implementation of the strategy with the development of tangible and intangible resources brought up new events, new problems and opportunities before, which were not previously mapped by the entrepreneurs. These new events, some of them from outside the business, involved in making new arrangements for the business model and also for the Technology Roadmap. And therefore, these new arrangements demanded entrepreneurs to use all the activities relevant to this step.

4.1.2.3 Managing Strategy in Action

This step is devoted to manage the strategy in action, noting two aspects. The first is related to the logic of management approaches defined above. The activities have to be implemented and controlled according to the management approach. The second aspect consists in observing how dynamically the business and the ecosystem in which it is inserted developed. The entrepreneurs should be alert to the effects of their actions on getting in contact with other events in the world. Reaction of competitors, new legal issues, etc. Likewise, the actions of other agents of the ecosystem may also lead to new decisions, emphasizing new opportunities or even new threats. At that time, the principle of ecology of action should lead the way entrepreneurs think, analyze and act.

4.1.3. Part III- Business Plan

In the traditional view of Entrepreneurship (ROBERTS, 1991), the Business Plan is seen as a document resulting from the planning process. For researchers aligned to this vision, the new venture is born to exploit a clear business opportunity. The problem is that not always a business opportunity is clear and explicit from the beginning of the project (VOHORA *et al.*, 2004). In such cases, the opportunity is built over time as resources are developed, lessons are learned and the market itself evolves. The Business Plan aims to raise funds to solve contingency problems of the project. The Business Plan is a state of planning, being more suitable for unpredictable

environments. Entrepreneurs seek financial and economic resources with different partners throughout the life cycle of the spin-off.

5. CONCLUSIONS, LIMITATIONS AND FURTHER RESEARCHES

The aims this paper is the proposition of a dynamic approach of technology roadmapping. This approach is must indicated for mutants and turbulent contexts like the birth of an academic spin-off. This kind of new venture is created to explore a radical innovation, capable to create a new niche, new market and same cases a new sector.

This approach consists of three parts. The technology roadmap is shown in Part I and follows the dynamic evolution of the business model of the spin-off (Part II). Part II represents the planning dynamic business model, the integrated management of unforeseeable uncertainty and complexity. In the proposed approach, there is no a separation between the planning and implementation of TRM. While this represented the third Business Plan, which is no longer a document resulting from business planning to be a state of planning. In this sense, the strategy or the business opportunity is being built according to the evolution of the firm, the new events and lessons learned.

In the future researches, the dynamic approach will be tested and evaluated in different contexts in order its validation.

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