REVISITING THE MANAGEMENT OF TECHNOLOGY-PUSH SITUATIONS BY MAXIMIZING DISCOVERY AND INHIBITING SCREENING

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ABSTRACT

While companies are increasingly investing in the development of new technologies, they are often faced with situations where they have to identify potential applications to a new technology. As it seems to be a major challenge, many methods addressing this application identification issue have been developed. However what makes them more or less successful remains unclear. Our paper proposes to explore the efficiency of an application identification method maximising functional discovery and inhibiting screening. Our research work relies on an empirical methodology, more specifically the efficiency of our method was tested on a single case study that respected very specific conditions. Maximising functional discovery and inhibiting screening proved to be an efficient way of identifying applications to the technology. This result provides new ways of managing technology-push method by highlighting efficient ways of designing application identification methods.

1. INTRODUCTION

In the context of industries shaped by technological trajectories (Dosi 1982), it has become vital for companies to innovate at an increasingly rapid pace. In the strategy and innovation management, a "technology-push" approach, defined as an approach driven by technologies, has been argued to be more efficient in leading to breakthrough innovations compared to a "market-pull" approach which is driven by market needs (Newbert, Kirchhoff, et Walsh 2007; Walsh, Kirchhoff, et Newbert 2002).The comparative efficiency of these two strategies has long been debated, but recent literature acknowledges that these approaches should be considered as complementary rather than opposed (Brem et Voigt 2009; Maier, Hofmann, et Brem 2016)

Some research has also focused on how firms could implement a technology-push approach in their New Product Development processes (G. L. Bishop et Magleby 2004; G. Bishop 2004). This branch of the literature usually proposes overall processes going from the technology concept to its commercialisation. A recent model was proposed in (Terzidis et Vogel 2018) to give a unified vision of all these processes. In the same paper, the authors highlight the importance of the application identification stage. Identifying applications seems indeed to be the core issue of the technology-push approaches. A large variety of methods can be found in literature addressing this issue. In the following paper, we will thus only focus on this application identification aspect, setting aside the aspects related to institutional factors, business model creation and commercialisation process.

However, it is unclear what explains the success of such methods. This paper proposes to explore this question by testing the efficiency of a method that would maximise functional discovery and inhibit screening. This study will lead us to rediscuss how methods of application identification could be efficiently designed.

2. LITERATURE REVIEW

To address the specific issue of identifying potential applications for a technology, many different methods have been developed and experimented. Some methods are presented in the literature detailing the overall process of a technology-driven product development, and the management of such a process including marketing and commercialisation considerations (Souder 1989; F. Lynn et Heintz 1992; G. S. Lynn, Morone, et Paulson 1996; Herstatt et Lettl 2004). Other researchers focused on designing appropriate methods by adapting an existing general method to the specific context of technology-push. These methods are for example based on technology road-mapping (Caetano et Amaral 2011; Jin, Jeong, et Yoon 2015), technology-performance scenarios (Wall, Gausemeier, et Peitz 2013), TRIZ method (Glaser et Miecznik 2009), the Lead User method (Henkel et Jung 2010).

“Screening” and “discovery” as common features in the methods of application identification

Despite being very diverse, it is worth noticing that these methods share common features. Indeed, all these methods seem to include a *screening* feature, consisting in examining different markets to identify where the technology could be used, based on its identified features. (F. Lynn et Heintz 1992) detail a “three-level technology screening process”, starting with a “needs screen” (to identify potential segments based on the benefits the technology could bring), moving to an “economics screen” (to further analysis how value could be created on the identified segments) and finishing by a “time screen” (to identify the appropriate timetable to develop and commercialise the new product). In the same vein, in (Henkel et Jung 2010) “trends” are derived from the technology features and used to identify the industry and market segments for which these trends are important. According to (Souder 1989), this “scanning effort” enables the company to identify new niches by not only relying on direct clients’ needs. Different techniques are proposed in the literature to better control this screening approach. (Glaser et Miecznik 2009) propose a method using publicly accessible data bases, aiming at helping the company to search opportunities outside its expertise domain. In technology road-mapping, (Jin, Jeong, et Yoon 2015) resorted to specific text mining and quality function deployment matrices to support the search for new business opportunities. Delphi method is also reported in (Herstatt et Lettl 2004; Wall, Gausemeier, et Peitz 2013) as a way of taking into account the forecasted dynamics of markets when searching for applications.

Within these screening-driven methods, it can be noticed that enabling a *discovery* aspect is often reported as being a success factor for the identification of applications. Indeed, the company learns as it goes through the screening process and markets are also constantly evolving. As a result, (F. Lynn et Heintz 1992) highlight that “screening the market is an iterative loop”: the discovered elements need to be taken into account to successfully follow the screening process. More specifically, several authors seem to suggest that companies should look for situations where discoveries are more likely to occur, for example by multiplying interactions with markets through rapid prototyping (G. S. Lynn, Morone, et Paulson 1996), or by confronting the technology to internal networks (Heiss et Jankowsky 2001) and external stakeholders (Herstatt et Lettl 2004; Henkel et Jung 2010). However, it seems that in the application identification approach, discovery is not as closely controlled as screening. Discovery seems rather considered as a factor contributing to the success of the screening approach.

To summarise, application identification methods seem to be largely screening-driven and recognise discovery as a fruitful element for the identification process. However, it still seems unclear *why discovery plays a significant role in the success of an application identification method and more generally what makes such a method successful.*

Overcoming the "presumed identity" of the technology as the key success factor

Further insights on these questions are brought by another stream of the literature dealing with creativity in design activities.

(Gillier et Piat 2011) highlight a major issue that hinders the identification of applications for emerging technologies: the specialists that have developed the technology tend to build a "presumed identity" of the technology drawing from the industrial contexts they assess as promising. Because of cognitive fixation effects (Agogué et al. 2014; Jansson et Smith 1991), the technologists only focus on this "presumed identity" and therefore may overlook other promising applications. Therefore, to design an efficient application identification method, it appears that specific efforts are needed to overcome fixation effects. More specifically, the key issue seems to consist in avoiding the "presumed identity" of the technology. Therefore, the following proposition can be formulated: *a successful application identification method has to avoid the "presumed identity" of the technology.*

To further explore how this "presumed identity" could be avoided, (Gillier et Piat 2011) precise the notion of "the identity of a technology". This notion has already been explored in the literature. (Faulkner et Runde 2009) underlines the "dual nature" of technology by defining its identity as what "flows from the combination of its physical form [physical characteristics and capabilities required to perform its functions] and its social function, that is the use to which the technology is put within this group". Similarly, (Gillier et Piat 2011) defines the identity of the technology as a (Technical Dimension, Usage Dimension) pair. In the present paper, we propose to slightly adapt this definition to better fit the different streams of literature regarding the identification of applications in technology-push situations. In (F. Lynn et Heintz 1992) it was pointed out that "technologists think and talk in terms of how technology works; marketplaces think and talk in terms of functional needs." In all the methods presented in the previous section, functions thus play a key role in the description of the technology: they were either deduced from the analysis of the technical features, thus turning the technical aspects into an understandable language for the markets; or they were deduced from the analysis of the markets, thus turning market needs into an understandable language for technologists. Therefore, the following definition is proposed: *the identity of the technology refers to the set of functions that articulate the relationship between the technical aspects of the technology and the markets.* As emphasised above, it can be seen as a language that makes the technology understandable for both the technical and market sides.

With this terminology, the "presumed identity" can be understood as a predetermined set of functions. According to (Gillier et Piat 2011), avoiding this "presumed identity" requires to make the identity of the technology evolve, that is discovering new functions through a controlled process.

These conclusions allow us to draw three important elements on the discovery feature of application identification method. First, its nature can be further detailed: the discovery feature actually refers to a *functional discovery*. This corresponds well to what is reported in the literature. Indeed, the learning elements that needed to be integrated in the "iterative loops" were interesting because they brought unexpected functions. In (Henkel et Jung 2010), resorting to lead users resulted in the discovery of functions that the technologists acknowledged to not have thought about. Second, the role of discovery in the success of application identification can be further clarified. With our new terminology, *discovery can now be understood as a way of overcoming the "presumed identity" of the technology*. Finally, the conclusions drawn from (Gillier et Piat 2011) suggest that a closely controlled process is needed. However, little research seems to have focused on how it could be handled in practice.

Therefore, in the following paper, we propose to explore the following question: *how to build an application identification method that generates functional discovery?*

Hypothesis formulation: an application identification method maximising functional discovery and inhibiting screening

Moreover, as explained previously, all application identification methods seem to include a screening aspect. So what could be the status of screening in a method that generates functional discovery? To further explore this question, we have found interesting to make a comparison with existing approaches in other disciplines, especially in algorithmic literature. Many fields in science and engineering use "search algorithms" to solve optimisation problems. These algorithms explore a search space to find high-performing solutions: for example, chemists searching through the space of molecules to discover new drugs, or to be closer to our subject, technologists searching through the space of functions to develop new applications. Most of these algorithms are performance-driven: they focus on maximising objective functions set by the user and defining the performance of the solutions. However, an alternative approach was recently proposed with "novelty search algorithms", that ignore the objectives and only search by maximising novelty. These algorithms proved to finally better perform than performance-driven algorithms (Lehman et Stanley 2010, 2011).

The functional discovery approach could be compared to novelty search approach and screening approach to performance-driven approach. Consequently, this algorithmic example has led us to formulate the following hypothesis: *a method which maximises functional discovery and inhibits screening is an efficient method to identify applications*. Our research work proposes to explore this hypothesis by testing it on an empirical case.

3. RESEARCH METHODOLOGY

To answer our research question, we rely on an empirical methodology: a hypothesis has been theoretically built and is tested on an empirical case, consisting in a single case study on which the conditions of the experiment were carefully controlled.

The empirical settings of this case study needed to be closely controlled at several stages of the experiment: the initial state (before the experimentation), the implementation of the method, and the final state (after the experimentation).

Empirical settings of the initial state

We chose to experiment our method in a company dealing with a technology-push situation and that had failed to find applications to the technology due to a "presumed identity". This setting has the following advantages. First, this context is coherent with the general context of our research. Second, this setting allows us to test our hypothesis by comparing two situations: the same company looking for applications without and with a functional discovery-driven method. This condition allows us to avoid "placebo effects", where the results could be explained by the only fact of having initiated a process of application identification, and not by the characteristics of the method itself.

In order to identify such a company, we relied on identification factors such as high investment in scientific characterization of the technology, use of screening methods and low outcome in terms of products.

Empirical settings of the method implementation

The method implemented in the company has to be specifically designed to include the two characteristics stated in the hypothesis: maximization of functional discovery and inhibition of screening.

Moreover, the tools used within this method need to be compatible with the company's resources and easily taken up by the employees. The experimentation also requires that the company is particularly willing to test such an exploratory approach.

Empirical settings of the final state

The analysis of the final state has to allow us to confirm or infirm our hypothesis. To do so, the efficiency of the method needs to be assessed.

First, the method would be qualified as discovery-driven if it results in the discovery of new functions. It is worth highlighting that functional discovery is a very specific kind of learning: it is not sufficient to learn something during the process but we have to make sure that what is discovered consists in functions as defined in the technological identity: that is articulating both technical properties and market needs. Therefore a specific attention is paid to characterize discovery beyond simple learning.

Second, our hypothesis will be confirmed only if the method proves to be successful. Therefore, we need to define what is success. A natural criterion would be to consider the profits made by the company through the commercialization of the technology. However, commercializing a new technology is a too long-term process to be observed in the time span of our experimentation. Furthermore, this criterion is not directly linked to the quality of the discovery. Indeed a first commercial contract could be signed based on the "presumed identity" of the technology and thus a poor discovery. Therefore, the method is considered successful if the company assesses the discovered functions as convincing and promising. This can be measured based on the investments made by the company to further capitalize on these functions.

4. EMPIRICAL MATERIALS

Our empirical case study was conducted in an engineering and research & development SME specialized in electromagnetism applied to electric motors, actuators and position sensors, mostly used in the automotive sector (ex. car ventilation cooling system, gas pedal feedback). In 2016, carrying out in-house research projects, the SME discovered a new flexible magnetic material. In 2016 and 2017, the company put specific efforts on identifying applications for this new technology. As further explained in the next section, no promising application had emerged from these investigations. Our discovery-driven method was then experimented from January to June 2018.

Our research work benefited from the access to a broad range of data sources. First, the documents related to the previous research works on the material and search for applications were gathered (results of experiments, summary reports). To complement these data, interviews of one to two hours were conducted with people representing all the professions in the company: the engineers that had worked on projects involving the new material, business developers, the heads of all business units, the intellectual property manager, the head of research, the CEO of the SME, and the CEO of the group that the SME belongs to. These two sources of data – written documents and interviews – enabled us to finely characterize the initial state of the experiment. Finally, the implementation of the method had been followed through regular working sessions and workshops, and a final session involving the group CEO, the head of research and IP manager to discuss the results of our experiment and the perspectives for the company.

5. RESULTS

Based on our empirical materials, the following results could be drawn.

Initial conditions of the experiment

This company fits particularly well with the conditions stated in the methodology section. Indeed, the SME was faced with a technology-push situation (the new flexible magnetic material discovered during in-house research projects) and was looking for potential applications of this material.

Second, before our experimentation, the company had long been trying to identify applications without any success. Three main trials had especially been carried out:
(1) an exhaustive technical characterization of the material through the launch of a PhD subject;

(2) brainstorming sessions trying to explore as many fields as possible, involving internal stakeholders (technical experts, heads of business units, supply chain managers) and external stakeholders (producers of the material);
(3) a second range of brainstorming sessions focused on one specific aspect of the technology (the combination of flexible and magnetic properties).

The results of these approaches respectively resulted in:
(1) a list of characteristics on the magnetic and elasticity properties, without clear idea of how to turn them into functions;
(2) a broad list of ideas with no clear value;
(3) a few ideas leveraging the combination of flexible and magnetic properties, but again without clear value.

The company thus seemed to be fixed on a presumed identity of the material, consisting in a list of functions associated with its flexible and magnetic properties, and hindering the identification of promising applications.

Implementing a method that maximizes the functional discovery and inhibits screening

The method was designed in order to respect the conditions exposed in the methodology section. To facilitate its adoption by the employees, it was decided to resort to classical approaches already existing in the literature and to adapt them to the resources of the company with specific tools. They were then tuned to fulfil our twofold goal – maximisation of functional discovery and inhibition of screening.

To build our method on existing approaches, we first identified three different kinds of contexts in which the technology could be used :
(1) a context which is well-known by the company (that is in an existing product and core business sectors);
(2) a context which is known by the company but in a new product (that is to meet demands or problems that are expressed but not addressed by existing solutions);
(3) a context which is not known by the company (that is to say different from its expertise fields and without any explicit need).

Each of these contexts can be linked to a common approach found in literature. The first context corresponds to a “substitution” approach, that has widely been discussed in literature (Friar et Balachandra 1999; Smith 1992). It is also much similar to the “embodiment” stage proposed by (Souder 1989). The second context corresponds to a “killer application” approach, that is finding an application with very desirable properties thus becoming superior to existing or rival solutions. Such an approach is for example discussed in (O’Connor et Rice 2013). Finally, the third context can correspond to a “demonstrator” approach, where the demonstrator is a way to reach people from unknown fields. Among these three approaches, only the two first ones were experimented. Indeed, the third one was more difficult to implement in practice with the company’s resources and the limited period of time of our experimentation.

To implement the substitution and killer application approaches, only tools based on the company’s resources were used. The substitution approach consisted in building a prototype by taking an existing actuator and replacing the rigid magnet by the flexible one. The killer application approach consisted in analyzing one identified and recurrent need for which no solution already existed. Existing engineering design tools were used as a framework, representing in a matrix “functional requirements” (functions derived from customer needs) and design parameters (technical characteristics that can be played on to meet the functional requirements). The analysis was carried out in collaboration with the head of the related business unit, that had both a technical and commercial background.

Furthermore, the two features of maximizing functional discovery and inhibiting screening were carefully integrated into these approaches. Indeed, the substitution and killer application approaches were not used with the same objectives as commonly found in literature. The discovery-driven substitution approach did not aim to test whether or not the technology could be used in existing products thanks to a better performance. Instead, it was used to reveal implicit functions associated with the integration of the technology in a product. In the same vein, the discovery-driven killer application approach did not aim to identify the applications where the technology would bring outperforming advantages, but at discovering new functions related to this specific need. Finally, the tools previously exposed were complemented by three workshops, involving around ten participants from different positions (engineers, researchers, head of research, head of a business unit, IP manager), to ensure that learning elements were turned into functional discoveries.

New functions discovered

The substitution approach driven by functional discovery and not screening proved to be particularly rewarding. Indeed, before our experimentation, the screening-driven substitution had automatically been discarded by the company’s engineers. It can be explained as follows: the performance of existing products (such as actuators and motors) were highly dependent on the magnetic strength of the magnet. As the new flexible magnet was far less strong than a usual rigid magnet, it seemed that it would be irrelevant to use it as a substitute of the rigid one. However, taken as a discovery-driven approach, substitution by prototyping compelled the engineers to go through all the steps required to build the product and especially how the magnet is integrated in such a system. During the process, it was discovered that the magnet could be magnetised in a completely new way. This new magnetisation process changed the way a product could be performant: before the experimentation, performance could be reached thanks to the strength of magnets; after the experiment, performance could be reached with a weak magnet and a specific magnetisation process. However, “being magnetised with this specific process” cannot be considered as a function defining the technological identity of the magnet. Indeed, so far it only articulates the magnet with its technical aspects and not with the market side. The series of three workshops enabled us to transform these pieces of learning into a proper functional discovery. Through these workshops, it appeared that the magnetisation process could specifically be used to make high-definition magnetisation patterns, bringing about significant advantages for certain types of motors and actuators. The proposition "being magnetised with a high-definition pattern" articulates both the technical and market sides and is therefore a new function constituting the magnet identity.

The discovery-driven killer application approach worked the other way round. We could easily learn unexpected elements on the market side as the approach started with an identified market need (in our case, "having sensors able to measure the position of an object on a longer range of movement"). However, to transform this proposition into a function defining the technological identity of the magnet, it has to articulate this market aspect with technical aspects. The engineering design tool enabled us to make this articulation and resulted in the discovery of functions, bringing about potential advantages on overlooked aspects (such as "not damaging the system in case of failure").

The interest of such a functional discovery was confirmed by the actions carried out by the head of the company to further investigate these functions, especially the one regarding high-definition magnetisation. Indeed, investments in new prototypes were made to integrate the magnet into several designs of products. The PhD thesis was also partly reoriented towards a better understanding of the physical mechanisms underlying this magnetisation process and the other functions identified within the killer application approach.

6. CONCLUSION AND DISCUSSION

Based on these results, our initial hypothesis can be confirmed: *whereas screening-driven methods had failed to bring about potential applications, a method maximizing the functional discovery and inhibiting screening proved to be successful.*

Managerial and theoretical contribution

This result offers new perspectives for scholars and practitioners on how emerging technologies and technology-push situations could be managed.

On the theoretical aspect, this study gives a better understanding of what makes an application identification method successful. It confirms the intuitions shared in literature about the significant role of learning and clarifies its nature, that is involving the discovery of new functions.

On the managerial side, our research also brings new insights on how technology-push situations could be handled. It first highlights that it is necessary to protect a functional discovery approach, distinct from screening. In practice, such a discovery-driven method can be designed by using existing tools and adjusting them by switching the objective from a screening objective to a functional discovery objective.

Limits and further research

Our hypothesis validation is based on a single case study. Although the empirical settings have been carefully controlled, it would be worth replicating the experimentation in other companies, from various industries.

This paper also suggests more research regarding the articulation between screening and discovery within a method. On the one hand, (Gillier et Piat 2011) showed that a method only based on screening cannot be successful because of the "presumed identity" trap. On the other hand, our study shows that a method only based on discovery can work. Inhibiting screening has enabled us to clarify the role of discovery, however we could wonder if a method could efficiently articulate both screening and discovery, making sure that screening does not take over discovery.

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