Applying technology roadmapping (TRM) for strategic product planning of start-up high-tech companies

Maicon Gouvea de Oliveira, Daniel Capaldo Amaral, Henrique Rozenfeld, Wagner Fonzi
University of São Paulo
e-mails: maicon.mgo@gmail.com; amaral@sc.usp.br; roz@sc.usp.br; wagnerfonzi@yahoo.com.br

Abstract: The benefits of technology roadmapping (TRM) are acknowledged by today's companies, especially in the high-tech industry. Nevertheless, it is still not clear whether this method can assist entrepreneurs in the strategic product planning. This paper explores this issue by a case study in a Brazilian start-up high-tech company, which have business in medical/hospital equipment industry. The technology roadmapping was implemented in the company following the roadmapping process proposed by T-Plan. This study noted an improvement of the strategic product planning by the technology roadmapping application. Hence it was capable of helping entrepreneurs to consider the integration of market, product and technology parameters.

Keywords: technology roadmapping, strategic product planning, start-ups, high-tech companies.

1. Introduction

The market opportunities for products based on new technologies are growing fast. Therefore, the birth of new high technology companies appears to be a current trend. However, before entering the marketplace, these companies must consider some requirements that will affect their sustainability and growth, such as: consumer demands, changing technologies and new product development.

The new product development (NPD) process begins with a strategic product planning phase (COOPER, 2001; CRAWFORD; BENEDETTO, 2006), which studies shown to play an important role in developing new products effectively (COOPER, 2008; BARCZAK; GRIFFIN; KAHN, 2009). The strategic product planning has been considered crucial for the survival of small high-tech companies. Since, it can complement their business plans regarding the NPD perspective (ALMEIDA; FERNANDO, 2008; DE COSTER; BUTLER, 2005; SUZUKI; KIM; BAE, 2002; RUOKOLAINEN, 2005).

Although the start-up high-tech companies have characteristics that can hinder an effective strategic product planning, there are methods that could help them in this so important phase. The technology roadmapping (TRM) is one of them. It enables the company to elaborate a plan that integrates business, market, product and technology (WILLYARD; McCLEES, 1987; ALBRIGHT; KAPPEL, 2003; PHAAL, 2004). In addition, Cooper, Edgett and Kleinschmidt (2004) consider the TRM as one of the best practices carried out by companies with success on new product development.

Considering this context, this paper presents a case study developed in a Brazilian start-up high-tech company, where is investigated the contribution of technology roadmapping application for the strategic product planning. The information gathered in the case study is used to analyse the difficulties to implement the method and the benefits that it could generate for the strategic product planning of this specific type of company.

This paper is divided into the following sections: research method, literature review, case study in a Brazilian start-up high-tech company, analysis of the case study and conclusions.

2. Research method

This study adopts an exploratory research method based on qualitative insights obtained in a case study. Firstly, it analyses the literature to identify characteristics about technology roadmapping and start-up high-tech companies. Here are underlined some possible connections that indicate opportunities to enhance the strategic product planning and it is also selected a roadmapping process that supports the application of technology roadmapping in a start-up high-tech company.

Following, a case study is developed according to roadmapping guidelines. In this moment is defined the team necessary for the technology roadmapping application and the procedure to organize the activities between the researches and the company during the study.

Finally, the results of the case study are analysed qualitatively concerning the difficulties to deploy the technology roadmapping and the contribution provided for the strategic product planning. At same time, they are compared to literature in order to search insights related to technology roadmapping application in start-up high technology companies.

3. Literature review

3.1. Technology roadmapping (TRM)

The technology roadmapping has received increasing attention from academy and companies due to its capacity to meet the need for innovation in the companies (PROBERT; RADNOR, 2003; RADNOR; PROBERT, 2004). This benefit could be related to the function of strategic product planning into new product development, since this phase involves the identification of opportunities for new products (CRAWFORD; BENEDETTO, 2006).

The definition of the method (technology roadmapping) as well as its outcome (roadmap) may change depending on the type of application. Consequently, they should be aligned to the context of the strategic product planning. This study focus on the product-technology roadmap type, which describes the market environment, directs new product development, defines technological capabilities and analyses resources so as to determine whether priorities are right and adequate (WILLYARD; McCLEES, 1987).

3.1.1. The roadmapping process

The technology roadmapping process, herein referred as roadmapping, is seen as responsible for adding value to the company (PHAAL, 2004; PROBERT; RADNOR, 2003; WILLYARD; McCLEES, 1987; WHALEN, 2007). Additionally, the roadmapping process needs to be adapted in order to best support the requirements of each application.

Two roadmapping processes were analysed to identify which one would support the objectives of this study: Albright and Kappel (2003) and Phaal, Farrukh and Probert (2001a).

Albright and Kappel (2003) suggested a process organized around three main sections: market, product and technology. A fourth, summary section, presents the action plan and the risks identified by the team. The process works as follows: initially the technologies and products are organized, showing the items in order of priority. At this point, the technological areas that support critical marketable product features are indicated as well as the product features that support the market requirements. Next, the team's analysis and conclusions translate the priorities of each section in a group of common drivers. Finally, an image of the external environment (competition, competing products and alternate technologies) is developed and aligned to internal plans. This image is then graphically represented by a roadmap. The Figure 1 presents a generic roadmap format.

The Phaal, Farrukh and Probert (2001a) process, named T-Plan, starts with a planning activity where the application scope, the team and the schedule is defined. Following, it suggests four workshops: market, product, technology and charting.

In the market workshop are identified business and market drivers. The business drivers represent the alignment with the enterprise's strategies, while the market drivers point out market trends related to the customers, competitors and market segments. In the product workshop, the product features involved with business and market drivers are selected. These features correspond to overall product features, such as: weight, power and noise. After defined the features, it is performed an assessment of their contribution for drivers achievement. In the technology workshop, the technologies are evaluated concerning their capacity to supply the product features. In the charting workshop, the results of the previous workshops are integrated in a multilayer roadmap, where the alignments among the business, market, product and technology are represented.

The analysis of those processes indicates that the first provides many examples of tools, but it does not detail the process, whereas the second presents a complete explanation on how to follow the process, but it does not offer examples of supporting tools. An important aspect is that both lead to the product-technology roadmap.

3.1.2. Success and hinder factors to implement technology roadmapping

Based on studies developed in UK manufacturing firms, Phaal, Farrukh and Probert (2001b) listed factors that can contribute for the success or failure of the TRM application (Figure 2). The most noticed success factors were *clear business needs* and *senior management commitment*. On the other hand, *initiative overload* and *required data/*

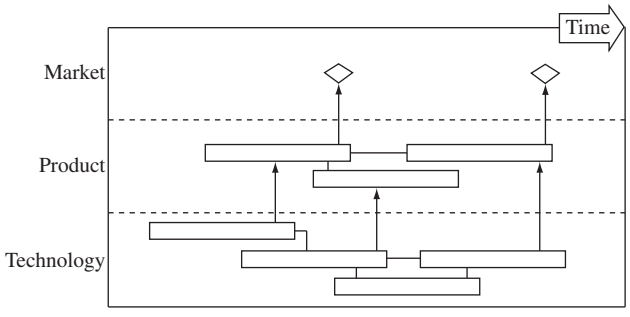

Figure 1. Generic roadmap (PHAAL, 2004).

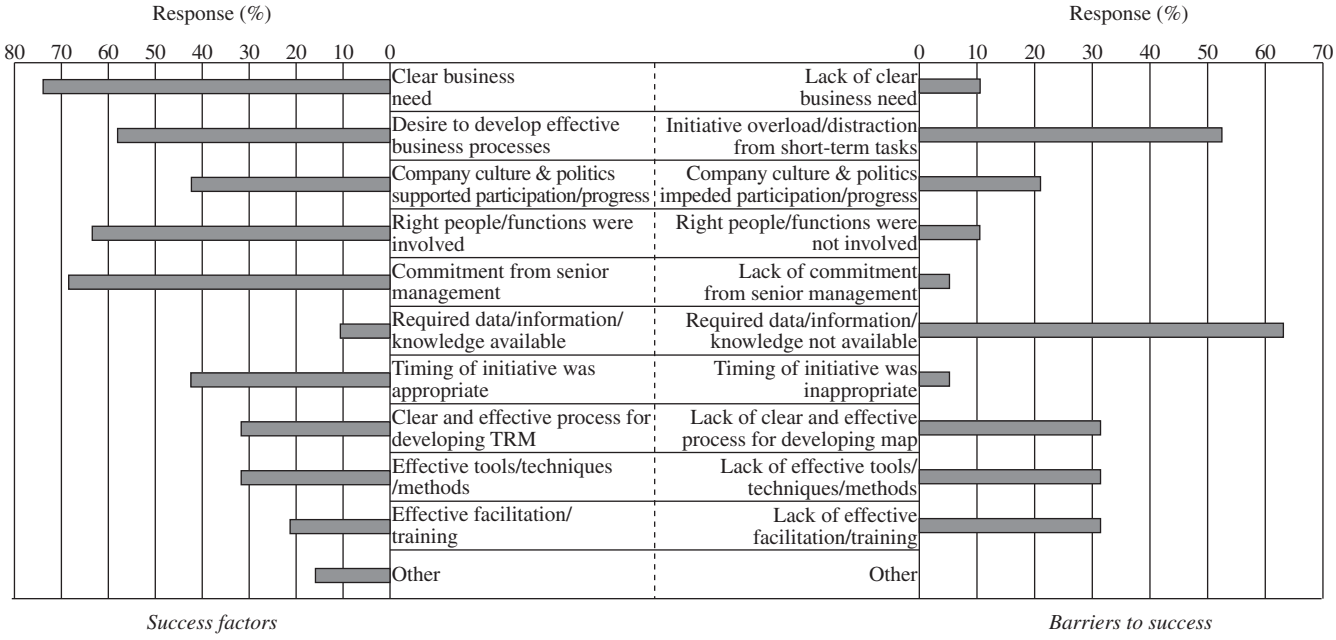

Figure 2. Roadmapping success factors and barriers to success (PHAAL et al., 2001b).

information/knowledge are the main hinder factors. Those factors should be considered during the case study in order to guarantee the effectiveness of the method application.

3.2. Start-up high technology companies

One of the most recent classifications of small high-tech companies was presented by De Jong and Marsili (2006). Based on results of a survey carried out with 2985 companies in The Netherlands, one type of firm identified by them comprises the high-techs with the following characteristics: products with innovative design or manufacturing process specifications, high-tech products, significant number of highly qualified collaborators, major investments in R&D, use of external sources such as universities and customers, managerial focus on innovation, and high level of collaboration.

At these companies, technology and product development activities draw considerable attention and are often viewed as the chief source of success. They are often characterized by having been established and developed step by step, beginning with a unique technology innovation and product proposal made by some very motivated entrepreneurs.

3.2.1. Types of small high-tech companies

Price and Chen (1993) classify small innovative companies into three levels (Table 1). A small company lies between the start-up and mature levels. Mature is used by the authors to describe the state of a company that has developed the skills and systems needed for long-term viability. The phase between start-up and maturity is the company's adolescence period, when it strives to grow on its early successes and to build organizational systems capable of supporting this growth. According to the authors, the company may be mature without necessarily becoming large. The Table 1 describes the company's main characteristics at each level.

3.2.2. Assistance issues of start-up high-tech companies

Irrespectively of type, all small innovative companies should provide product innovation aligned with the market and its business model. In the case of start-ups, the challenges are greater due to the entrepreneurs' lack of market experience. The literature indicates the necessity of external assistance in these areas. Carayannis and Zeldwitz (2005) propose an incubator model and identify some best practices. One of them is extrapolating the business vision and technological aspects of start-up companies. These authors assume that the majority of incubators have not been able to provide appropriate coaching for them.

Usually the entrepreneurs start with technical background and they do not have previous market experience or knowledge about the industry sector. Therefore, consultancy support is fundamental at this early stage. Aerts, Mathyssens and Vadenbempt (2007) identified services offered by European organizations by means of a survey with 654 business incubators pertaining to the Cordis database: 88% of them offered business planning support, while 61% provided assistance in development of new products and services. The percentage of support regarding intellectual property rights is 58%. Those data show a necessity of

Table 1. Types of small high-tech companies.

Type of company	Organization	Primary business focus
Start-up	Many functions not yet established	Producing initial products
Small	Functions established but minimally staffed	Producing follow-on products and expanding market share
Mature	Functions established, staffed, and experienced	Protecting share and expanding into new markets

complementing the assistance related to market and product planning.

Clarysse and Bruneel (2007) reinforced that innovative start-ups requires more than just financial assistance. The intensity and nature of these needs seems to change during the different stages of the enterprise's life cycle. During the initial stages product and market identification is recognized as vital.

This problem is even more significant when the advances and diffusion of business plan practices are taken into account. One example is Almeida and Fernando's study (2008) of nine cases of IT start-ups. Contrary to ineffective companies, successful ones were characterized as having a holistic strategy regarding business, market, product and technology. Therefore, the existence of a business plan alone does not seem to suffice for it.

4. Case study in a brazilian start-up high-tech company

The T-Plan (PHAAL; FARRUKH; PROBERT, 2001a) process was selected to be applied in the case study. This choice reflects the necessity of a detailed process to guide the team. The people involved were: the entrepreneur, the researcher and a new product development (NPD) specialist. The first two persons worked full time on the project, but the remaining one was only involved in accordance with the needs.

The company where the study was developed is a Brazilian start-up company of medical/hospital equipment industry, referred here as HLG. It has the same characteristics of several start-up high-tech companies: inexperience in market, entrepreneurs with technical background, few resources available and lack of business strategy. Therefore, the results of the case study may indicate a contribution for other companies of this same type.

The mentors from the company had identified an opportunity in the field of skin treatment (MORTON et al., 2002). The business idea was to develop a product with an improved performance, based on a technology that allows lower cost. The initial market focus was skin treatment clinics and hospitals.

The HLG entrepreneurs had technical expertise to develop the technology. However, since they did not have knowledge on new product development, they decided to take advantage of a partnership with a NPD specialist to identify an opportunity to improve their current situation. Then, the application of technology roadmapping to support the strategic product planning was selected as an initial stage.

The next sections describe the activities performed during the case as well as the difficulties and solutions that appear in the way.

4.1. Planning activity

This phase includes the following targets: definition of participants, scope definition and customization of standard model. Considering the possibilities and the HLG characteristics, the team was composed by two people: the entrepreneur and the researcher. They were designated as sponsor and facilitator, respectively.

Concerning the requirements and business goals as well as the unit of analysis for the TRM implementation, the results were:

- Unit of analysis: therapeutic market related to human skin treatment with hospitals and clinics as the target customers; and
- Requirements and business goals: to understand current status and evolution of the therapeutic market and define product features to satisfy the drivers of that specific market.

4.2. Market workshop

The goals here are: to introduce TRM concepts and T-Plan standard model, to confirm goals defined in first phase, to identify set of product performance dimensions; to identify and prioritize business and market drivers, to consider enterprise strategy position and carry out a SWOT analysis, and to identify knowledge gaps and areas for further work.

The identification of product performance dimension demanded a big effort, because the meaning of the term *product performance dimension* was unclear for the entrepreneur. Following, the definition of the market and business drivers reveals that no business strategy was known. Therefore the business drivers were not considered in this moment.

The market drivers were defined with information provided by clinics and hospital contacts. Another important source for market drivers was the entrepreneur attendance to a conference, where specialists were contacted. This strategy seemed to be very efficient, since the conference was a source of quality information and required a small investment.

Defined the drivers, the next step was to evaluate them using the score 1 to 10. Due to the evaluation to be concentrated in one person, an auxiliary tool was used. This tool consisted of a matrix where each driver was assessed by comparison to other drivers. In the end an average score was calculated. This method tried to prevent tendencies deriving from personal judgments. The Table 2 presents the matrix to give a better understanding of the tool used.

Although the T-Plan indicates a SWOT analysis, the amount of information available engenders major difficulties in accomplishing it task. Hence, the SWOT analyses were not taken into account in this study.

4.3. Product workshop

The goals here are: to review information provided by market meetings, to identify product features capable of satisfying selected drivers, to assess the importance of each feature according to drivers, to consider strategic aspects of product development, in order to using product families or platforms, and to identify knowledge gaps and areas for further work.

At this workshop, a brainstorming of ideas was fundamental to define product features and achieve better results. During this activity, benchmarking competitors' products became the main source of information used by the team.

The next activity was to evaluate features according to their impact on drivers by means of a T-Plan matrix. It provides scores 0, 1, 2 or 3 (positive and negative) to recognize the impact of features on drivers. The tool produces a balanced weight that includes the driver scores provided by the previous matrix. Table 3 contains the matrix used and results obtained in this case study.

4.4. Technology workshop

The goals defined for this workshop are: to review information provided by marketing and product meetings, to identify technology solutions capable of satisfying product features, to prioritize the potential of these solutions, and to identify knowledge gaps.

Here, the relationship between technology and other factors was more easily found, since some issues had already been discussed by the team. Nevertheless, the team had difficulties in the identification of the suitable technological areas and solutions for the business under consideration.

The assessment of the impact of the technological areas on the product features (Table 4) used the same matrix adopted in the last workshop.

4.5. Charting workshop

The actions intended for this workshop are: to review information provided by market, product and technological meetings; to develop roadmap identifying market and strategic milestones, product evolution and preferred technologies; to identify knowledge gaps and prepare a report presenting barriers and success factors of application.

The information generated during the entire process was integrated at this time. The market and business drivers, product features and technological solutions were aligned to prepare the roadmap. One important outcome was the view of the business's objectives and how they could be achieved

Table 2. Matrix to support the identification of drivers' priority.

	Product cost	Flexibility of applications	Facility of use	Maintaining cost	Mobility	Safety	Score	Weighted score
Product cost	10	5	8	5	5	1	34	5,2
Flexibility of applications	5	10	8	7	5	1	36	5,5
Facility of use	2	2	10	3	5	1	23	3,5
Maintaining cost	5	3	2	10	1	1	22	3,4
Mobility	4	3	7	6	10	1	31	4,8
Safety	10	10	10	10	10	10	60	10

Table 3. Matrix to evaluate impact of product features on market drivers.

	Product cost	Flexibility of applications	Facility of use	Maintaining cost	Mobility	Safety	Score	Weighted score
Table 2 scores	5,2	5,5	3,7	3,5	5,4	10	-	-
Lightening power	0	3	0	0	0	0	16,5	8,8
Maneuverable	–2	1	2	0	3	0	18,7	10,0
Modularity	–1	0	0	3	0	0	4,4	2,4
Safety system	–2	0	0	–1	0	3	16,4	8,8
Users interface	–2	0	–1	–1	0	2	2,7	1,4

through the opportunities identified for new products and technologies. A roadmap similar to the one generated is represented in Figure 3. The original data was changed due to confidential implications.

Once the roadmap was ready, the implementation phase should start by the definition of action plans. In this way, the roadmap becomes active and has more probability to introduce improvements for the company.

5. Analysis of the case study

The analysis is divided according to the four workshops to facilitate the understanding and to organize the results. The planning activity was not considered here.

5.1. Market workshop

The first barrier encountered here was the absence of a multidisciplinary team. For that reason, it was possible that the priority of market and business drivers might have been influenced by the entrepreneur view. This fact increased the chance of mistakes concerning the definition of roadmapping guidelines.

The evaluation of the market drivers included a tool to support the entrepreneur prioritization of market drivers. This tool helps in the achievement of more reliable scores of market drivers. In the end, the HLG was capable of identifying its objectives for the product. One of the aspects learned at this workshop was that safety and flexibility drivers were more important than product cost, which was unanticipated by the entrepreneurs. This is a strong indication of the method's potential to offer a better business scenario to the participants.

5.2. Product workshop

The team found some difficulties here due to the lack of experience in developing the product. One of them was the unavailability of required information. The main action used was the brainstorming based on information from competitors' products, conference papers and information gathered from potential customers.

The main outcome from this workshop was the planning of a product platform. This platform will allow the enterprise to establish a product evolution that can attend to market and business drivers in the next years. The TRM application seems to be more useful than business plan approach in this aspect, because it forces entrepreneurs to think in terms of product timeline.

Table 4. Matrix to evaluate impact of technological areas on product features.

	Lightening power	**Maneuverable**	**Modularity**	**Safety system**	**Users interface**	**Score**	**Weighted score**
Table 3 scores	8,8	10,0	2,4	8,8	1,4	-	-
Lightening source	3	1	0	–1	0	27,6	10
Structural system	0	3	1	0	0	32,4	4,4
Control system	0	0	0	0	3	4,2	0,6

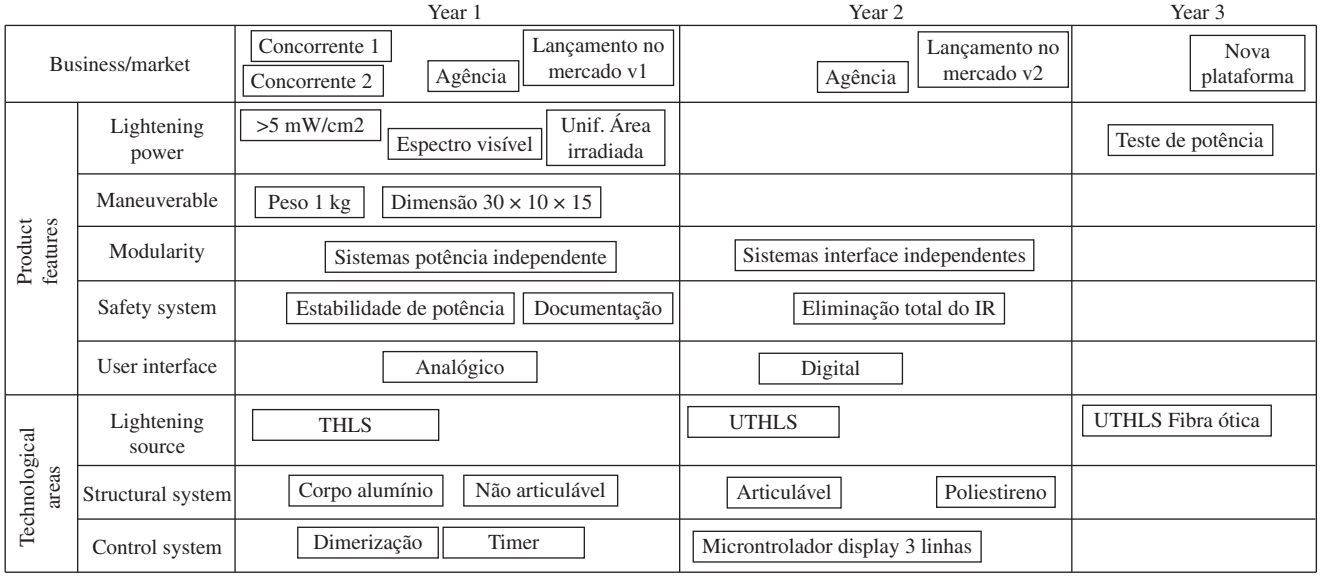

Figure 3. Product-technology roadmap created by technology roadmapping application in HLG.

5.3. Technology workshop

The main barrier of this workshop referred to the knowledge about existing technological solutions, what caused difficulties in recognize the difference between technological areas and technological solutions. Thus, an additional brainstorming was necessary to reach some conclusions. The sources used here were the same of the aforementioned workshops, despite of the focus on conference papers, where technological issues can be more easily found.

5.4. Charting workshop

The main contribution of this workshop was the building of the integrated planning. Some misunderstandings arose due to visual aspect of the roadmap. This compelled the team to rework some points to achieve an optimized alignment of business, marketing, products e technology targets.

6. Conclusions

The Table 5 summarizes the barriers found in the TRM application in this start-up high-tech company. It compares the relevance of barriers indicated by Phaal, Farrukh, and Probert (2001b) with those noted here. The relevance was qualitatively evaluated as follows, according the participant perceptions: 1 (low impact), 2 (medium impact) and 3 (high impact). Additionally, the Table 5 separates the barriers among those already mentioned in the literature, those not cited and those that were perceived in this case.

The comparison shows differences between the barriers presented in the literature from those of the case study. This insight may indicate that the application of the technology roadmapping in start-up high-tech companies has unknown characteristics, what would be an opportunity for investigation in future researches.

By the application of technology roadmapping, the case study provided a useful method to support the strategic product planning of the start-up high-tech company. The entrepreneurs started to understand the market wants regarding their product, what contributes to formulate a more efficient product strategy. Moreover, the technologies necessaries for the product development were defined according to current company competencies.

Since the HLG Company has the same characteristics of several high-tech start-ups in Brazil and even in other countries, this paper shows the potential of TRM to enhance the strategic product planning of this company type. Obviously it is necessary to carry out more case studies to understand in detail this opportunity. However, the results of HLG Company are a signal that may be considered in further researches.

The support in new product development for start-up high-technology companies is a current necessity that may help them to survive and grow. Therefore the results of this paper may indicate an opportunity beyond of achieving a successful product; it may indicate a way to collaborate with success of the high-tech companies.

This paper is part of a research project aimed at analyzing techniques, methods and tools used in strategic product planning. Other projects related to TRM, as portfolio management, are in progress. By way of that, the research may build guidelines to help companies to improve their new product development process.

Table 5. Comparison between barriers of this case study and those published by Phaal, Farrukh and Probert (2001b).

Compared Barriers	Phaal et al. (2001b)	HLG case
Lack of clear business need	1	3
Enterprise culture and politics impeded participation and progress	1	1
Lack of commitment from senior management	1	1
Unavailability of required data / information / knowledge	3	3
Timing of initiative was inappropriate	1	2
Lack of clear and effective process for developing map	2	3
Lack of effective tools / techniques / methods	2	3
Lack of effective facilitation / training	2	3
Published barriers not applied in HLG case	Phaal et al. (2001)	HLG case
Initiative overload / distraction from short-term tasks	3	-
Right people / functions were not involved	1	-
New barriers identified in HLG case	Phaal et al. (2001)	HLG case
Lack of a new product process in action	-	3
Absence of people to compose a multidisciplinary team	-	3
Lack of experience on focused market	-	3

7. References

AERTS, K.; MATTHYSSENS, P.; VANDENBEMPT, K. Critical role and screening practices of European business incubators. **Technovation**, v. 27, n. 5, p. 254-267, 2007.

ALBRIGHT, R. E.; KAPPEL, T. A. Technology roadmapping: roadmapping the corporation. **Research Technology Management**, v. 46, n. 2, p. 31-59, 2003.

ALMEIDA, S.; FERNANDO, M. Survival strategies and characteristics of start-ups: An empirical study from the New Zealand IT industry. **Technovation**, v. 28, n. 3, p. 161-169, 2008.

BARCZAK, G.; GRIFFIN, A.; KAHN, K. B. PERSPECTIVE: Trends and Drivers of Success in NPD Practices: Results of the 2003 PDMA Best Practices Study. **Journal of Product Innovation Management**, v. 26, n. 1, p. 3-23, 2009.

CARAYANNIS, E. G.; von ZEDTWITZ, M. Architecting gloCal (global-local), real-virtual incubator networks (G-RVINs) as catalysts and accelerators of entrepreneurship in transitioning and developing economies: lessons learned and best practices from current development and business incubation practices. **Technovation**, v. 25, n. 2, p. 95-110, 2005.

CLARYSSE, B.; BRUNEEL, J. Nurturing and growing innovative start-ups: the role of policy as integrator. **R&D Management**, v. 37, n. 2, p. 139-149, 2007.

COOPER, R. G. **Winning at new products.** 3 ed. Cambridge, Massachusetts: Perseus Pub., 2001.

COOPER, R. G. Perspective: The Stage-Gate Idea-to-Launch Process: Update, What's New, and NexGen Systems. **Journal of Product Innovation Management**, v. 25, n. 3, p. 213-232, 2008.

COOPER, R. G.; EDGETT, S. J.; KLEINSCHMIDT, E. J. Benchmarking best NPD practices – II. **Research Technology Management**, v. 47, n. 3, p. 50-59, 2004.

CRAWFORD, M.; BENEDETTO, A. D. **New Products Management.** 8 ed. New York: McGraw-Hill/Irwin, 2006.

DE COSTER, R.; BUTLER, C. Assessment of proposals for new technology ventures in the UK: characteristics of university spin-off companies. **Technovation**, v. 25, n. 5, p. 535-543, 2005.

DE JONG, J. P.; MARSILI, O. The fruit flies of innovations: A taxonomy of innovative small firms. **Research Policy**, v. 35, n. 2, p. 213-229, 2006.

MORTON, C. et al. Guidelines for topical photodynamic therapy: report of a workshop of the British Photodermatology Group. **British Journal of Dermatology**, v. 146, n. 4, p. 552-567, 2002.

PHAAL, R.; FARRUKH, C.; PROBERT, D. **T-Plan:** fast start to technology roadmapping - planning your rote to success. Cambridge: Cambridge University Press, 2001a.

PHAAL, R.; PROBERT, D.; FARRUKH, C. **Technology Roadmapping:** linking technology resources to business objectives. 2001b. Disponível em:<http://www.ifm.eng.cam.ac.uk/ctm/publications/tplan/trm_white_paper.pdf> Acesso em: 15/10/2007.

PHAAL, R. Technology roadmapping - A planning framework for evolution and revolution. **Technological Forecasting and Social Change**, v. 71, n. 1-2, p. 5-26, 2004.

PRICE, M. J.; CHEN, E. E. Total quality management in a small, high-technology company. **California Management Review**, v. 35, n. 3, p. 96-118, 1993.

PROBERT, D.; RADNOR, M. Technology roadmapping: Frontier experiences from industry-academia consortia. **Research Technology Management**, v. 46, n. 2, p. 27-30, 2003.

RADNOR, M.; PROBERT, D. R. Viewing The Future. **Research Technology Management**, v. 47, n. 2, p. 25-26, 2004.

RUOKOLAINEN, J. Gear-up your software start-up company by the first reference customer-nomothetic research study in the Thai software industry. **Technovation**, v. 25, n. 2, p. 135-144, 2005.

SUZUKI, K.; KIM, S. H.; BAE, Z. T. Entrepreneurship in Japan and Silicon Valley: a comparative study. **Technovation**, v. 22, n. 10, p**.** 595-606, 2002.

WHALEN, P. J. Strategic and Technology Planning On A Roadmapping Foundation. **Research Technology Management**, v. 50, n. 3, p. 40-51, 2007.

WILLYARD, C. H.; MCCLEES, C. W. Motorola's Technology Roadmap Process. **Research Management**, v. 30, n. 5, p. 13-19, 1987.