Comprehensive Innovation and its Implications on New High-Tech Product Development

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Nowadays, innovation represents an essential ingredient within organizations for their survival in a strong competitive marketplace. Innovations emerging from R&D projects could represent key factors for the foundation of new businesses. Various supporting programs for establishing innovative start-ups within business incubators, as well as spin-offs within universities are promoted by authorities at local and national levels. Statistics have shown that only a small percentage of these initiatives (around 30%) succeed to survive more than three years. There are various causes which keep the success rate only at this level, but a major one is the lack in understanding the complex nature of innovation by the people which initiate these businesses; they are mainly focused on technological innovation (product innovation). This paper is going to give a broader perspective on innovation, seeing it as an integrated model of product innovation, marketing innovation, production process innovation and business model innovation over their life-cycles. From this enhanced view of innovation, consequences on new product development are further analysed.
Keywords: *innovation, spin-off, new product development, life-cycle model*

Introduction

High-tech industries are key driving forces for economic development at regional and national levels. This justifies the interest of governments to support the foundation and development of businesses operating in the high-tech sector. High-tech companies are those engaged in the design, development and introduction of new products and/or innovative manufacturing processes through the systematic application of scientific and technological knowledge [9]. The Organization for Economic Cooperation and Development (OECD) defines high-tech in terms of the ratio of R&D expenditures to value added of a particular industry [7]. From this perspective, around 40 industries are considered in the category of high-tech [9].

Various studies reveal that all high-tech industries share some common charac-teristics, the most notably being the followings: market uncertainty, technological uncertainty and competitive volatility [1], [3], [5], [9], [10], [11], etc. The key sources of market uncertainty, technological uncertainty and competitive volatility are well-captured in [9] (pp. 7-11). High levels of uncertainty and volatility generates high business risks. Because of this reason, as well as because the unit-one cost of a high-tech product is very high relative to the costs of reproduction, the conception and development of new high-tech products should be somehow supported by society in large. In this respect, local and central authorities run various programs for setting up the so-called innovative start-ups within business incubators or technological parks, as well as spin-offs within universities [1], [5], [6], [8], [12], [13].

There are surveys that prove the positive role which university spin-off companies play in improving regional economies. It is mainly the case of less favored regions, which seem to be permanently disadvantaged because they lack a critical mass of knowledge capital to initiate accumulation, growth and economy development processes [1].

However, it was found out that new ventures have a high rate of failure [5]. Statistics have shown that only a small percentage of these initiatives (around 30%) succeed to survive more than three years [1], [5], [6], [12], [13]. There are various causes which keep the success rate only at this level, but a major one is the lack in understanding the complex nature of innovation by the people which initiate these businesses. In most of the cases the entrepreneurs of spin-offs are mainly focused

on technological innovation (product innovation), omitting the key roles which some other business aspects play on the commercial success [2]. Usually, the initiators of high-tech spin-off companies are people with very good technical and creative skills, but with poor managerial and business aptitudes and skills – this makes them "not seeing the forest from leafs".

Synthesizing various researches and findings in the literature, an approach that assesses new technology ventures is presented in [5]. It considers five criteria, with guidelines, for quantifying potentials of new technology ventures: technological and commercial risk, level of product innovation, market criteria, product extensions and entrepreneurial background. However, even very meritorious, the approach presented in [5] lacks in analyzing new product innovation from a broader perspective (e.g. life-cycle perspective, multi-dimensional innovation). In a highly dynamic market environment, a comprehensive approach of product innovation is crucial [2], [4].

The importance of market scanning before starting-up a new technology venture is scientifically demonstrated in [10]. It was found that both narrow and broad scanning each affects the new product development process in a unique way. Narrow scanning has a strong positive effect on profitability through incremental product adaptation [10]. Broad scanning positively influences spin-off knowledge [10].

To strengthen the idea of broader approach of innovation, researches presented in [6] show the importance of collaboration between the university spin-off, with both the parental organization and outside organisms, to acquire external competencies in the technological area. The parental organization plays a pivotal role in the spin-off process, especially in its early stage where its catalyses the emergence of the business idea by supporting the spin-off firm with infrastructure and expertise in a specific field of mentorship. However, as the spin-off evolves, this pre-incubation service complements yet more support services of municipality and region, which stand to be more important in the technological and business development of the spin-off [6]. The key role of the business model in setting up successful spin-offs is analyzed in [12]. It is shown that corporate spin-offs combine the rapid growth of new firms with a considerably lower failure rate than other types of start-ups.

Analyzing the limitations of tools and approaches currently used for supporting the decision-making process during setting up high-tech spin-off companies, this paper introduces the concept of comprehensive innovation and highlights its implications on developing new high-tech products. Conclusions of the theoretical foundation are exemplified on a novel software tool for quality cost management. This software tool comes up from a research project. It is shown that commercial success could be increased if several dimensions of innovation are concurrently considered within the design of new high-tech products.

About comprehensive innovation

One of the crucial factors for market success of a new product is referring to the level of innovation that product incorporates. When superior solutions to critical problems on the market are elaborated, radical innovation occurs [9]. Radical innovation must generate either a complete novel product or significant improvements in the performance characteristics of an existent product [3]. In the current business environment, having a high quality product and attractive prices does not necessarily guaranty product competitiveness; "high value for money" is the new paradigm [2], [3], [9]. When radical innovation is achieved, either a "consistent differentiation" with respect to competing products is realized or new markets are opened [2]. Through innovation, high value-added must be created for beneficiary; an innovation that cannot be fully exploited by its target beneficiaries is useless. In addition, an innovation is really radical only when it generates positive effects upon production costs, too, as well as upon the supporting processes over the new

product life-cycle. However, besides product innovation, other three dimensions of innovation must be considered when new product is going to be developed. They refer to production process innovation (also known as infrastructure innovation), marketing innovation and business model innovation (also known as organizational innovation) [2], [3], [4]. The consideration of product innovation, infrastructure innovation and industry innovation is highlighted in [4], but it lacks of marketing innovation, as well as on considering a concurrent approach of these innovations in the framework of a business system.

This paper proposes integration of the four dimensions of innovation: product innovation (PI), marketing innovation (MI), production process innovation (PPI) and business model innovation (BMI), within an aggregated model called "comprehensive innovation" (CI). In this model, dynamics of each type of innovation, as well as the coupled effects of these dynamics should be considered in the equation of commercial success. Thus, life-cycle model of the aggregated innovation must be taken also into account when developing new products, especially for those in the category of high technology. The generic model of comprehensive innovation is proposed in figure 1.

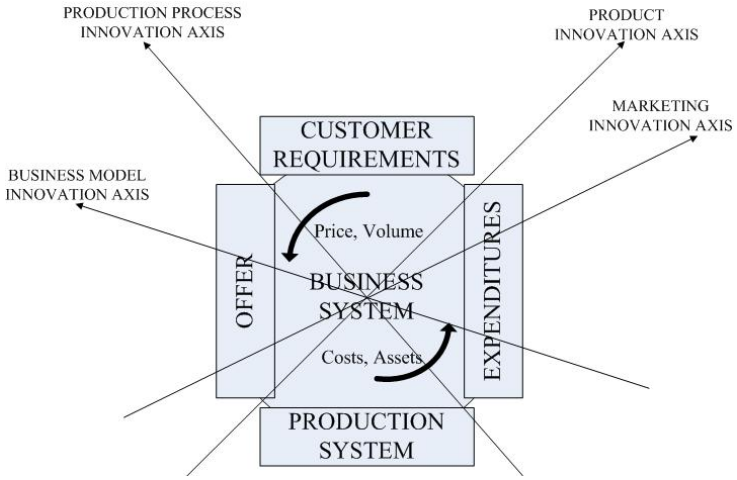

Fig.1. Conceptual model of comprehensive innovation

When a new innovative business is set-up, those which are going to invest and support the new business (e.g. venture capitalists, public authorities, universities, etc.) must have a clear view about all core blocks of the business system (customers and their requirements, offer in the broad range, production system and expenditures), as well as about their correlations with price, sales volume, costs and assets. But this is not enough; they also should be aware on how the four axes of innovation (see figure 1) will define the maturity of business system in time, as well as on the timing between the four axes such as the business system to evolve in a balanced way (effective and efficient). Usually, those that start-up a business based on technological innovation have poor or very poor understanding and grounding of these issues. As a result, even if the innovation incorporated within product is high, they fail to sell the product. A comprehensive innovation is achieved when at least the effects highlighted in figure 2 become visible.

In the case of high-tech products, product innovation leads marketing innovation, production process innovation and business model innovation. If product is designed with low intrinsic potential with respect to marketing innovation, production process innovation and business model innovation, the success rate of the new business is relatively low. The author observed that radical innovative ideas in marketing, production and organizational dimensions emerge from product properties, features and characteristics. Without an adequate support from product side, the other three dimensions of innovation are very

much constrained. In conclusion, when a new high-tech product is going to pass into the business phase following the fundamental and/or applied research, the product itself should be reanalyzed and very probably redefined on certain aspects such as to support the commercialization process.

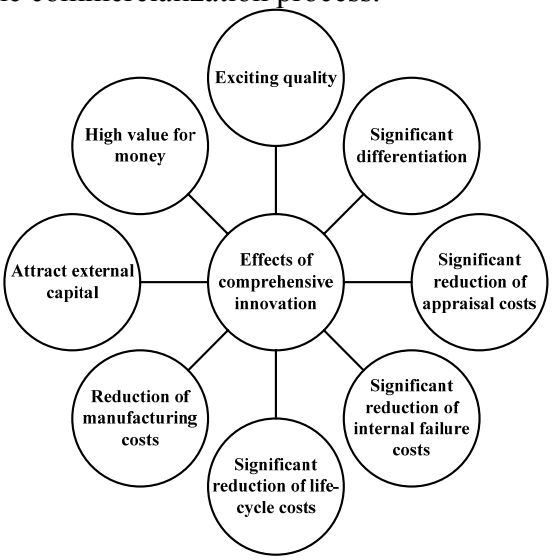

Fig.2. Effects of comprehensive innovation

Life-cycle model of comprehensive innovation

As a product or a business, or as any other entity (physical or abstract), innovation itself has its own life-cycle. In this respect, there is an inception phase, a growing phase, a maturity phase and a decline phase (because of industry innovation) as distinctive parts of the innovation life-cycle. Because, in a broader range, innovation (as comprehensive concept) is the compounded effect of four kinds of innovations, innovation life-cycle should be viewed both as a set of four life-cycles belonging to each dimension of innovation and as an aggregated life-cycle of the four specific life-cycles. The life-cycle model of comprehensive innovation is shown in figure 3.

There are several curves and symbols represented in figure 3. They are: CZ – critical zone (it is the time-interval when either decline continues if no product innovation occurs or the business system is reborn if company succeeds to bring new innovations into the product); 1 – cash flow over the "first" life-cycle; 2 – industry viability over the "first" life-cycle (product related); 3 – maturity level of product innovation over the "first" life-cycle; 4 – maturity level of production process innovation over the "first" life-cycle; 5 – maturity level of marketing innovation over the "first" life-cycle; 6 – maturity level of business model innovation over the "first" life-cycle; 7 – industry viability over the "first" life-cycle (business system related); 8 – maturity level of aggregated innovation over the "first" life-cycle; 9 – cash flow evolution if no further innovations occur; 10 – maturity level of product innovation if no further improvements occur; 11 – maturity level of business model innovation if no further improvements occur; 12 – cash flow evolution in the "second" life-cycle if relevant innovations occur in time; 13 – industry viability (product related) in the "second" life-cycle; 14 – maturity level of product innovation over the "second" life-cycle; 15 – maturity level of production process innovation over the "second" life-cycle; 16 – maturity level of marketing innovation over the "second" life-cycle; 17 – maturity level of business model innovation over the "second" life-cycle; PB – payback period; ROI – return on investment; IRR – internal rate of return; NPV – net present value.

Some important remarks should be done with reference to figure 3. The scale selected to quantify the level of cash flow is not the same with the scale used for quantifying maturity of innovation; there are no quantitative connections between curve 1 and the other curves within the "first" life-cycle, as well as between curve 9 or 12 and the other curves within the "second" life-cycle. Connections are only qualitative. It is denoted "first" life-cycle and "second" life-cycle just to highlight the need of radical transformations within all dimensions of innovation after a certain period of time since the business was started-up such as both the product and the business system, as a whole, to survive onto the market. Actually, we discuss about a reborn of the business system. With reference to figure 3, an innovative start-up (e.g. a university spin-off) is initiated because a product innovation occurs.

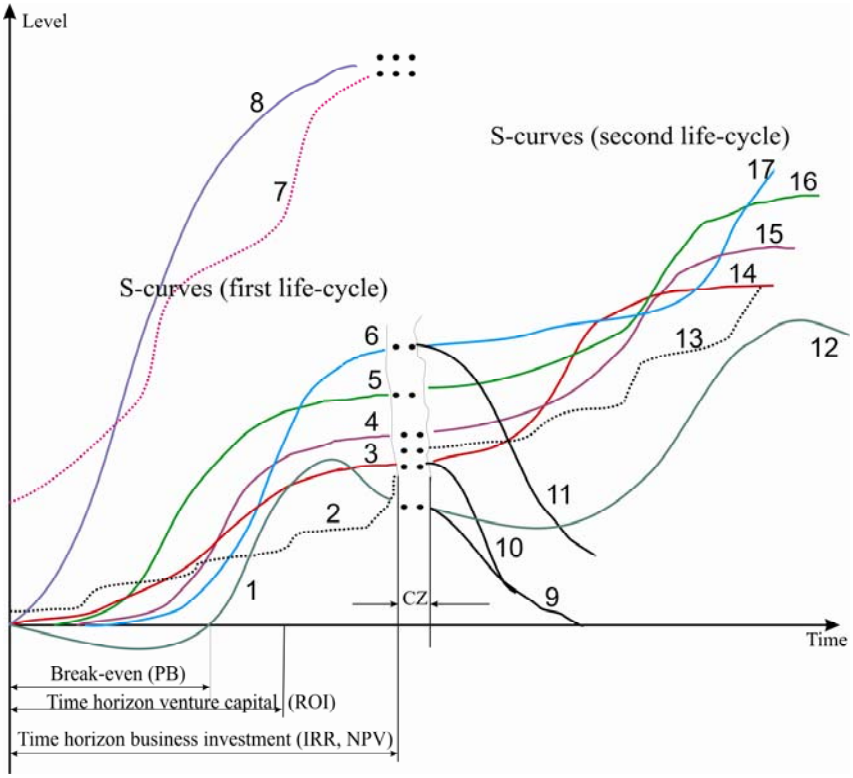

Fig3. Life-cycle model of comprehensive innovation

Based on a business plan, entrepreneurs access funds (usually from venture capitalists) and used them to support business development according to a well-defined budget and time plan. In the development phase, cash flow is negative, because company only consumes resources. When product innovation level reaches the viability threshold, product can be launched onto the market. However, without basic innovations in terms of production process and business model, the product alone cannot support the market success. So, during product development phase, innovations in terms of infrastructure, formalization of processes, business capitalization, etc. should occur, too. More than this, marketing innovation should reach in this period even a higher level of maturity than product innovation to support properly the introduction phase of the product onto the market. In the introduction phase, the slope of the cash flow is changed to a positive one. When break-even point is reached, innovation must happen consistently in all its four dimensions. As figure 3 suggests, resources necessary to support the start-up phase of the new business are significantly higher when all aspects of innovation are taken into account. It is a common characteristic of most business plans related to innovative start-ups to define only poor solutions in terms of marketing innovation, business model innovation and production process innovation; as a consequence, sub-estimated budgets, limited activities and poor schedules are considered. These lead to lack of capability to support properly the launching process; and from here bad consequences on the commercial success.

Another critical issue that occurs from the life-cycle model of comprehensive innovation is referring to the financial feasibility of the business. The initial financial plan should calculate the attractiveness of ROI over the time horizon T_i imposed by investors (e.g. a cumulated ROI of over 250% in a time horizon of 6-7 years), as well as to calculate the feasibility in terms of IRR and NPV over the time horizon T_b the business is considered viable with the planned innovations. IRR, NPV and T_b are extremely important indicators for investors, because they usually sell their shares after the period T_i.

Because in calculating ROI, IRR and NPV,

the operating costs, price and sales volume over time are very important, an accurate estimate of them is strongly required. If the business plan lacks of reliable solutions and appropriate effort estimation in terms of marketing innovation, process innovation and business model innovation, the results might look good, whereas the reality to be vice versa. That is why, in 80% of cases, venture capitalists radically change the business strategy to keep the start-up alive and only 30% of the new innovative businesses survive more than three years. Considering the viability threshold curves both for product and for the business system (see curves 2 and 7 in figure 3), it is clear that product innovation and overall business innovation should be permanently kept over these levels, otherwise the financial performances and even company's survival are jeopardized.

In conclusion, the message that comes out from the life-cycle model of comprehensive innovation is that, besides a strong articulation of product innovation, the business plan must demonstrate from the very beginning, in more details and to a higher extend how actually marketing innovation, production process innovation and business model innovation will evolve in time. This will lead to a more realistic view about the market potential of the new business, being beneficial both for initiators, supporters and investors.

Implications of comprehensive innovation on new high-tech product development

Taking into account the aspects revealed in the life-cycle model of comprehensive innovation, new product development should be viewed from a new perspective. Seeing the importance which marketing innovation, production process innovation and business model innovation play in the equation of business competitiveness, it should be determined how actually these categories of innovations could be supported by product innovation. In other words, an appropriate concept and appropriate features within the new product could significantly contribute to the definition of highly mature innovations in marketing, infrastructure, organization, etc. Without having the ambition of covering all aspects, table 1, table 2 and table 3 present challenges on new high-tech product development considering a comprehensive view of innovation.

Table 1. Implications of marketing innovation on new high-tech product development

Characteristic of marketing innovation	**Implications on new product development**
Meeting market requirements	Deep quality planning before design Customer-oriented design
Deep market segmentation	Design for easy customization
Proper price policies and pricing strategies	Design based on measurable performance characteristics Value-to-money approaches Inclusion of product features able to support various payment policies (e.g. temporary access codes)
Highly differentiated unique selling points	Novel product features for stringent market needs Highly visible differentiation for key performance characteristics (close to ideal states)
Meeting a stringent need	Product to be designed for a relative large market High level of utility incorporated
Value orientation	Product capable to define a new market value
Building a cultural trend around the product	Transformations in customer behaviour Make visible a specific identity for product users (proud to use it)
Fast capturing of customer's confidence	Capacity for early demonstrations to a very small market segment, with high impacting results
Increasing markets and open new markets	Easy to distribute Easy to install and upgrade Easy to learn how to use it Fast prove of value-added and financial benefits

Table 2. Implications of process innovation on new high-tech product development

Characteristic of process innovation	**Implications on new product development**
Competitive production cost objective	Meet a well-defined cost objective Capacity to prove the value incorporated in each module or part of the product (meet a cost objective for each part and module)
High process capability	Product design to facilitate production process quality
Minimize failures (low level of poor quality costs)	Simple and robust design of the product Highly reliable design
High process productivity	Product design facilitate process automation
Low maintenance and supporting costs	Features to ensure easy maintenance and support (even remotely – see tele-service)
Fast adaptation to a new product generation	Modular and reconfigurable design Open architecture Fast and easy translation to a new technology Deep technical documentation Well-defined testing procedures and well understanding of current performances
High technical flexibility	Highly modular design Standardized interfaces

Table 3. Implications of business model innovation on new high-tech product development

Characteristic of business model innovation	**Implications on new product development**
Business risk minimization	Configuration design to integrate modules and parts that already exist onto the market Innovation at architectural level Include modules with well-protected intrinsic functional features and/or technological processes Capacity to be attached to other products as a functional module or accessory
Increasing profitability (high operating income)	To involve low operating costs To bring high value-added for customer (price can grow)
High ROI in short time	Lower development costs (simplicity) Radical technical innovation (uniqueness) Key features of the product to raise difficulties for being copied or reproduced in short time
High IRR and NPV	Product vision to be defined on longer term Multi-objective optimization from early stages of design Design for product life-cycle
Financial sustainability	Potential of successive releases with relevant improvements (continuous technical innovation) Directed product evolution Flexible to integrate any new technology

The implications which are highlighted in tables 1, 2 and 3 show that new product development cannot be approached only from technical point of view; by contrary, product design and development should be driven by market and business environment. The commercial success of the new product will be significantly influenced by the capability to "translate" market and business environment into design.

Conclusions

Successful start-up businesses in high-tech industries ask for significant and continuous innovation along the planned time horizon of the respective business. Because of the high risk involved in this category of businesses, careful business planning is required from the early stages of business initiation.

This paper shows that business planning is reliable when four dimensions of innovation are taken into account in resource definition

and scheduling. It is formulated the concept of comprehensive innovation and it is put into evidence its life-cycle model. It considers the dynamics of product innovation, process innovation, business model innovation and marketing innovation relative to each other, as well as in correlation with the evolution in time of industry viability's threshold and with the cash flow. It is revealed the fact that a good design of the new product maximizes the potential of innovation in all its four dimensions. From this perspective, several new issues should be integrated within the design and decision- making processes to set up highly mature and sustainable products. These issues belong to marketing, production and organizational processes.

Due to these aspects, initiators of spin-offs must spend some time in a pre-incubation phase, where they have to learn and accumulate deep knowledge and skills in engineering and management of innovation, in sales, in communication, in intellectual property protection, in promotion, in marketing, in entrepreneurship, in quality management, in production planning, monitoring and control, in business development and financial analysis for being able to set up a reliable business plan that puts into practice an innovative technical idea. Only afterwards, the business idea could be incubated with a higher rate of success.

The holistic view of innovation within a new business automatically generates transformations in the technical solution; further innovations should be considered in the new product to support itself the commercialization process. In the paper are highlighted some of these challenges. Further researches will be conducted to identify new challenges in product development from the perspective of comprehensive innovation, as well as to see how a business plan and a feasibility study should effectively look in the new light.

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