Managing Product Development
-Challenges related to Embeddedness in Time and Space

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Abstract

Product development is of great importance to many companies. At the same time, product development is risky, as companies set out to do things they have never done before. Literature has introduced a variety of models on product development for *management* of this type of challenging processes. These models include product development depicted as a series of activities, as a departmental-stage model, as a decision-stage process, or combinations of these. These models are often supplemented by numerous key success factors, techniques or advices. In accordance with these models for management of product development, literature has introduced various techniques for evaluation in relation to follow-up and measurement of success. Time, cost and performance can be measured throughout the product development process, or after its completion. Following the completion of the product, measures such as payback period and break-even time based on the sales of the product are quite common. This paper emphasizes the embeddedness of product development processes. Two basic types of embeddedness are introduced. First, embeddedness in time exists. The development of a single product often rests upon past achievements, referred to as path-dependence, technological trajectories and cumulative aspects of technology. In other words, history matters. Likewise, the development of a product bears with it effects for future products. Second, embeddedness in space exists. The development of a single product often draws upon other products or adjacent technologies that involve a network of companies. As examples, some products are developed on the basis of close cooperation with suppliers, whereas others involve strong customer relationships. Likewise, the development of a product bears with it effects for companies in a network and the relationships that connect them. The empirical material in this paper is based on a biotech company and its network. More than 30 interviews have been conducted. In addition, various secondary information has been collected. The empirical material illuminates some challenges related to the traditional techniques for management of product development processes. Accordingly, this paper brings implications to theory on product development.

Keywords: product development, embeddedness, management, time, network

Introduction

The journey from a development project to an established company is an uncertain and risky enterprise, an understanding often expressed by practitioners, and underlined by scholars studying technological development in an interactive perspective. The famous Minnesota study (van de Ven et al., 1999: ix) describe innovation work as "highly unpredictable and uncontrollable". Others refer to innovation and product development as "messy". Product development is further seen as a "trial-and-error" process with features of "muddling through" when describing possible ways of managing it (Tidd, Pavitt & Bessant 1997). Being involved in an "innovation journey" means dealing with processes where time and space are crucial variables in terms of understanding innovation, but also how one should evaluate and measure success of a new product.

Innovation work and product development is an important activity for most firms. In fact it is by many scholars perceived to have become growingly important (Tidd, Pavitt & Bessant, 1997). Yet, the literature covering product development issues does not seem to agree on "one way" to view the phenomenon, or how it should be organised internally and externally in relation to the firm's environment. What makes product development interesting and crucial to plan and monitor is its risky nature: companies are set out to do things they have never done before and this activity can have profound impact on the firm's profitability and even survival. Going for the wrong solution might prove to be devastating for any firm. Customers may abandon the firm. So may also employees. In the end, the whole survival of the firm will be questioned.

The success of a product is strongly dependent on the moment of time for the evaluation. The spatial condition where a product is developed and used also affects its possibilities to survive. In addition, the success of a new product is also dependent on what physical, legal and financial boundaries that are drawn around it. A product might be seen as a very successful one if boundaries are drawn in one way, and less successful when the boundaries and the positions of actors in a network has changed. A firm has to take into consideration both time and space issues when new products are developed. At the same time, single product development projects has to be managed internally, resources must be allocated and be evaluated from the logic of an internal efficiency. In this paper we argue that all three dimensions must be taken into consideration when developing new products.

Therefore, lately, there has been an increased urge to manage product development, to monitor it in order to decrease the risks that are inherent in the process of developing new products or new technologies (e.g., Abernathy & Brownell 1997, Kaplan & Norton 1992). What is especially interesting is that the way a company chooses to evaluate product development will also have great implications on how the firm will manage the new product development process. If some variables are seen as more important than others to measure, the process will be directed towards fulfilling these goals, while offsetting others that also might be decisive for the long term success of the product.

The whole idea of managing a new product concerns delimiting physical and organisational resources in time and space. The delimitation in space concerns for example accounting and control of a firm or a relationship. What costs should end up at the project group's income statement? By asking this question we also ask what counterparts, internally and externally we should work together with and what relational resources these counterparts can bring to the table and jointly develop. The time aspect has to do when in time a new product should be evaluated. As a product is embedded both in a space-like environment, a network, which in turn is changing constantly over time, this is not an easy question. At a given point in time, the "space" might be favourable and the product is evaluated as being successful. However, the network can change quickly and just a short time later, the picture will be different.

This network like picture involves several important trade-offs, which the single firm has to manage, where the constant trade-offs between short term goals with long term visions is only one among several. Our aim with this paper is to illustrate this complexity and by doing this develop a framework which takes into account the fact that product development is embedded both in time and in space, but still has to be managed as an internal affair.

We will use a case from the Swedish biotech sector, where a new innovation in relation to analysing genetic variation was developed at the Royal Institute of Technology in Stockholm. The innovation was "productified" and commercialised in the Uppsala based biotech firm, Pyrosequencing. We will use this

example on how the development of a product is both embedded in space, how the technological solution is dependent upon how it relates to other existing and emerging technical solutions (market or network space) and how the geography of a company also influences its road map in new product development work. In addition, the case will illustrate the importance of time: how a product might seem to very successful at one point in time, while a certain period later the product will have lost its momentum and is now losing users. There is also a financial logic that is important to note, the way a firm and its products are evaluated is often dependent upon time, as there is a time value of money that investors often act upon.

Managing Product Development

Our actions are guided by the perspective taken; how we view things. The way product development is viewed is decisive for how it is attempted managed. See figure 1.

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In this section we will present and discuss three different ways to view product development. First, we will look into how product development is viewed as an isolated process. We argue that this is so, to a large extent because the way product development is managed emphasise an internal, or even isolated, perspective on product development. Second, therefore, we will examine the effects upon the view of product development when it is seen as embedded in time. Third, we will discuss the product development as embedded into space. I.e., the two latter sub-sections have the notion of embeddedness (e.g., Granovetter, 1985) in common. See figure 2.

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Product Development Viewed as an Isolated Process

In many ways, the view of product development as an isolated process can be said to represent a dominant perspective in literature. Basically, this view implies that the product development process and the product as an outcome are fully separated from the context. Focus is set on the process and the product *per se*. The process becomes a means to obtain an end: the product (see Løwendahl, 1995: 347; referring to Meredith & Mantel, 1989). The models are traditionally divided into planning and implementation steps (Lindell, 1991). This view underlies numerous models on managing product development, depicting product development as a process that starts with an idea or a discovery, and results in a product. Among the more widespread of these are the seminal model of Booz, Allen and Hamilton from 1968 (see Biemans, 1992), and Cooper's Stage-Gate™ New Product Process (Cooper, 1993; 2005). Common for such models is that they provide distinct advice on how to manage product development. These advice include how to divide the product development process into a number of stages, or activities, and how to establish gates, or checkpoints, throughout the process. The models point at various key success factors that ought to be followed as part of managing the process, such as "strong market orientation", "effective quality control procedures" and "speed, but not at the expense of quality" (e.g., Rothwell, 1992; Cooper, 1993; Cooper & Kleinschmidt, 1995). In a similar vein, different techniques for managing product development are launched, such as concurrent engineering (CE), quality function deployment – "house of quality", cross-functional integration, the design-build-test cycle, computer assisted design (CAD), test panels and design for manufacturability to mention some (e.g., Clark & Wheelwright, eds., 1994; Crawford, 1997).

Product development can be regarded as a particular type of project, as projects can be divided into two types: R&D projects and construction projects (Løwendahl, 1995; referring to Meredith & Mantel, 1989). Product development projects, due to being characterized by a relatively high degree of newness and uncertainty about the outcome, can be regarded as a type of R&D projects. By reviewing literature on project management, similar observations as for literature on product development projects can be made: models that are clearly based on the project and its outcome being viewed in

isolation are common, i.e., the focus is on a singular project as a lonely phenomenon (e.g., Engwall, 2003). Literature is furthermore strongly influenced by the normative project management theory (ibid.). Management of projects becomes a question of sticking to plans, avoiding changes in the latter phases of the project and managing resource availability. Various techniques are introduced for management of projects, whereof Gannt charts, CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique) and WBS (Work Breakdown Structure) as presented in "The Wiley Guide to Managing Projects" by Morris & Pinto (2004) represent the more widespread ones (see also Packendorff, 1995: 321). By applying this approach to projects, they are regarded as tools rather than organizations (Packendorff, 1995: 325).

These models, techniques, key success factors and advice on managing product development are accompanied with corresponding advice on evaluating product development, also referred to through terms such as control, evaluation, audit, and determination of the degree of success. As product development is viewed as an isolated process, the evaluation concerns this *process* and the *outcome*. Time, cost, and performance represent three basic types of measures that are frequently used to evaluate the process of product development, both throughout the process and subsequent to its completion. Evaluation becomes a question of meeting the plan, i.e., goal-fulfilment. How is the product development project doing with respect to time consumption compared to the plan? Is the project behind or ahead of the time schedule? Similar questions can be asked with respect to costs. What about the performance of the product? Is the prototype performing as planned within e.g., the specified temperature range? Product development processes that meet or are ahead of these three types of measures are often referred to as successful, whereas processes that fail to meet these measures are often regarded as unsuccessful. This ought not to be confused with measures that report successfulness related to the process implying a successful product, or the other way round. After all, a product development project that is regarded as successful due to meeting the plan on the time, cost and performance measures as determined in the plan can still result in little or no sales, thus leading to the product being regarded as unsuccessful from an economic point of view. After all, the product is subject to its own measurement, e.g., sales results, shares, margins, and profits (e.g., Cooper, 1993). On the basis of these measures, the economic success of the product is often estimated on the basis of its return on investment (ibid.), i.e., whether or not the earnings from the sales of the product exceed the costs related to the preceding development process and is put in relation to the capital invested.

Product Development Viewed as Embedded in Time

The view of product development as a process that is embedded in time entails looking beyond the single project/"short terminism" (Dunk & Kilgore, 2001). By viewing product development as a process that is embedded in time, the unit of observation changes, from the single product development project to an "interrelated clustering" (Rosenberg, 1982: 59). This type of embeddedness connects a product development process to the past and to the future. The development of a product rests upon the past in the sense of earlier achievements, i.e., history matters (e.g., Rosenberg, 1982; Teece et al., 1997). Path dependence is a frequently used concept that refers to this phenomenon (e.g., David, 1985; Teece et al., 1997). Path dependence can be used to draw attention to the effects that follow from past products, knowledge, routines, investments in facilities, etc. (e.g., Coombs & Hull, 1998). The structure of the past represents a "heaviness" that bears with it distinct restrictions for development of a product (Håkansson & Waluszewski, 2002). But this past also entails opportunities, i.e., past achievements can lay the foundation for the development of a product. In this way, the past holds a grip over the development of a single product (Lundgren, 1995). In relation to path dependence, lock-in effects are often referred to (e.g., David, 1985). These effects refer to how one path, e.g., a particular type of product technology, often hinders development of other solutions. Product development is furthermore identified to often take place "close in" to previous successes (Teece, 1998; in Dosi et al., 1988). After all, at least in a short-term perspective, the resource structure of companies is quite stable (Penrose, 1959). As a consequence, in particular within the resource-based view, some authors argue that companies can utilize their past achievements in product development in order to maintain a sustained competitive advantage (e.g., Amit & Schoemaker, 1993; Barney, 1991; Hamel & Prahalad, 1994). Incremental innovations, also referred to as improvements or refinements, represent a type of new products that obviously draw extensively upon past achievements (Rosenberg, 1982). Similar observations are also made for projects on a more general basis (Engwall, 2003). Obviously, the notion of "cumulativeness" (cf. Teece, 1988; in Dosi et al., 1988) becomes important in relation to development of this type of products.

In a similar way as present product development rests upon the past, it entails effects for future development of products. The development of a product can open up for new opportunities, but can also impose restrictions for future product development.

The view of product development as a process that is embedded in time is not so common in the managerial, instrumental part of the literature. However, within this field of the literature, portfolio management tools, such as product/market-matrixes and the BCG-matrix (e.g., Ansoff, 1965; Kotler, 1997), can be regarded as recognitions of the advantages related to connecting several product development processes. In a similar vein, Wheelwright & Clark (1994) refer to an "aggregate project plan" that can help managers to focus on a set of product development projects. (2001: 409).

Compared to when product development is viewed as an isolated process, managing product development obviously becomes dramatically different when viewed as embedded in time. Managing product development concerns the taking into consideration potentially valuable outcomes from the past as well as creating outcomes for the future beyond the product itself. Managing product development concerns a challenge of delimitations. What are the total outcomes created from the product development? What will in the long-term be the value of these outcomes? An aggregate level needs to be undertaken when evaluating product development.

Product Development Viewed as Embedded in Space

The development of a new product can also be seen as the development of a new "space" or area where resources are going to meet. These impressions of developing new technological solutions, including establishing new supplier-customer interfaces, are also close to those described in studies of technological development carried out with an Industrial Network Approach (see e.g. Håkansson ed, 1987, Waluszewski, 1989, Lundgren, 1991, Holmen, 2001, Wedin, 2001, Håkansson & Waluszewski, 2002). With the assumption that resources are heterogeneous, inspired by Penrose (1959) and others, the focus is directed toward how they are combined with other resources, and *where* these resources are combined – since both the features and the value of the resources are evoked in the combination activities, it is of great interest to design these in relation to the position, the space, of others in a network. Thus, it is an approach coloured by the understanding that developments occur when companies and organizations encounter one another in terms of sets of resources and that development mean that positions shift, relatively strengths can be a weakness when a position change in a network.

Product development can thus be viewed as a process that is embedded in space in the sense that it involves suppliers, customers, and other cooperative partners along with the network of relationships that connects these organizations (e.g., Håkansson, 1987; 1990). A similar embeddedness of projects in a network structure is identified (Kreiner, 1995), referring to projects as "conceptually-embedded" in their environment (Engwall, 2003). This view contrasts the more traditional one, where product development is seen as a company-internal problem (e.g., Lindell, 1991). Viewing product development as embedded in a network draws attention to two aspects.

First, the network can influence the product development. This form of embeddedness has received considerable attention in literature. Customer relationships are identified to be important sources of knowledge in relation to product development, e.g., "lead-users" (von Hippel, 1988). Suppliers and other cooperative partners are in a similar vein identified to be important (e.g., Lei & Slocum, 1992; Teece, 1992). In relation to product development, Håkansson (1989: 120) points out that *"relationships tend to open the way towards a variety of solutions"*. Powell et al. (1996) point at the network of relationships as a source for knowledge in relation to product development, in particular when this product is complex and when the sources of expertise are widely dispersed among companies.

Second, product development can influence the network (Gressetvold, 2004). This form of embeddedness has not received considerable attention in literature. A main reason for this is that relationships have traditionally been regarded as tools, or means, for product development. By employing a rather untraditional view of relationships as valuable resources for the companies that they connect, the question of utilizing the product development process in a way that stimulates the development of relationships becomes a highly interesting one.

There are several reasons for why product development may be embedded in a network. One of them can be illustrated with the following: *"Inventions hardly function in isolation."* (Rosenberg, 1982: 56). This statement seems increasingly important, as focus on specialization, outsourcing and core competencies is advancing in literature (e.g., Hamel & Prahalad, 1994). In other words, the network may play an important role in the diffusion of innovations (Rogers, 1995). Furthermore, the statement by Rosenberg draws attention to interdependencies, such as complementary assets (Teece, 1992). Complementary assets are assets that are required in relation to the development of a product. For a company, lack of knowledge of these complementary assets often makes it difficult to conduct the product development single-handedly (Penrose, 1959). After all, a company's resource structure is relatively stable in the short-term. Relationships thus project as a way of reducing time and costs in relation to product development. Product development processes that require such complementary assets are often referred to as systemic innovations, as opposed to autonomous innovations (Teece, 1988; in Dosi et al., 1988). These assets, or resources, are often possessed by different companies. Successful product development is dependent on the ability of developing and connecting these resources.

In relation to incremental innovations, embeddedness in time and past solutions were pointed out to play an important role. Radical innovations, on the other hand, tend to draw attention towards embeddedness in space. Radical innovations involve creation of a high degree of new resources, either by use of new resources or by use of existing resources in new ways. This is often experienced as a problem for companies. A company may feel "trapped" by its past achievements, unable to break out of its pattern of incremental innovations. This is also referred to as "the innovators dilemma" (Christensen, 1997), and illustrates how a company's core capabilities are also – simultaneously – its core rigidities (Leonard-Barton, 1995: 30). Involvement of other companies through use of relationships may represent one way of coping with this type of challenges, as new resource structures are introduced and confronted (Håkansson & Snehota, 1995).

By viewing product development as embedded in space, it becomes evident that the outcomes of the process exceed the product itself. As examples, a useful customer relationship may be developed, or investments in a critical test laboratory may be conducted by one of the suppliers. These outcomes are difficult to assess, as they need not be visible to the participating companies on beforehand. Moreover, their value is dependent on their use, or the "useful customer relationship" and the "critical test laboratory" may first appear useful a long time period after the development of the product. In this way, the outcomes of the product development become blurred and difficult to deal with. This does, however, not make such outcomes less important. Such outcomes are not only difficult to assess. Several of these outcomes emerge and change throughout the development of the product, rather than exist as parameters that are well-defined and immutable from the initiation of the development process. In relation to this, Kreiner (1995) points at the challenge of "drifting environments" in the sense that the outcomes of projects tend to change throughout the development process.

Managing product development when viewed as embedded in space becomes a challenge of coping with boundaries. This implies that managing product development becomes a challenge that goes beyond the isolated product development process and its product as the outcome. Managing product development may become a challenge of utilizing existing resources at a customer or making use of the skills that are developed over a long time period through cooperation with a supplier. In this way, the network is attempted used in order to influence the product development. But the challenge of managing product development may also concern how to utilize the outcomes of the process, e.g., a promising software tool developed at a customer as part of the product development process, or immaterial resources, such as trust and willingness to share information in a relationship with a supplier. Managing product development needs to be looked at in a way where the outcomes in the network are included. One central question becomes how these outcomes can be utilized in the future in order to increase their value. A central question for a company is how it can seek to achieve value from the outcomes of product development, taken into consideration that several of these outcomes appear within relationships and other companies, i.e., on a network level.

Since these combinatory efforts, whether within or between organisations, are carried out in relation to other resources, attention is directed to the interplay between resources and those handling them; individuals, projects, companies and other organisations. This interplay is treated as a phenomenon that can have a wide variety of expressions – ranging from *distant* relationships to *close* interactions – where both social and technological resources are confronted and adapted. Thus, the interplay of

resource development and utilisation is treated as both an organising process with effects on a meso level (for a larger network of related units) and as a development process that is critical for the value creation of the individual company's set of resources (Håkansson & Waluszewski, 2002; Waluszewski, 2002).

To sum up, the way we see space in this paper, is to a large extent derived from the IMP tradition's view of position in networks and how technological solutions are treated in relationships. Space in terms of creating new areas to meet, or using already created spaces or thirdly combining new and old spaces in a network is probably of great importance in the endeavour to create and shape a successful product.

Summary of Three Different Ways to View Product Development

Our aim in this paper is to develop three different ways to view product development. One where the process is viewed in isolation, one where time plays an important role and lastly, one where space is required as crucial for the success of a new product. These three worlds exist side by side and must accordingly be managed in parallel by the companies that are involved in developing new products. A summary of the three different ways to view product development is presented in table 1.

Method

The discussion on how product development is embedded in time and space, but also handled in isolation is illustrated with a single, embedded case study (Yin 1984). The empirical setting is the biotech sector that had a great upswing in Sweden in the late 1990s. The focal firm of the case was for some time seen as a success story and was also put on Forbes list of the 300 most interesting companies in 2000. A few years later the situation does not look the same. The company has merged with two other companies and plays a rather marginal role in the new company.

The empirical material consists of some 30 interviews with individuals working in seven different organizations. The interviews were conducted between 2002 and 2004. Further, secondary information such as annual reports, internal documents such as financial reports, product descriptions and organizational charts have been used in order to increase our understanding of the focal firm.

The interviews were semi-structured. They were tape recorded and then transcribed. The questions focused on the development of the firm and its product development activities. The product, which in fact is a system consisting of three parts, a hardware, software and biological reagent kits, developed over time and how customers used their system, in what activities the system was used, in combination with other products or systems etc. In addition, the competitive situation was also covered during the interviews, that is, what alternative technological solutions were considered by the customers.

As the study continued, time emerged as a central issue. For the investors, it was apparent that time played a major role, both in how they were evaluated, but also how this affected the focal firm and how it measured by the owners. However, time but also space showed to be decisive in relation to the customers of the focal firm. From having been one of the fore runners, the firm saw its position in the network more or less disappear.

Pyrosequencing: a Biotech New Venture

Pyrosequencing's technological roots were a research project conducted by a group of researchers at the Royal Institute of Technology (RIT) in Stockholm. Pyrosequencing was founded to take advantage of the increasing interest in applied genomics that followed from the HUGO project. More specifically, the group developed as specific method for sequencing and detection of single nucleotide polymorphisms (SNPs) – information that the firm thought could be used in the development of new drugs.

As most new ventures, Pyrosequcing was in need of capital in order to develop its products. The venture capital firm Health Cap was founded in 1996 and was trying hard to find (as quickly as

possible) what is of utmost importance for any such company, especially a new one: a reference object in order to create an impressive track record in relation to its investors. Having invested in just a few firms before, Health Cap invested 17 million SEK into the new company in 1997. The CEO put it like this in the annual report from 1999:

"…This [the market] is not the DNA sequencing market as such, but rather the segment of applied genomics that studies genetic variability between individuals"

It was decided that the company would approach firms and academic institutions that were involved in the early processes of drug discovery, where SNPs were assumed to become a major tool in the identification of target molecules.

Product development was concerned with productifying the research from RIT. These activities took place in parallel with the organizational development activities. It was decided that the offer to customers would consist of three parts, an hard ware instrument, a reagent kit and a software package for analysis. The idea was to use a "razor blade" business model, selling hardware systems that in turn would consume reagents, where the profit was going to be made. PSQ96 could read 96 tests simultaneously and manage about 5,000 tests a day. Capacity-wise this would surpass alternative technologies. The software program should be able to foresee theoretical results for the analysis, and create a database for the SNP sequences and enable a qualitative assessment of the data collected.

Pyrosequencing was growing at a very fast pace from its start in 1997, both in terms of sales and in terms of employees. The company was far from profitable however, break-even was planned to be in 2002. The company's head office and production facility was located in Uppsala and a US sales office was soon opened located in Boston, MA. In Japan and some other countries Pyrosequencing was represented by independent distributors. Early on, the Pyrosequencing management became involved as shareholders through stock options in the company. Collective incentives among the employees to speed up the development process were then created. One of the engineers at Pyrosequencing expressed it like this.

"Of course, an exit through an IPO seemed as a very interesting solution for all of us. We had never had the possibility to make real money on being researchers before. Suddenly we saw that wealth was behind the corner if we did things right".

The majority of the people engaged in transforming the pyrsosequencing technology into a product had their background in one of the world's largest biotech tool companies, Amersham Biosciences (today GE Helthcare), with decades of experience in developing tools for drug development and testing in the later phases of clinical tests. As a consequence, it was in this area that they were able to identify the majority of the possible applications. This can be exemplified by one of the engineers at Pyrosequencing:

We were extremely focused. In just a few years we were about 100 people and more than half of these came from Amersham Biosciences. All had experiences with development of tools and I think this was one reason that made it such a successful development process."

Developing a biotech tool was also a path that appeared attractive to Health Cap. Choosing the "biotech tool path" appeared as the fastest and safest way to reach the wanted reference object. The process of translating the new technology to a product was also permeated by the venture capital firm's formulation of milestones to be reached in a certain time. One of the involved in the development of the instrument put it like this:

"Everything was designed to shorten the time to achieve different milestones. Time objectives were of great importance. The quality as well was certainly important, but cost was never an issue".

Since a rapid launching of the instrument was such an important issue for the management, to set up its own production unit for the hardware was not an option that was considered. PartnerTech based in Southern Sweden became the main supplier of the hardware. The relationship with PartnerTech was considered a key success factor by Pyrosequencing in the early days.

The relationship with Pyrosequencing and the development of PSQ96 became important for PartnerTech since it opened the doors to many other firms within the Swedish biotech industry and especially for the firms within the Health Cap portfolio. The same thing happened with the soft ware supplier, Prevas.

Three years after its establishment, Pyrosequencing launched its first product, PSQ96, in late 1999. The tough time schedule meant that the product was developed rather close to the original idea of how the technology could be used. In order to keep the tight time schedule the firm hired people. By the end of 2001 Pyrosequencing had almost 200 employees.

In 1999 the instrument was developed, prototypes were out for test using at potential customers. When everything seemed to work, Pyrosequencing started serial production of the PSQ96 system and in November the same year the company got its first customer when AstraZeneca, the Swedish-British big pharma company, purchased a first system. Soon a second pharmaceutical placed an order. Pyrosequencing's marketing director noted:

"This is particularly encouraging. Our predictions about the market segments for PSQ96 have proven to be correct". (from the annual report 1999).

With a robust, simple and safe instrument for SNP analysis at hand, both a technological and commercial success appeared to be within reach. The results from the first installations revealed that the users found the product strong and reliable. Once the customers were educated on the instrument, they did not demand a lot of support to interpret the result of the DNA analysis. The first customer, AstraZeneca put it like this:

"It was an important system for us when it first came. It was indeed reliable as it had a built-in control for the whole analysis, which made the instrument very fascinating. I think everybody in engaged in drug discovery found it fascinating actually."

In fact, soon AstraZeneca had purchased two systems and eventually the Swedish-British pharmaceutical firm had invested in five systems all in all and had become a prime reference customer for Pyrosequencing.

Many, if not all, of the milestones developed around the product were also met. In fact, Pyrosequencing seemed to be able to fulfil most of the goals set forward by the venture capital firm. The CEO put it like this in the annual report for 1999:

"We met every key milestone set for 1999, culminating in the commercial introduction and first sales of PSQ96 System…"[1]

In 2000, only three years after investing in the company, Health Cap could provide their investors with an "exit" when Pyrosequencing went public. Pyrosequencing received some 875 million SEK. The company share was offered at a price of 10 EURO in 2000 and peaked at a share price of 20 EURO during the same year. Health Cap stayed as an owner after the IPO.

Being a public company meant that Pyrosequencing had to relate to the rules and regulations at the Stockholm Stock Exchange. The firm had to produce quarterly financial reports and inform the financial markets about critical events. As the value of a firm to a large extent hinges on the predicted future cash flow that it can generate the search for indicators that showed, or at least promised a future good performance became more important than before. One manager at Pyrosequencing put like this:

"To get instruments out to the customers became one of the most important key indicators at the end of the quarters".

1 After this statement the key milestones are described: Alpha and beta site testing completed, serial production started, commercial availability, sales and support office opened in Boston, USA, sales force established, first order from USA and Europe received, patent portfolio strengthened, private placement raises 120 million SEK (about 13 million EURO).

Thus, sales and tech support were encouraged to prioritise the placement of new instruments with customers at the end of the quarters. The ability to report this production of sales to Health Cap and to the stock exchange therefore influenced how Pyrosequencing related to its customers and users. Even if this was not happening on a daily basis, the included training of personnel had to be squeezed in directly after a purchase at some occasions as the firm was being forced to rapidly conclude the sales process. This could contradict the objective of creating customers that used the instrument frequently, and then continue to buy the economically important reagent kits.

For AstraZeneca, the first positive impressions started to fade however. Considering the interaction around the PSQ96 from the users' perspective, the SNP analysis is only the last one in a chain of closely related items. Before being analysed in the PSQ96 instrument, a choice of which SNPs to analyse must be made. This choice is dependent on the application area and the numbers of SNPs in focus. These can vary from one single SNP to hundreds of SNPs. Second, the organisation must design and develop an assay for each one of the SNPs. This central activity is time consuming and also labour intensive. The third step involves so-called PCR amplification and preparation of the tests. The number of tests per SNP can vary between one and hundreds and the scope of this step also varies among different suppliers' systems. The fourth and last step concerns the DNA analysis, post treatment and evaluation of data. From a user perspective, in order for an SNP analysis to be thorough and effective as well as time and cost efficient all the different steps must be taken into account. When deciding on what activity to develop in this cycle of activities, Pyrosequencing chose to go only for the DNA analysis, partly because this was the activity that was seen as the bottleneck in the process, partly because this made it possible to focus on something manageable. Thus, the firm let the customers manage the rest of the activities themselves. This was also a strategic choice that fitted into the venture capital logic to reduce the time from prototype to finished instrument. This decreased the development of the instrument as only one step in the analysis chain was included. However, for their reference customer AstraZeneca it proved to be problematic:

"The preparation of the test was really time consuming and that was a problem for us. I remember that we told this to the Pyrosequencing people, but we got the feeling that they found themselves unbeatable at that time"

In fact the numbers of system sold increased for every year. The first year, 1999, two systems were sold. There were sold 55 systems in 2000, followed by 83 systems in 2001. Everything was going according to plan.

If Pyrosequencing had been one of the first companies that could offer this type of safe and reliable SNP analysis, other firms started to approach customers. For example, Applied Biosystems (ABI) and their TaqMan technology, an already existing technology but used for other purposes, which also was more complicated to handle than the Pyrosequencing solution when it came to design assays. Therefore, ABI had to be more involved with users than possibly Pyrosequencing had to be, due to a more user-friendly system. ABI was therefore more or less forced to interact with customers concerning how to design assays and what SNPs to analyse[2]. One of the interviewee commented it like this:

"The interaction with customers that ABI was forced to probably facilitated the development of integrated systems that could deal with all four steps in the analysis of chains of DNA".

Customers started to demand new features; speed and volume and lower cost per sample became issues they wanted from Pyrosequencing. These features had been part of the original instrument, but were now even more demanded by users, at least the ones that produced large amount of tests on a daily basis, such as AstraZeneca. Furthermore, the reagent kits were by some customers considered to be too expensive.

2 Other firms supplying similar solutions are Sequenom and Orchid. Sequenom can be described as a "post genome firm". They sell large instruments that require experts. Orchid has turned out to be more of a service supplier, conducting tests for its customers. ABI is seen as the "giant" within this industry. ABI supplied the important HUGO laboratories with equipment and has a solid reputation.

When other suppliers were able to offer systems integrating the whole process, Pyrosequencing felt forced to engage in similar development activities. One of the involved engineers put it like this:

"We added more features to the [second generation] system, made it faster, more automated etc. We aimed for the big pharmaceuticals and in order to reach them we believed that the high-through put system was essential. "

However, the development of the high-through put system did not at all go as smoothly as the first generation. It was more complex and the involvement of new suppliers did not work out as well as one had hoped for. It was especially an important component from a local supplier in the system that there were major problems with and this delayed the launching of the system with several months. As the firm was still aiming for sales growth, the sales people did not try to sell the old systems as they waited for the new to come. As a result, sales dropped significantly in the second quarter of 2002.

--------Insert table 2 here-------

Even if sales went according to plan during the first years, in 2002 sales was far under budget. The company was no longer growing in terms of sales, only in terms of employees. Approximately 250 PSQ96 systems had been sold and installed so far. With a planned sales growth of 40 percent this was not enough for the investors and the price of the stock fell sharply. Further, sales of the reagents have only been a fraction of what was anticipated. The user patterns had been totally misinterpreted.
There are at least three reasons, all related to different patterns in buy-sell and producer-user interactions behind this complication. First, those individuals that purchased the PSQ96 system were not necessarily the same as those that used the instrument, a rather common phenomenon whether the users are in the industrial or academic sphere. Before a new research instrument develops from being "just another nice equipment" in the research lab to becoming a useful production unit, the users have to learn how it can facilitate their production processes. Second, although the buyer of the instrument found it beneficial to be supplied with reagent kits, this was not necessarily the opinion of the users. The majority of the customers, over 70 percent, were to be found within academia. A research lab is often populated with laboratory assistants and doctoral students trained and skilled in preparing their own reagent kits and it was also a way to save money for the research labs. Another reason why fewer reagents are consumed than anticipated is that customers have several systems that they use. Thus, Pyrosequencing's system is only one of several analytic instruments. In those cases competing systems where the quality demands are less significant, or when time is a high priority (as preparation of tests took some time with the Pyrosequencing system) those systems were used instead.

The AstraZeneca relationships did not develop as planned. The ABI solution proved to be as strong and reliable as the Pyrosequencing technology. Furthermore, ABI could offer lower prices on the reagents and had also a large organization that backed the technology. There were further some doubts at AstraZeneca to invest in a technology with a young and unproven company. When AstraZeneca's central laboratory in England chose to invest in the ABI technology, the unit in Södertälje also had to change supplier and made ABI a preferred supplier of SNP analysis technology.

Even if the firm was about to become more efficient in its operations, there was still a need for revenues. The firm was not yet near profitability and revenues are in most cases something that comes from customers. So, how can one describe the "demand" for Pyrosequencing's system? The company was started in the wake of the HUGO project, aiming for the booming research and drug discovery market. The technology was directed towards this group of users. However, the companies active in this market to a large extent looked like Pyrosequencing itself; small, expanding start up firms financed with VC money. When their market and financial situation started to look troublesome, these problems soon became Pyrosequencing's problems. Thus, a large share of the anticipated market, small firms active in drug discovery vanished and this hurt Pyrosequencing badly.

For this reason Pyrosequencing rather early had to focus on the academic side of the research market. Even if the firm was rather successful in selling their systems, a big part of the planned "market" had disappeared and the one that was left did not behave as planned as they did not buy enough reagent kits.

When sales and further not the gross margins did not develop as planned, the stock market reacted as mentioned above. From a market cap in October 2000 on 5 billion SEK (about 600 million EURO), the value plummeted and in 2002 when the market cap of Pyrosequencing was 250 million SEK (27 million EURO). In fact, the equity of the firm was worth more than the market cap of the company. Surely this was not a situation that the owners were satisfied with. Management had to focus more on cost reduction and staffs were reduced by 20 percent. In a press release in October of the same year, Pyrosequencing´s CEO promised that the focus now was to reach "near term profitability", moving away from expansion and growth. During the fall 2002, the firm started to lay off work force and the number of employees was reduced to 150 in early 2003.

Despite the program for profitability, the focus on sales never paid off. The first quarter of 2003 showed that the firm was far from being profitable. Now the board of directors reacted:

"They saw that here is a company that keeps on burning up all the money. They had to do something". (engineer at Pyrosequencing)

A new member of the board was appointed in the spring, with a mandate to get the company on track and make it profitable. The last months of 2003 became turbulent for Pyrosequencing and its employees. In August 2003 Pyrosequencing announced the merger with Personal Chemistry, another life science (not biotech however) start up, located in Uppsala and owned by the same VC firm, Health Cap. The CEO resigned as so did most of the employees that had been part of building up the firm. [3]

The fact that both companies are part of the same portfolio family certainly helped the whole operation. A third company was acquired with Pyrosequencing's cash in the autumn of 2003. After the mergers in 2003 Pyrosequencing became a unit within the new company, named Biotage. The original market was more or less abandoned, the firm never managed to adapt to the user patterns in industry nor in academia. And for the big pharmaceuticals they could not give the users the volume they needed and within academia, 96 test samples (as in PSQ96) in fact seemed t be too much sometimes. The SNP market and their users were in the end hard to catch. Instead Pyrosequencing, now part of Biotage, has identified new areas, closer to health care and diagnostic tests on hospitals. As one of the interviewees put it:

"Then there is no need for high trough put. It might be ten or even fewer tests. Then there are other features of the technology that become important"

Discussion

Having presented the case above, this section aims at analysing why things took place they way they did, by focusing on how PSQ96 was managed and evaluated. Thus, in this section we will return to the three different ways to view product development and discuss them in relation to Pyrosequencing's development of products.

A First Way to View Product Development: as an Isolated Process

PSQ96 was dominated by being managed and evaluated as an isolated process by Pyrosequencing. Together with the board of directors, the product development team set up mile stones, worked out what the product would look like, consist of etc. The use of the milestones definitely coloured the way management looked upon the development of the firm and the technology as was illustrated in the case. The meeting of milestones were also important indicators that were communicated to the two different markets that the firm was so dependent upon, the customer market of course, but perhaps

3 There are several similarities between the two Uppsala companies. They are both tool companies, selling systems comprising of a hard ware, a soft ware and a kit of reagents that are supposed to be used in together with the instrument. However, when comparing Pyrosequencing with Personal Chemistry, where Pyrosequencing's customers are found in the drug discovery field, Personal Chemistry's customers can be found among the Pharmaceuticals and in the later phases of drug development.

even more the capital market. The product's features were based on assumptions from a core group of people. These assumptions were made by people with long experience from the international biotech sector. One can perhaps argue that the development work was done to some extent with a generalized environment in mind, and not specific customers or users. However, the product development process, which to a large extent mirrored the development of the firm, was in a rather early staged "frozen". That means, features of the product were early on decided upon and the time to reach these goals was considered as the main thing. The reason was partly driven by "market" reasons; Pyrosequencing saw a window of opportunity after the HUGO project and saw that this opportunity required speediness. PSQ96 was at the time of the IPO evaluated as highly successful, whereas the same product was evaluated as dramatically less valuable only two years later.

Health Cap, the venture capital firm, can be said to have played an important role with respect to encouraging, or even imposing, how PSQ96 was managed and evaluated. First, this company was a major investor in Pyrosequencing. Second, a partner from Health Cap was brought in as a "serial CEO" in Pyrosequencing. Health Cap put forward goals for Pyrosequencing that put a high pressure on speeding up the development of PSQ96, and later on also on reporting the sales on a quarterly basis. The motivation for Health Cap to manage PSQ96 in this way can be found in its interest of displaying the value of Pyrosequencing; first in order to conduct the IPO, later on as part of its strategy to conduct an exit. As a rather new venture capital firm, Health Cap was in need of an exit that could serve as a reference object for its *present* investors, but perhaps more importantly, its *future* investors. Thus, Pyrosequencing was to large extent, even if only implicitly or indirectly, managed for an IPO in a rather short time. In order to go public, growth and promises for the future are considered important. The investment in the production facility and how much of it that actually was used is an interesting example of this. The investment was in one way necessary as it promised future growth and thus an increased value of the firm. The technology had therefore to be "mature" and tested and ready for a market. The financial logic therefore had a clear direction on strategy and the operations of the firm.

A Second Way to View Product Development: as a Process Embedded in Time

Although we get the impression that the development of PSQ96 was dominated by being managed and evaluated as an isolated process, this product was truly both rooted in the past and came to influence the future. Naturally, Pyrosequencing was, or became, aware of this embeddedness in time. However, this never came to dominate the way PSQ96 was managed or evaluated.

Regarding the past, parts of the technology underlying PSQ96 was developed at the Royal Institute of Technology, among other things through the HUGO project. One of the inventors, a professor at this academic institution, was also a board member to a company that would turn out to be a highly important cooperative partner for Pyrosequencing, namely Amersham Biosciences. In other words, past achievements played a crucial role as the development of PSQ96 was initiated.

Regarding the future, PSQ96 clearly formed a foundation for the development of a second generation of the product. For this second generation product, Pyrosequencing faced difficulties, both with the development and the launching. By viewing the development of this second generation of the product as embedded in time, as part of an "interrelated clustering", e.g., highly dependent upon PSQ96, it becomes evident that some of these difficulties can be traced back to the path chosen at earlier moments of time. First, PSQ96 was developed under a lot of time pressure, hereunder alpha and beta versions of prototypes where the development work had to be "stop half ways". Even though this rapid development seemed important for launching PSQ96 successfully, such a development strategy resembles "short terminism", and may entail negative effects for future product development. Second, and closely related to this time pressure, PSQ96 could be regarded as a quite "narrow" product in the sense that it only included one step in the analysis chain. In particular throughout the sales process, Pyrosequencing experienced that its customers requiring a product that could handle several steps in the analysis chain, also gradually offered by the competitors. Pyrosequencing now found itself in a situation where the development of a second generation of the product became particularly cumbersome due to the past achievements and decisions on how to develop PSQ96. Third, Pyrosequencing recruited the majority of its employees from Amersham Biosciences, and also learned about the majority of the possible applications from this company. Furthermore, Pyrosequencing aimed at customers within the booming research and drug discovery market. This approach may at one time have looked promising, and likely had its advantages when it comes to speediness. However, the majority of these relationships had to be abandoned for the development and launching

of the second generation of Pyrosequencing's product. Whereas PSQ96 was at a certain moment of time regarded as a commercial success, it is evident that the new generation of product has so far not at all shown to be as successful. So, when evaluating these two products combined, as embedded in time, the question of PSQ96's degree of success becomes a much more open one. Furthermore, the story is not over yet; Pyrosequencing has been merged with another company, and yet other products that draw upon PSQ96 are on their way.

A Third Way to View Product Development: as a Process Embedded in Space

A firm's position in a network is constantly changing. A product that is developed for one type of network, or space, is therefore sometimes left with new conditions, with new firms entering, changing relationships with customers and thus, there is a new space to deal with. For Pyrosequencing it was clear that the space had changed, competitors, had entered the market, or rather, the network and taken up the race for quick and reliable SNP analysis. For example, the first generation seemed to have worked very well in relation to customers and users. It was easy to use, intuitively users could quickly could get it up and running and do tests on it. However, as speed and cost per sample was something that guided product development, a second generation, a high throughput instrument was considered as necessary. The resources that were needed were much more complex, as was the whole instrument. As the firm only had one product out, it was very sensitive to set-backs. There was no "space" for failures, not even small ones. This compared with the focus on time, now from the stock exchange, made the whole situation very stressful for the involved people. If the firm had been in another space, within a large company, the product development project, probably only had been given more time, and more resources, but now it was a fight of life or dead more or less.

Within some spaces certain logics are very dominating. One such space is the stock exchange. The financial time logic continued once the firm entered the stock exchange, where the quarterly reports in some cases seem to have affected how the firm interacted with customers. How this affected the firms is of course hard to say, we can only speculate about its possible effects. However, to press in sales and training sessions in order to get a sale within a certain quarter, can not possible be the idea with a stock exchange. However, it is an interesting illustration of the old saying that "you get what you measure". It is interesting to note how these two different spaces, the financial space the industrial space or network, exists side-by-side, but to large extent live under opposite logics.

Conclusion

This paper has examined the role of time and space in relation to product development. We offered three different views that lead to different ways when it comes to managing and measuring product development. Further, we saw how different actors (e.g. venture capitalists, companies that develops new products etc) apply different views on how to manage product development, but also how to measure product development. This is evident when one examines in what type of time and space logic these firm acts and how they have to adapt to these logics in their relationships with resource providers. Thus, measuring and managing product development is a matter of identifying the boundaries that might affect what is affecting what makes a product or a project successful. Sometimes, these boundaries can be manipulated in order to reach short term goals. However, these type of actions can be costly in the long run, if these boundary braking actions, violate the logic of an interrelated space.

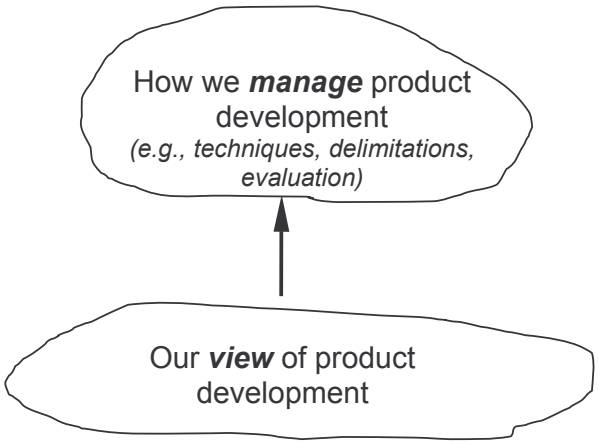

Figure 1: How product development is viewed and managed

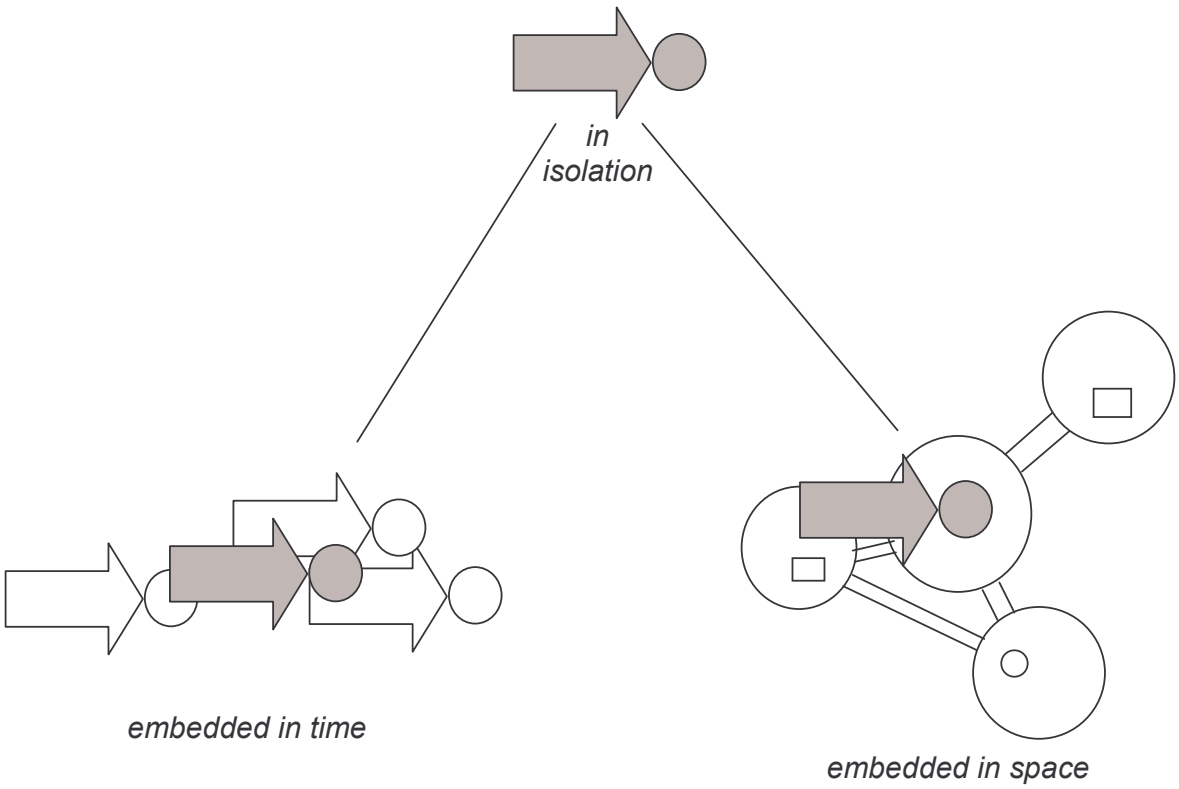

Figure 2: Product development as a process viewed (1) in isolation, (2) embedded in time, and (3) embedded in space

Table 1: Three different ways to view product development

	View of product development:		
	in isolation	**embedded in time**	**embedded in space**
Fields of literature where this view is dominant	-mainstream literature on managing product development -mainstream literature on managing project -normative literature	-literature on technological development as evolutionary processes	-literature on innovation and cooperation, networks
Central concepts	-time, cost, performance, key success factors	past, present, future, path dependence, trajectories, lock-in, cumulative,	cooperation, relationships, network, complementary assets, interdependencies, specialization, lead-user
Central authors	-Cooper (1993, 2005), Crawford (1997), Morris & Pinto (eds., 2004)	-David (1985), Rosenberg (1976, 1982), Dosi (1988), Teece et al., (1997)	Teece (1992), von Hippel (1988), Håkkansson (1987), Håkansson & Snehota (1995), Powell et al., (1996
Unit(s) of analysis	-single product development (process, product) -single company	-several product development processes, interrelated	-several interrelated companies, network
View of how product development should be *managed*	-key success factors and focus on efficiency	-build on history, "adding a stone", include strategy for the future, long-term	-cooperate, interact, participate, openness
View of how product development should be *measured*	process: time, cost and performance product: value; revenues and costs short-term	series of products, long-term	-assess how costs and revenues are distributed in the network short/medium-term

Year	Sales [mill SEK]	Operating loss [mill SEK]	Gross margin [%]
1997	Founding year	-	-
1998	0,185	35,6	100,0
1999	1,300	70,6	80,7
2000	46,000	102,9	77,0
2001	108,000	174,5	71,8
2002	97,600	172,6	67,2

Table 2: Some key ratios and their development at Pyrosequencing 1997-2002.

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