How to transfer discontinuous technology into radical innovation – Some evidence from three nanotech cases

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July 2004
Working Paper Nr. 26

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Abstract

In this paper the focus is on the strategy formulation processes, specifically supportive methods and structures, which address various managerial issues concerning discontinuous technologies and radical innovation in the early phase of strategic decision-making. In three in-depth case studies how companies proceeded with discontinuous technology and radical innovation ideas in strategy formulation was investigated ex-post. Based on literature and the analysis from the cases nine propositions are suggested for the design of an idealized strategy formulation process model for the simultaneous and differentiated strategic management of radical innovation *and* incremental innovation. The propositions are transformed into a visualized process model showing the interaction and arrangement of the latter.

Keywords: discontinuous technology, radical innovation, strategic planning

1 Introduction

An innovation is said to be radical, if it involves the application of significant new technologies or significant new combinations of technologies to new market opportunities (Tushman & Nadler, 1986).

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Radical innovation “departs dramatically from the norm” (Anderson & Tushman, 1990) and “transforms the relationship between customer and suppliers, restructures marketplace economics, displaces current products, and often creates entirely new product categories” (Leifer, McDermott, O'Connor, Peters, Rice, & Veryzer, 2000). Radical innovation breaks with the continuity of existing technological paradigms and sets the stage for new technological trajectories (Dosi, 1982).

The approach to deliberately break with continuity was originally discovered by Schumpeter (1934) and described in his theory of innovation and economic development in which “creative destruction” is the driver of change. Radical innovations allow companies to take the leading position in market entry, to initiate and shape the structure of the industry and the new rules of competition.

Coping with radical innovation is not only an advantage in overcoming accelerated technology change, it also responds to the increasing pressure for long-term growth. A recent study conducted in Germany showed that the average profitability from radical innovation projects was at 14.7% compared to an average of only 6.9% generated from incremental innovation projects (Berth, 2003). These findings support what Song and Montoya (1998) found in their study that examined 163 radical new products and 169 incremental products.

Coping with radical innovation is a difficult task for companies, especially for established ones (Christensen, 1997; Leifer, McDermott, O'Connor, Peters, Rice, & Veryzer, 2000; Stoelhorst, 2002). From a technology management view this task often falls to the management of discontinuous technologies right at its initial appearance in the early stage of an innovation. Discontinuous technologies are the result of totally new scientific insights that conclude with existing technology paradigms (Dosi, 1982). Breaking with existing technology paradigms can result in a mature industry in radical product innovation (Lambe

& Spekman, 1997). Some scholars also refer this early stage as the fuzzy front end of innovation[7]. Several studies indicate that firms are mastering this fuzzy front end when technological innovation is incremental, however they achieve only a poor rate of success once a technology turns out to be discontinuous (Christensen, 1997). Nevertheless most companies still manage discontinuous technologies and radical innovation in the same way they manage continuously evolving technology and incremental innovation (Rice, O'Connor, Peter, & Morone, 1998; Veryzer, 1998a; McDermott & O'Connor, 2002) – they do not seem to be aware of the major differences in the character between the two (Colarelli O'Connor, 1998).
Poor insight into the management of discontinuous technologies and radical innovations represent a strong threat to companies as rapid, complex and technological-driven change is becoming an increasingly disruptive force in today's markets, business, economics, and society. The convergence of different technologies that emerge more quickly is accelerating this trend (Canton, 2003).

1.1 Aim and structure of this paper

It is intended that through this paper a contribution will be made to a better understanding of this threat to strategic technology management in established companies. The use of the term strategic mangement is meant to describe the process of formulating a technology-oriented strategy. The term strategy formulation refers to the extensive research conducted by Mintzberg and Lampel (1999) in the field of general management. In the present paper the design and planning school are also referred to. Here, a process known as the strategy implementation process designs the implementation of strategy.. Following this course of research a set of propositions as guidelines for the development of a strategy formulation process including supporting methods and structures are elaborated. The basis for propositions is successively deduced in the course of the paper. The paper is organized in 7 chapters. After this first chapter introducing the subject, the second chapter reviews current literature showing the common

[7] For example: Cooper, R.G. (1994), Gupta, A.K. Wilemon D. L.(1990), Bacon, G et al (1994), Khurana, A. /Rosenthal S.R.(1995; 1998), Herstatt, C. (1999), Reinersten, D.G.(1999), Smith, G.R. et al (Smith, Herbein, & Morris, 1999). Although there is a great deal of research being done in the „fuzzy front-end“ of innovation, all these authors are in the first place focused on continuously evolving technologies and incremental innovation (Reid & Brentani, 2004).

understanding of characteristics and challenges of managing discontinuous technologies and radical innovations. Furthermore we present existing approaches of strategy formulation processes designed for discontinuous technologies and radical innovation. The third chapter describes the in-depth investigations conducted in three cases of industry projects dealing with discontinuous technologies and radical innovations. The fourth chapter describes the findings derived from the cross case comparison of these cases. Based on insight from literature and the case studies, the propositions are elaborated in the fifth chapter, with in the sixth chapter a process concept reflecting the latter. The seventh chapter closes the paper with a summery and a conclusion.

Our concept is based on the idea of a systematic and coordinated management approach to simultaneously design and commercialize both incremental and radical innovations – the latter based on discontinuously evolving technologies. In doing so the aim is to improve the reliability of this process identifying radical innovation opportunities so as to increase the number of radical ideas successfully realised and commercialized. In the meantime the process enables incremental innovation ideas to be handled in order to secure daily business.

2 Research on discontinuous technology and radical innovation

Research conducted in the field of discontinuous technologies and radical innovation can generally be grouped into two clusters. The first cluster concentrates its research on an industry level. This research analyses the influence of radical innovations within a whole industry. The second cluster is based on a company level and analyses projects that handle discontinuous technologies and radical innovation. Despite this different focus of research, both clusters agree on the major characteristics and challenges of discontinuous technologies and radical innovation. Thus firstly the common understanding of these research clusters is presented before the differences in their findings are explained.

2.1 The common understanding between industry and company focused research

There is a broad agreement among researchers that usually the emergence of discontinuous technologies and radical innovation is treated with a low sense of urgency (Rafii & Kampas, 2002) as research and development of these technologies takes a lot of time. Generally such projects last for up to ten years and more (Rice, O'Connor, Peter, & Morone, 1998). They usually require a lot of resources and attention (McDermott & O'Connor, 2002) before they can eventually be transferred into marketable products. From basic research via development to the first stages of commercialisation these endeavours are accompanied by high uncertainty or risk (Abernathy & Utterback, 1978; Rice, O'Connor, Peter, & Morone, 1998; Veryzer, 1998a). Such uncertainty is of multiple dimensions (Milliken, 1990; Leifer, 2000). For instance such uncertainty is due to a lack of technological and market knowledge as no previous technological or reliable market insights exist in the company (Christensen, 1997). Market data is seldom available and customer requirements are often vague[8] (Song & Montoya-Weiss, 1998; Veryzer, 1998). This uncertainty makes an evaluation of radical innovation projects very difficult. In addition the existing organisation as well as resource uncertainties complicate the implementation of radical innovation projects. In sum these uncertainties coupled with high assignment of resources makes discontinuous technology and radical innovation projects very risky. This is why many organizations are reluctant to engage in such projects (McDermott & O'Connor, 2002) and rather tend to further develop their competencies within a relatively narrow scope and range (McKelvey, 1996) focussing on short term revenues. Thus once a discontinuous technology is ready for the market, it is often commercialised by outsider companies instead of established industry leaders (Utterback, 1994; Strebel, 1995; Christensen, 1997).

In general there is broad agreement between scholars that discontinuous technologies and radical innovations have a very specific character and are distinct from continuously evolving technologies and incremental innovation (Lynn, Morone, & Paulson, 1996; O'Connor, 1998; Rice, O'Connor, Peter, & Morone, 1998; Kessler & Chakrabarti, 1999). This distinction of technologies and innovations ask for

[8] Herstatt & Lettl (2004) found a case where customers were successfully involved in the development of radical innovation products.

different styles of management including differentiated types of strategic actions and organisational capabilities (Kessler & Chakrabarti, 1999). Thus conventional management techniques are not suitable until the technological innovation has reached a certain maturity level so that it can fit the pattern of incremental innovation (Abernathy & Clark, 1985; Rice, O'Connor, Peter, & Morone, 1998; Veryzer, 1998a; Kessler & Chakrabarti, 1999; Leifer, McDermott, O'Connor, Peters, Rice, & Veryzer, 2000a). Authors (Tushman & Anderson, 1986; Tushman & O'Reilly, 1996; McDermott & O'Connor, 2002) agree that sustainable growth requires specific management skills for both types of innovation (incremental vs. radical) at the same time. Thus Tushman and Anderson claim (1986) that companies have to overcome the dilemma to master "evolutionary and revolutionary change" simultaneously. Tushman and O'Reilly (1998) emphasize that on the one hand companies have to plan and align their activities along a relatively stable and evolutionary change. On the other hand they have to eliminate these achievements once the competitive environment changes radically knowing that new ones will substitute the foundations underlying their present products.

These understandings that reflect the very different nature of radical versus incremental innovation represent the initial positions for both research clusters, mentioned earlier in this paper. Both clusters acknowledge that the inherent uncertainty and risk of radical innovation needs a distinguished management from the one used for incremental innovation. However important this distinction is scholars agree that the dilemma lies in the necessity for the simultaneous management of both types of innovation as sustainable innovation is the combination of changes initiated by radical innovation followed by continuous incremental improvement innovation.

Taking this common understanding as a base the next two subchapters show the different findings of the two clusters of research mentioned earlier.

2.2 Industry focused research

Research focused on industry level analysis builds on these understandings and describes the changes that happen within a given industry structure. Scholars have collected empirical data over long periods of time and within specific industries. They describe patterns that emerge whenever a discontinuous technology or radical innovation occurs. The benefit of this research is that it helps to better understand and describe the phenomenon of discontinuous technology change. A number of descriptive models have emerged that describe the mechanisms of discontinuous technology change and radical innovation. One of these models is the technology S-Curve, which visualizes technology performance that evolves continuously with cumulating R&D expenditures along an S-shape curve (Foster, 1986). This model assumes that every technology has a certain performance level that cannot be exceeded. The S-curve is discontinued when a radical innovation appears that is based on a new technology with the potential to exceed performance of the old technology[9]. This new technology is said to be discontinuous compared to the old one. Another industry model is the technology lifecycle model[10]. It is based on the observation that over the time a technology runs through different development stages similar to the product life cycle model. According to experience, the technologies' competitive capacity declines progressively through its lifecycle. While the progression through the lifecycle is driven by incremental innovation, the emergence of a new technological lifecycle will be generated by a radical innovation. A third example is the industry lifecycle model, which originated from the observation that structures and competition within many industries are influenced to a great extent by the technological paradigms applied in it (Utterback, 1994). Thus a discontinuous change of a specific technology, even initiated by a single company, can have a considerable effect on the whole of the industry (Tushman & Anderson, 1986). The observed pattern is that a radical innovation enlivens the innovation rate in an industry during the so called area of ferment (Anderson & Tushman, 1990). The number of innovations rises until a dominant design emerges and a new technology cycle is established. A forth model, developed by Stoelhorst (2002), describes the process

[9] For criticism about the S-curve: Osterloh / Wartburg (1998)
[10] Different autors developed technology life cycle models: Litte, A, (1998), Roussel, P.A. (1984), Ford, D., Ryan, C. (1981)

by which a radically new technology evolves through different phases into a regime that is subsequently only incrementally improved. Stoelhorst further describes competitive rules that apply in each of these phases as well as the challenges they pose to management.

Besides contributing to the understanding of the phenomenon of radical innovation, the contribution of these models for strategic formulation is limited as their considerations are only descriptive and ex-post.

Research conducted on the industry level also deduced management implications for organisations to successfully cope with discontinuous technologies and radical innovation. One implication for organisations challenged by discontinuous technologies is the requirement of flexibility (Utterback, 1994). It requires organisations to quickly adapt to new circumstances created by invading technologies. Furthermore, organisations need to build up tolerance for failure (Christensen, 1997), often indispensable for organisations managing radically new innovation projects. Furthermore, the creation of stand alone and autonomous projects teams (Gilbert & Bower, 2002) that combine in-house competencies and relations with external agents (McKelvey, 1996) seem to be supportive. Quick decisions and execution is critical as first mover advantages coupled with the subsequent build up of sustainable barriers against latecomer is crucial with the costly radical innovations (Suarez & Utterback, 1995; Gilbert, 2003). When looking for market applications of discontinuous technologies authors recommend to start with small radical businesses and to go for customers outside established markets (Gilbert & Bower, 2002). Christensen (1997) points out that companies that stick too much to their existing customers unwilling to look for customers outside their existing markets are especially vulnerable to discontinuous technologies.

2.3 Company level research on discontinuous technologies and radical innovations

Company level research focuses on projects and concentrates on analysing project-related activities in the context of discontinuous technology and radical innovation. The community of researchers active in this field does not intend to capture observed mechanisms explicitly in models. They rather describe detached patterns in projects that promote or hinder radical innovation. Veryzer (1998a) for example observed that the initiating and driving forces of a radical innovation project play an extraordinary important role in advancing the project, and that there is a need for a strong project promoter. Rice et. Al (1998) support these findings and emphasise the importance of champions for such projects and further advocate a separation of the latter from other, more routine business. When it comes to developing and commercialising radical innovation Lynn et al (1996) observed that successful companies proceed along a probe and learn process. This process describes a market learning rather than market evaluation. It is realised by introducing early versions or prototypes of the planned product into the market. In this sense immature products are used as vehicles of learning.

Besides these observations a number of authors developed prescriptive processes (Noori, Munro, Deszca, & McWilliams, 1999; Rice, Kelley, Peter, & O'Connor, 2001; Savioz, Lichtenthaler, Birkenmeier, & Brodbeck, 2002) designed to mange discontinuous technologies and radical innovation. However all these authors fully concentrate on radical innovation and describe the strategy formulation process isolated from an overall management context. Hence integration and link to the strategic management process of incremental innovation is not explained.

In sum, mechanisms of discontinuous technology change and radical innovation seem to be well described on an industry level. However such insights are valuable to understand the phenomenon from a macroeconomic perspective, their contribution to strategy formulation and management action is rather limited.

Research conducted on the company and project level gives more detailed insight. However, this research seems to be less popular and there is no overall strategy formulation process addressing the various managerial issues concerning discontinuous technologies and radical innovation in the phase of strategic decision-making. Furthermore structures supportive to such an overall process have not yet been described.

In addition there is one other aspect that most authors seem to neglect: The need for companies to master radical innovation as well as incremental innovation in order to be successful in the long as well as the short term. Most authors acknowledge this necessity, but none of them describes a strategy formulation process supportive to such a simultaneous management of radical and incremental innovation. All authors at least analysed in this paper concentrate on describing the mechanisms, challenges and processes related to either incremental or radical innovation. But none of these authors explain how their considerations would have to be interpreted in an overall innovation management context or process.

2.4 Contribution of this research

The purpose of the paper is to contribute to step by step closing this gap in literature by developing a framework for a practice-oriented process to formulate a technology orientated strategy that suits both the management of incremental and radical innovation.

To do this a case study approach was chosen, which seems to be appropriate reflecting the state of research in this field (Yin, 1988; Eisenhardt, 1989). The guiding question for the cases was to detect how established companies strategically plan discontinuous technologies and radical innovation and what the specific challenges and problems are connected to this. Furthermore a better understanding of the state of the art in managing discontinuous technology and innovation was sought, where likely consequences of this management could be observed and emerging patterns recognized. Based on a series of in-depth interviews management activities that had been carried out were reconstructed in order to transfer discontinuous technology into radical innovations, beginning with idea from its birth to the strategic decision. In the next chapter the background of the cases and their design will be described and their content reported. A cross-analysis of the cases follows.

3 Evidence from three cases

The cases have been conducted in technology driven companies from different industries during a ten-month research project in 2003. In total 32 interviews with different representatives from each of the three companies contributed to the cases. These investigations were part of a major Swiss governmental founded research project[11] on nanotechnology. Thus in all analysed cases the companies intended to introduce products based on nanotechnology. In one case nanotechnology was used to create a new business in the other cases it was intended for existing applications. All companies are leading companies in their industry, but they had no previous experience with Nanotechnology.

3.1 Case A: a chemical company

The first case study was conducted on the corporate level in a global chemical company. This company employs about 20,'000 employees. The case analysed the efforts undertaken by the company to introduce a discontinuous technological approach for one of its businesses (Fig. 1). This approach was based on recent achievements from the field of nanotechnology. It represented for the company a totally new and radical solution for UV absorption. First considerations for the nanotechnology approach rose from the bottom up, out of one of the company's divisions in the winter of 2001. This was triggered by the fact that nanotechnology represents a potential substitution technology for conventional UV absorber substances used in many products of that division. This awareness initiated several technological feasibility studies that were conducted within the division. Although the feasibility studies could shed light onto many aspects of the nanotechnology approach one major technical problem connected directly with the physical characteristics of the nanoparticles could not be solved. By June 2001 the business unit turned to the Technology Board with a request for a company wide inquiry aiming to acquire technical support within the company. The Technology Board is a consultative body to the CTO on corporate level composed mainly of the division's R&D heads. It used its connections all over the company and started a general call for technical support from all divisions. The outcome of this call showed that the problem with the

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[11] TopNano21

nanoparticles was in general an unsolved problem. All divisions that were active in the field of nanotechnology research had encountered the same problems for which the Technology Board had requested solutions.

As a result of this unsettling outcome, the CTO as head of the Technology Board took the initiative. In October 2001 he informed top management of the situation. In reply, top management demanded the Technology Board to clarify the strategic relevance of nanotechnology for the company. One month later, in November, the Technology Board presented its findings to top management. It reported that all divisions saw a great potential in nanotechnology and that research and development activities in the company in this area were generally quite advanced. All divisions had already started projects related to Nanotechnology. Nevertheless nanotechnology still represented a fairly unknown field for the company. With this information, top management instructed the Technology Board to coordinate a nanotechnology monitoring in all the divisions and to secure efforts that would allow the company to follow future opportunities triggered by nanotechnology. Besides setting up monitoring activities, the Technology Board recommended that the divisions should proceed with their present projects.

In a second phase, which started one year later, in autumn 2002, the Technology Board introduced a concept that connected nanotechnology research activities all over the company in order to use synergetic effects across the divisions: a knowledge network called competence network for effects based on nanomaterials was established. The following goals were defined for the network: (1) Coordinated research and knowledge sharing in Nanotechnology research over all divisions, (2) Extension of existing competencies in Nanotechnology and build up of core competencies in nanotechnology, (3) Company internal and external identification of new approaches in the field of Nanotechnology, (4) Promotion of project requests in the field of Nanotechnology.

Insert here: Fig. 1: Chronological course of case A

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3.2 Case B: Fragrance Company

The second case winds up the introduction of a discontinuous technology in a flavour and fragrance company employing nearly 6,000 people. This case describes how a company tried to introduce a technological approach so far unfamiliar and radical to the industry, based on the latest research from the field of Nanotechnology.

The idea to use nanoparticles as a carrier for perfumes was triggered by a researcher in the fragrance research division at the end of 1997, which resulted in the first internal tests (Fig. 2). The initiator of the idea mainly conducted these tests without official commitment from the department. The tests were not very promising at the beginning, but they sufficed to show an initial feasibility. A few months later in December 1997, a commercial research laboratory published a presentation on the subject. This confirmed the need to continue the so far small and loosely conduced research efforts.

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In spring 1998 the research department became involved in the ongoing activities in order to contact the research lab about a joint development agreement. The aim of the collaboration was in the first place to extend the present research activities without having to apply for its own project from the division's management. The signed cooperation allowed indeed an acceleration of the acquisition of knowledge and furthered the feasibility phase with a clearly appreciable financial commitment. The possibility to benefit from the knowledge and the resources of the collaborating partner was especially valuable, as the research activities within the company had barely been intensified even after this partnership. The commitment toward the nanoparticle project had still only low priority.

In the beginning of 1999 the collaboration delivered its first results. They were mainly due to the research partner. The results were estimated to be good enough to apply for status as a project at the division's management level convincing to the perfumers for a fragrance creation project based on the new technology. At that time, there were still no official and consequent activities in the nanoparticle project within the company, which was due to a lack of resources and to the still low priority classification of the project.

In spring 1999 a product focused research alliance with a major customer of the company operating in the field of fabric care conditioning was signed. Through this alliance the nanoparticle project finally succeeded in attaining higher priority. As a consequence, the project was soon presented to strategic planning committee. By that time strategic planning had no choice other than to agree, as the customer's influence was quite strong. This was the official start of the nanoparticle project and in October 1999 a nanotechnology specialist was hired as project manager.

From November 2000 to August 2001 a post-doctoral position at a university was financed by the company aiming to visualize the deposition of nanoparticles on textiles. An experimental setup was developed and built. But as a consequence of new budget restrictions, this work was stopped just before the experimental setup could be systematically operated.

In spring 2002 the research collaboration with the lab was also stopped as the main goals of the projects had been achieved and a new level of knowledge did not seem to be emerging.

In 2003 the nanoparticle project was technically finished. The feasibility was proven and the scale up had been carried out successfully. Product-specific perfumery work and application was being run. The final concept had to be presented to the collaborating customer, but by the end of our case study there was still no guarantee from the customer that the benefit from the nanoparticle project was going to be used commercially.

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3.3 Case C: Injection moulding company

The third case was carried out in a large company with 2200 employees that specialises in injection moulding technology. It is positioned with high quality products in different industries. The case analysed the introduction of a discontinuous process technology based on research achievements from the domain of micro and nanotechnology. Up to this point, injection moulding had never advanced in to micro and nanostructures scales. The ultimate goal for the company was to build up a new business in the medical market through the application of micro and nanostructures on injection moulded surfaces. Thus a project group "Medical" was founded in the beginning of 1994 in one division of the company (Fig. 3).

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At the beginning, the Medial group worked mainly on customer projects with conventional injection moulding technologies. Very quickly the idea arose to develop a strong business around a specific technology that could bring the company a long-term unique selling proposition in the medical market. In spring 1994 some of the customer projects started to indicate an increased need for microstructures in plastic surfaces. Further customer inquiries confirmed this impression. As a result, the project team created a small research sub team to investigate technological aspects, to check the patent situation and to clear state of the art literature.

The technology development began with first pilot tests in summer 1994, but very quickly the need for more sophisticated equipment required further funding. The project group began to detail market analyses in order to present a commercial and technical proof of concept to the executive board. After new means were freed with the approval of the executive board in winter 1994 the technology could quickly be developed so that it could be presented to potential customers.

In the meantime the technological advances in development narrowed the application range of the technology and developed a first strategy for the emerging new business.

In spring 1995 first customers were attracted to collaborate in the development of the technology. While these collaborations financed the biggest part of development, the customers received their own tailor-made prototypes. This level of knowledge resulted in the development of a business plan including the necessary structures in summer 1995, which was approved by the board of directors in late summer 1995.
At that time the project group medical was operating on two complementary levels. On the one hand the consequent development of the new technology and on the other hand contract projects with conventional technologies. Many of the latter projects were acquired thanks to the new research project, which turned out to have a fairly good advertising effect and allowed the company to differentiate itself from its competitors as an innovator in the industry.

Under these favourable conditions where cash flow was secured through the specific projects with conventional technologies, the structures enabling the new business were continuously extended. In the meantime the collaborative research development projects with customers allowed the technology to take shape for mass production. Some of the customer projects were followed by promising projects for the production of single use products.

By the end of 1995 the medical business had grown to an independent unit. But before this process was completed it became clear that the turnover calculated in the initial business plans could certainly not be achieved. Especially in the new technology based business only a few projects turned into attractive orders. Thus the board of directors decided in the third quarter of 1995 to initiate a consulting project in order to verify the market position of the new medical business. At the end of 1995 the board of directors decided to carry on with it after the consulting company determined that the business was still attractive.
Until today the technology has never been in mass production. At the end of the case study in October 2003 only one product based on this process wass under production, which contrary to initial assumptions sells only a small number of pieces with low margins.

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4 Findings

Analysing and comparing the cases led to the identification of a number of issues related to processes, methods and structures (see next paragraph).

4.1 Process related issues

Dominant activities not systematised – missing systematic process: The three cases show that none of the companies had a systematic strategy formulation process tailored for discontinuous technologies and radical innovation. As the uncertainty and risk inherent with project ideas could not be handled by the existing NPD processes it took the ideas much longer to be evaluated and mangers said that they did not know how to proceed in order to be sure that the ideas had been assessed in the best possible way. Thus all the projects were assessed in an ad hoc process. Comparing this process across the three cases four main activities turned out to be dominating. These activities were the (1) initiation of the process itself and (2) the evaluation, (3) the decision and (4) the realisation of innovation idea. However the activities were not defined as such thus it was not clear what their focus was. Furthermore the activities were not arranged systematically along a process that provided guidelines in order to efficiently assess the innovation opportunity in an aligned way. They were to the contrary, found to be uncoordinated and loosely related.

Difficulties in reliable strategic decision-making - missing evaluations activities on strategic level: Analysing the various ad hoc process activities in more detail a critical pattern emerged in all three cases. The evaluation of the innovation ideas was carried out almost exclusively on an operational level and evaluation on the strategic level was very rare. Thus an innovative idea that triggered the initiation of the process, independent from its originating level (strategic or operational), was always assigned to the operational level for evaluation. Such evaluations included efforts to prove technical feasibility as well as to examine preliminary market expectations. While these analyses were running there was almost no activity that investigated the strategic implications of the innovation idea. Objectives between the strategic and the operational level for the evaluation were not given. This made it difficult for managers on the strategic level to decide on projects, since all decisions had to be made based on information elaborated exclusively from an operational perspective.

Slow process lead times - missing coordination and interrelation between strategic and operational level: This observation was generally made in all three cases and concerned most activities we analysed. Within the ad hoc process the various activities from initiation of the process through evaluation, decision and implementation, lacked a coordination or interrelation between operational and strategic level for the various project activities. Findings that had worked could not be benchmarked with prior set exceptions. An iterative and determined course of actions that narrowed the scope of analysis step by step with clear strategic goals was not explicitly visible in any of the cases. As a result the analyses conducted in operational level projects were executed with a lacking focus. Thus all activities related to radical innovation idea analysis turned out to be time consuming and slow.

4.2 Methods related issues.

Ineffective information processing - missing market and technology intelligence tools: To gain a first mover advantage, which is highly beneficial with radical innovation, it is critical to identify an innovation opportunity early. None of the companies systematically gathered information in order to catch weak technological and market signals leading to radical innovation. Only one company conducted some kind of monitoring activities; however these were explicitly designed to follow the continuously evolving trends and therefore designed toward incremental innovation.

Once the reception and identification of such signals has succeeded, a company has to filter which ideas to analyse in more detail and which ones to eliminate. A first evaluation needs to be quick in order to process as many ideas and related information as possible. Furthermore, such a process should guarantee an acceptable degree of accuracy. In the analysed cases none of the companies applied such a quick assessment tool.

Eliminating potential radical innovation ideas by in appropriated evaluation - missing evaluation tools for decision management under high uncertainty and risk: The analysis of the methods used to support evaluation and decision making further showed that in all of the three cases, companies did not differentiate innovation opportunities with either incremental or discontinuous character. Managers used the same set of techniques for both types of innovation. Such methods relied heavily on the idea of quantitative assessment, for instance return on investment, net present value, etc. Irrespective of this, the adequacy or accuracy of such methods for evaluating breakthrough projects in a very early stage and applying the same set of evaluation methods for all innovation projects in a company bears the danger that many radical ideas are eliminated too early as a result of being seen as either too uncertain or too risky. A possible consequence of applying such evaluation procedures might be that it prevents companies from generating and tracking radical innovation ideas.

4.3 Structure related issues

Emergence of skunk works - missing clear assignments of tasks and responsibility: In none of the cases was there a designated person responsible for acting as a key or contact person taking explicit care of radical innovation ideas existed. Often such ideas just do not fit into ongoing business activities of a company and thus it is not obvious at all who might be assigned to which tasks. This was the case in all three projects and as a result it took project ideas much longer to gain attention compared to incremental innovation activities. In two cases a consequence was that project evaluations had already been started before informing top management. Leifer et al (2000) call such hidden activities skunk work. Although skunk work can be sometimes be effective for generating radical innovation (Christensen, 1997) , it is not part of a systematic process to promote radical innovation through an organization.

Another issue concerning responsibility was the ownership of the project idea. We observed that responsibilities on a strategic level were only assigned once the ideas had been evaluated and the decision had been taken that the idea was further investigated in a project. During the period of time where ideas did not yet have project status, no responsibilities were assigned. The consequence was that the initiation of the evaluation and the drive of the latter were much slower than top management wished it to be in general. In addition there was no standardized planning responsible to direct the operational evaluations or that formulated and reviewed evaluation deliverables.

Structural conflicts between daily business and radical innovation activities - missing organisational alignment: In all three project ideas that we followed from birth until the decision confirming it as an official project, hardly any left their organisational home. Most of the activities registered were conducted besides the ongoing business in the regular organisation. This caused structural conflicts between the two kinds of projects. On the one hand researchers complained that resources that had been granted for radical innovation purpose, could not be used as daily business and ongoing innovation had higher priority. On the other hand managers, who were under pressure to perform, reported that their daily business suffered form radical innovation projects.

The key findings from the cases are summarised table 1. The analyses follow the categories described in this chapter (process, methods and structure related issues). “Non-existent” means that an approach towards this issue could not be found, “Partly existent” means that the company already had rudimentary approaches or considered this issue implicitly in one way or the other, “Existent” means that this issue was explicitly implemented and in use.

Insert here: **Table 1**

5 Requirements to an overall process managing sustainable innovation

Based on the case studies and literature a number of propositions concerning the design of a strategy formulation process that supports sustainable innovation by simultaneously linking radical and incremental technological innovation will be developed. Methodological and structural propositions follow and are meant to enable and support this process. Therefore in the following section some propositions based on theory and practice reported in this paper are elaborated. Whenever possible and data available we will connect them with best case practices from various industry examples. Finally we outline a draft concept for the management of sustainable innovation – including radical as well as incremental innovation (final section of this chapter).

5.1 Process propositions:

Proposition 1: The design of the process, managing radical and incremental innovation, should be structured systematically along the main tasks of strategy formulation: (1) identification, (2) evaluation, (3) decision and (4) implementation of innovation project ideas.

Proposition 2: The action of the process should be continuously extended in order to cover all major tasks referring to both, strategic and operational levels.

Proposition 3: The process should include complementary assignments on the strategic and operational level and should be coordinated continuously by the strategic level.

Proposition 4: The process design should allow a simultaneous but differentiated management of radical and incremental innovation ideas according to their level of newness and risk.

In the course of this research a number of companies whose process design today already fulfils at least facet wise these propositions were identified, for example the German company Degussa or the Dutch DSM group, both active in the chemical industry. Both companies have a process designed for the management of radical innovation ideas that covers the main tasks of strategy formulation. It is run in parallel to a market oriented innovation processes of incremental project ideas in the business units. The differentiation of idea evaluation according to different levels of newness and risk for example is realised at another company, at IBM. Their innovation project ideas are clustered in three horizons depending on the newness and risk they represent for the company. Ideas that are well calculable concerning risk is assigned to Horizon one (H1), realisation of this project ideas target extension, and defence of core business. Ideas with moderate risk are assigned to Horizon two (H2), these project ideas have scale proven business models. Their mission is to increase market share and growth opportunity. Finally high risk and uncertain project ideas called emerging business opportunities (EBO) at IBM are regrouped in the Horizon three (H3) clusters. This differentiation allows IBM to evaluate later more easily the different types of projects with different types of methods (next sub chapter).

5.2 Methodological propositions:

Proposition 5: Methods should be created to support market and technology intelligence systematically during the identification phase.

Proposition 6: Methods should be created to quickly assess the relative newness and risk of innovation ideas for the company.

Proposition 7: Methods should be designed to evaluate the strategic impact of innovation opportunity differently according to their level of newness and risk.

Taking up the case of IBM with its different evaluation horizons, in each cluster different evaluation methods are applied. For H1 projects ideas methods to evaluate profit, return on invested capital or costs are most important while in H3 project ideas the analysis is rather focused to option valuation, pace of conversion form idea to business launch and organisational learning goals. For these projects it is not a proven business plan that is important, goals for H3 projects are recorded in a so-called “Learning Plan”. The Learning Plan can be considered the strategic counterpart of a business plan. It is a strategic instrument that promotes radical innovation projects.

An example for a technology intelligence method used by many established companies is the use of corporate venture capital. Corporate Venture Capital is money invested by established companies in order to promote small technology start up companies. The motivation of such investments is more strategic than financial. It is the motivation to identify small innovative companies developing radical technologies that can be of interest for established enterprises. By looking for such companies and financing their development established companies have a direct window on these innovative technologies. For example the Degussa constantly monitors several hundred technology intensive start up companies in a so-called watch list in order to stay a head of technological change.

5.3 Structural propositions

Generally structures should be designed to enable execution of processes and methods. Additionally keeping with the guidelines of the two following propositions is suggested:

Proposition 8: Structures should be created that provide a contact point and assume responsibility for the management of radical innovation ideas.

Proposition 9: Structures should allow simultaneous and harmonized management of radical innovation beside daily business in order to insure organisational alignment.

In the case of Degussa a unit that takes care of radical innovations which is organised as an independent company is called Creavis. It represents the contact point for all radical innovation ideas emerging within Degussa or discovered outside of it.

Besides monitoring radical technological innovation opportunities for Degussa, Creavis also evaluates these opportunities, plans and coordinates their realisation. For the realisation of projects Creavis runs two distinct structural approaches: project houses or internal start-ups. A project house is a small innovation team where researchers from all business units that are interested in building up competencies with the radical technology work together under the supervision and coordination of Creavis. During their time in a project house researchers are released totally form their daily responsibilities. Project Houses are strictly limited to three years. After this period the researcher returns to their business unit taking with them their acquired knowledge. Project Houses are set up only if business units have a direct interest in learning about the radical technology. If this interest is not established as the radical technology does not seem to bring any advantage for given business units for Degussa, Creavis has the possibility to create internal start up companies to develop the technology independently. This way whole new business areas can be opened up. Once successful the start-up company can be reintegrated into Degussa.

The Dutch chemical group DSM runs a different approach in realising radical innovation. Instead of creating a company of its own a business unit called "Venture and New Business Development" was created that is assigned to promote radical innovation. They also dispose of an overall radical innovation process in the same way as Creavis. While technology and business intelligence is done independently from the market oriented business units as is done at Creavis the two tasks of project idea evaluation and realisation is differently approached. Venture and New Business Development virtually buys expertise from different business units. This means that researchers stay in their divisional home and work part time on radical innovation projects under the supervision of Ventures and New Business Development. Being independent from daily business pressure this organisation can take measures in order to create organisational alignment between radical innovation projects and daily business projects.

6 A strategy formulation process model for sustainable innovation:

In this last chapter the findings and propositions are described in an integrated strategy formulation process model to transform (discontinuous) technology into radical innovation without neglecting the management of incremental innovation (Fig. 4). The purpose of this model is not of a normative nature but rather to illustrate how the various elements described in this paper could be intertwined and simultaneously managed for the purpose of incremental and radical innovation.

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On the one hand the model is structured according to strategy formulation and strategy implementation and on the other hand at a strategic and operational level. Strategy formulation comprises four process phases: information gathering in (1) strategic intelligence, (2) identification of innovation opportunities including the decision of assigning the innovation idea one of the two following evaluation phases, (3) the two different parallel running evaluation phases and (4) the decision and formulation phase. Within these phases the methods described above are located as follows: Venturing activities are placed within strategic intelligence. The quick assessment of the relative newness and risk of innovation ideas is done in the identification phase in order to decide about the assignment to either one of the following evaluation phase. Finally goals expected form the realisation of innovation ideas are recorded in the "decide and formulate" by a business plan for competitive strategic[12] projects or in a learning plan for development strategic[13] projects.

The implementation on the strategic level consists of redesigning operational processes if this is necessary for the realisation of accepted project ideas, controlling- and updating the process.

On the operational level technology, product and business intelligence processes support strategy formulation. They are coordinated from a strategic level. They process information is an iterative way to enable the strategic tasks.

Strategy implementation means at the operational level, the execution of strategic projects through technology development, product development and business development. A structural element here is the project house in order to develop the technology.

[12] Competitive strategic projects aim in the first place to increase short to middle term competitiveness (Tschirky & Bucher, 2003)

[13] Development strategic projects aim to implement the more radical change a company has to go through in order to secure long term survival (Tschirky & Bucher, 2003)

7 Summary and Conclusion

Poor insight into the strategic management of discontinuous technology and radical innovation increasingly represents a strong threat to companies. However most of the research in this field focuses on the industry level rather than concentrating on a company level investigating directly radical innovation projects. Company level research on radical innovation seems to be less poplar than that at the industry level. There is no overall strategy formulation process addressing the various managerial issues concerning discontinuous technologies and radical innovation within an integrated context of radical innovation *and* incremental innovation. Three in-depth case studies were conducted, which identified a pattern that seems to be at the root of some of the difficulties that companies encounter when faced with radical innovation. These insights together with previous research on radical innovation led to the development of nine propositions for the design of an idealized strategy formulation process, for supportive methods and for enabling structures.

We further transformed these propositions in a visual strategy formulation process model showing how the elements described in the propositions could be utilized together. This model shows how radical and incremental innovation can be managed simultaneously while differentiating between their different natures.

Further research is needed in order to detail the process model, as the number of case studies underlying it was limited. Additionally it could be interesting to validate the applicability of the propositions and model.

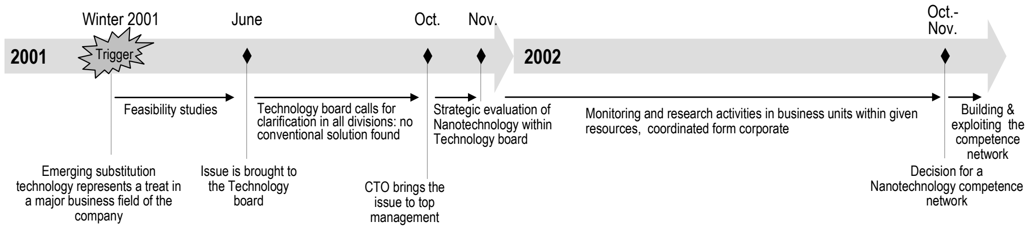

Fig. 1: Chronological course of case A

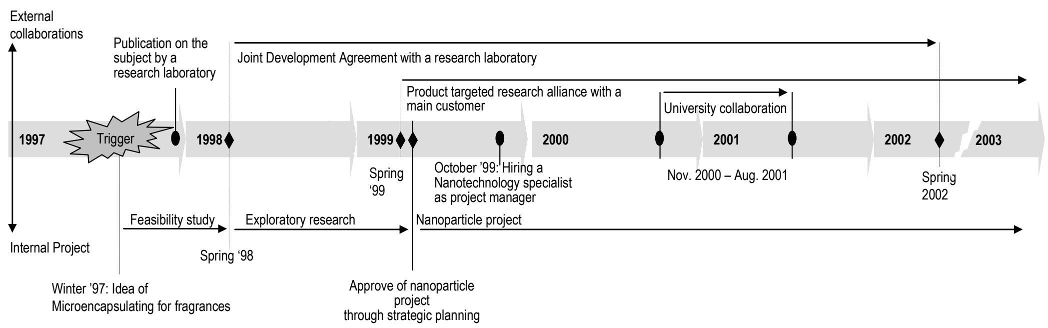

Fig. 2: Chronological course of case B

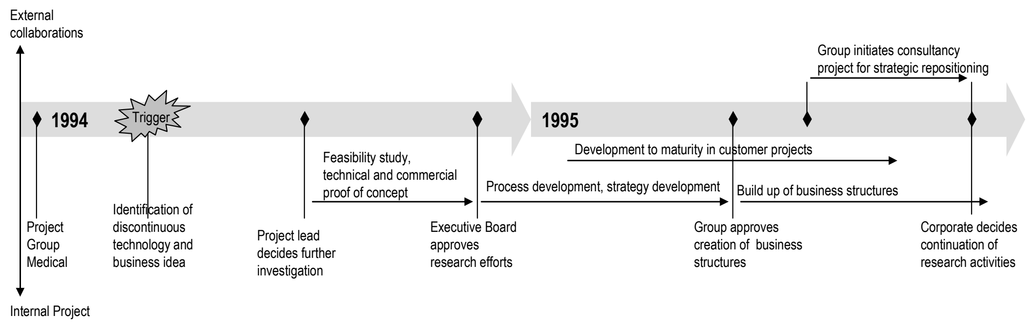

Fig. 3: Chronological course of case C

	Case A	Case B	Case C
Process related issues			
systematic process	○	○	○
evaluations activities on strategic level	◐	○	◐
coordination and interrelation between strategic and operational level	◐	○	◐
Methods related issues			
market and technology intelligence tools	◐	○	○
tools for decision management under high uncertainty and risk	○	○	○
Structure related issues			
clear assignment of tasks and responsibility	◐	○	◐
organizational alignment	◐	○	◐

○ Non existent
◐ Partly existent
● existent

Tab. 1: Cases overview

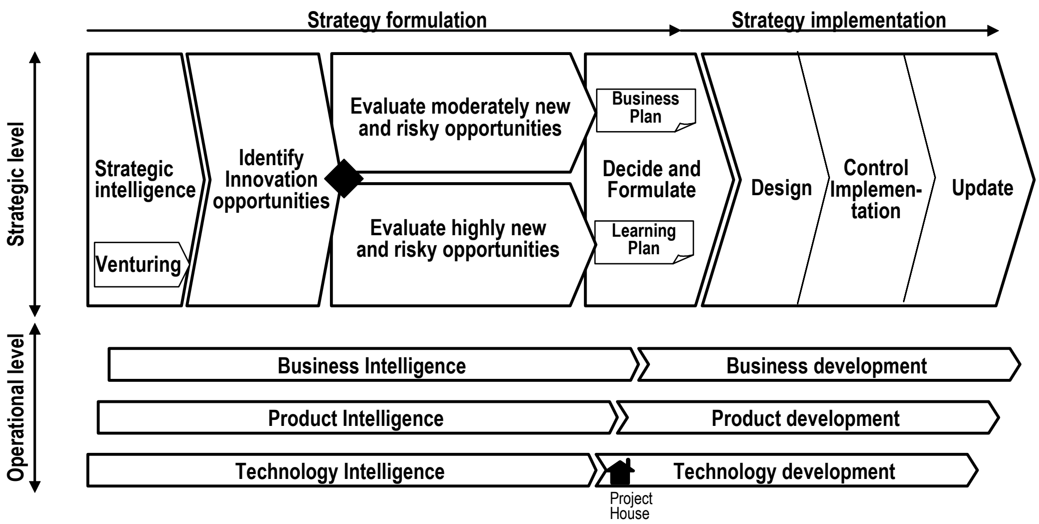

Fig. 4: Idealized process model for the management of sustainable innovation

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