On the way to electric cars - a case study of a hybrid electric vehicle project at Volvo Cars

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Several large actors in the automotive industry have tried to realise the paradigmatic shift from internal combustion engine to electric propulsion, where hybrid electric vehicles (HEVs) can be considered an intermediate step. The Toyota Prius project is probably the most well-known example. However, not all automotive firms have the resources to launch an initiative as radical as Toyota did. Previous research on technological discontinuities and the management of radical innovation provide some valuable insights but there are still few empirical studies available. The aim of this paper is to provide an example of how a small auto maker can approach such a substantial challenge to the whole automotive industry in a less resource demanding way. Based on a case study of an HEV project at Volvo Cars being technologically and chronologically close to the Prius project, it contributes to the growing field of innovation management research and practices.

1. Introduction

With a growing focus on the negative climate impact of the emissions caused by vehicles propelled by fossil fuelled internal combustion engines, automotive firms are exposed to a strong pressure to challenge this more than a century old technology paradigm. Most car manufacturers are currently working on both alternative powertrains and alternative fuel strategies. The need for more than incremental innovations is substantial. Previous research on technological discontinuities (e.g. Olleros, 1986; Tripsas and Gavetti, 2004; Tushman et al., 1997) and the management of discontinuous innovation (e.g. Christensen, 1997; Leonard-Barton, 1992; March, 1991; Tushman and O’Reilly, 1996; Tushman and O’Reilly, 1997; Utterback, 1994) has provided valuable insights on how to organize discontinuous innovation, but there are few examples of how firms actually deal with innovations of a more discontinuous nature.

Toyota has set one example of a promising approach to develop new hybrid propulsion technologies with the Prius project. Previous studies describe a project driven by a strong strategic vision of leadership in the area, a huge budget to build all needed competences in-house and a high degree of risk taking (e.g. Itazaki, 1999; Magnusson and Berggren, 2001; Nonaka and Peltokorpi, 2006; Willander, 2007). Although the Toyota case is an illustrative and highly relevant project to learn from, the prerequisites for this specific approach differ from the resource scarce conditions that usually reign in product development projects in automotive firms. It is difficult and maybe not even advisable for other firms to directly copy the strategy and therefore a reflection on alternative approaches could be useful, which is the purpose of this paper.

This paper provides a detailed description of an alternative and, in most dimensions, considerably less demanding approach. The Desire project at Volvo Cars was chronologically, as well as technologically, close to the Toyota Prius project. Volvo Cars has been quite active in the field of hybrid electric vehicles (HEVs) and the studied project represents a critical phase (1997-1999) in a series of attempts. The project was a focused R&D effort with limited resources and support in the

1 This study is partly financed by R2DS Île de France and partly by Vinnova.
organization, breaking with the dominant design of the combustion engine based powertrain, and the series hybrid tradition at Volvo Cars.

The case is analyzed using the four core capability dimensions proposed by Leonard-Barton (1992). The paper provides some insights on how to manage innovations of a more radical nature, such as the type of discontinuity that a HEV represents. The paper is structured as follows: First, previous research on radical innovations is presented. Thereafter the hybridization challenge is outlined and exemplified by the Toyota Prius case. Then the used methodology is described followed by the empirical data from the case study. Finally the analysis is presented and the insights from the case are summarized and discussed.

2. Managing radical innovations

2.1 What is radical innovation?

Innovation is often defined as the application of a new idea to create a new product or process (e.g. Galbraith, 1982; Tidd et al., 2005). The degree of novelty is described as incremental (new), really new or radical (Garcia and Calantone, 2002) or as a continuum ranging from incremental change (doing things better) to radical change (doing new things) (Tidd et al., 2005). Other authors propose to distinguish between the degree of influence that the innovation has on existing products, where sustaining technologies are those improving the performance of a previously available product and disruptive technologies bring a different value proposition to the market (Christensen, 1997). A complementary dimension concerns the degree of system integration, ranging from modular (component) innovation – where the linkages between core concepts and components remain unchanged – to architectural innovation where these linkages are ruptured (Henderson and Clark, 1990).

2.2 How can firms deal with innovations of a more radical nature?

Managing radical innovations is often described as problematic as it is inherently linked to risk and uncertainty (Burns and Stalker, 1961; Galbraith, 1982; Birchall and Tovstiga, 2005). Few empirical studies describe how innovations actually happen in large firms (Sharma, 1999) or how firms can build innovation capabilities.

The capability of the firm is considered to be its ability to deploy the available resources as their main assets (Prahalad and Hamel, 1990). According to Christensen (1997), an organization’s capabilities are defined by its processes (methods for transforming inputs to higher value output) and its values (criterion used for decision-making). Leonard-Barton (1992) describes the core capabilities of firms as the set of knowledge that provides competitive advantage. The four dimensions are 1) employee knowledge and skills, 2) technical systems, 3) the managerial systems that guide knowledge creation and control processes and 4) the values and norms associated with these processes. To avoid that core capabilities become core rigidities, a dynamic perspective on capabilities was introduced by Teece, Pisano and Shuen (1997) where the need to systematically revise and develop organizational capabilities underlined (Helfat et al., 2007; Nonaka and Kenney, 1991).

Addressing mainly the knowledge and skills dimension, innovative capability has been defined as “the internal driving energy to generate and explore radical, new ideas and concepts, to experiment with solutions for potential opportunity patterns detected in the market’s whitespace and to develop them into marketable and effective innovations” (Assink, 2006:219). Assink (2006) further argues that a way of developing this capability is to enhance the absorptive capacity, i.e. the capacity to recognize and understand external knowledge, assimilate and apply it internally (Cohen and Levinthal, 1990; Lane et al., 2006). Other authors have underlined the generative aspects of innovative capabilities where values are collectively recreated (Le Masson et al., 2006). Recent literature on open innovation argues that to be innovative, firms need to open up the innovation processes and work beyond the boundaries of the firm (e.g. Chesbrough, 2003) since it is becoming impossible to develop all knowledge in-house. Open innovation research even argues that firms need to consider knowledge external to the firm as being as critical as the internal knowledge (e.g. Enkel and Gassman, 2007).

Relating to the technical system capability several authors stress that the regular product development processes are inadequate for developing innovative products (Leifer et al., 2001; McDermott and Colarelli O’Connor, 2002; Rice et al., 1998; Veryzer, 1998). A separate organization, with dedicated teams, is often suggested for projects dealing with potentially radical innovations (Galbraith 1982; Govindarajan and Trimble, 2005; Quinn, 1985; Sharma, 1999; O’Reilly and Tushman, 2004). This setup shields the project and allows freedom, speed and experimentation. But separating the explorative activities from the core business also leads to isolation and resistance against the resulting ideas (Birkinshaw and Gibson, 2004; Moss Kanter, 2006). Instead, others have underlined the need for a management system that encourages learning and experimentation (e.g. Colarelli O’Connor and De Martino, 2006; Eisenhart and Tabrizi, 1995; Hatchuel et al., 2003). This difficult trade-off between short term returns and long term capability building (Bartezzaghi et al., 1997) has been described as exploration/exploitation (March, 1991) and the ambidextrous organization (Tushman and O’Reilly, 1996; 1997). Leonard-Barton (1992) argues that technical and managerial systems are easier to change than knowledge and skills. “The value embodied in a core capability is the dimension least susceptible to change” (Leonard-Barton, 1992:121). She also stresses that the number of capability dimensions being challenged relates to the degree of misalignment of the project, which in turn relates to the severity of the paradox of making use of the core capabilities at the same time as trying to alter them.
3. The challenge of hybridization in the automotive industry

3.1 Hybridization in the automotive industry

Several large actors in the automotive industry have tried to realize the paradigmatic shift from internal combustion engine to electric propulsion, but so far with limited impact. About a decade ago, an intermediate solution, a hybrid in a double sense (c.f. Geels, 2002), reached the market – the Toyota Prius. As hybrid electric vehicles use existing automotive knowledge and add new competencies, it is competence enhancing in Utterback’s terms (1994). In comparison, a “pure” electric vehicle has a clear competency destroying aspect, as it eliminates the need for an internal combustion engine, which has been dominant during more than a century.

Technological discontinuities occur at various levels. Even though a break-through innovation can be characterized as radical in a retrospective it is seldom very radical when it first reaches the market. Changes at subsystem level dominate (Tushman et al, 1997), the hybridization of the powertrain is one such example. There is a clear parallel between the degree of electrification of the vehicle’s powertrain and the radicalness of the technological change. Perspective also matters; for a supplier of hydraulic servos a shift to electric servos might eliminate the business completely whereas for the car manufacturer, the shift to electrically assisted steering is just a small step in the improvement of energy efficiency.

3.2 The Toyota Prius project

Late 1993, Toyota established the G21 project that resulted in the market introduction of the Prius in December 1997 (Nonaka and Peltokorpi, 2006). In 1995 it was decided to use a power-split hybrid topology; the Prius uses a planetary gear to distribute the power between the motors/generators and the Atkinson cycle engine (Itazaki, 1999). The initial production volume of 1 000 vehicles per month was soon doubled, due to large order volumes (Nonaka and Peltokorpi, 2006). Sales outside Japan started in the year 2000 with the second generation Prius. In 2007 Toyota had 75% of the US market for HEV passenger cars with five HEV models. The Prius accounted for an accumulated total of over 800 000 units (GreenCarCongress, 2007). Since the introduction of the Prius Toyota has grown steadily and is now approaching a position as the world’s largest car maker (OICA, 2007). Toyota’s ambition was to be the first company commercializing HEVs (Itazaki, 1999). At least one thousand Toyota engineers were involved in the Prius project (Nonaka and Peltokorpi, 2006) and, with a strong support from top management, resources were not a significant restriction. The project management was situated in the “red carpet room” (Itazaki, 1999:13) separated from the rest of the R&D organization. The team members were all young and dedicated solely to the project (Nonaka and Peltokorpi, 2006). A strong focus on learning characterized the project (Williander, 2007) and the Prius was designed from scratch, with a carte blanche to develop all parts internally if necessary. It was decided that all hybrid parts based on brand-new technologies should be manufactured in-house to retain the ability to understand, evaluate and produce the basic technology within the firm (Itazaki, 1999). Also, the G21 project strived for a minimum of prototypes and no back-up alternatives. “The task was an extreme challenge for the senior engineers appointed to the project.” (Williander, 2007:208) Very intensive test driving took place around the clock during the summer of 1997 to meet deadlines and use the test vehicles more efficiently. The tests totalled five times longer distances on the test course than other new vehicles and involved approximately 100 test vehicles of four generations (Itazaki, 1999). The project first had a clear focus on technology viability, and changed focus to cost reduction only after this goal was achieved (Magnusson and Berggren, 2001).

4. Methodology

This paper builds on a case study of a HEV project at Volvo Cars. The case study research method (e.g. Eisenhart, 1989) is in line with other attempts to increase the knowledge on radical innovations. This case study is mainly based on data from 14 semi-structured interviews, lasting between one and two hours. To avoid or at least limit the bias of retrospective sense-making (Eisenhardt and Graebner, 2007), informants with different positions in relation to the project were selected; from directly involved and positive to quite distant and negative. Several hierarchical levels in the organization were represented, from workshop staff via the project team to line managers and top management. Half of the informants are still at Volvo Cars, others have retired or work at other firms. Notes from each interview were submitted to the informants for review and approval. The main complement was the ‘project archive’ - a CD containing project documentation such as test reports, drawings, presentations, photos and press cuts.

Table 1. Data sources

<table>
<thead>
<tr>
<th>Informant category</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desirée team member or leader</td>
<td>D1 – D5</td>
</tr>
<tr>
<td>Manager at Volvo Cars</td>
<td>M1 – M7</td>
</tr>
<tr>
<td>HEV specialist at Volvo Cars</td>
<td>H1 – H2</td>
</tr>
<tr>
<td>not involved in Desirée</td>
<td></td>
</tr>
<tr>
<td>Project archive</td>
<td>CD</td>
</tr>
</tbody>
</table>
Using the theoretical framework, the results were systematically analyzed through an abductive analysis approach, also referred to as systematic combining (Dubois and Gadde, 2002). The analysis also draws on knowledge from a number of other studies on product development and concept development at Volvo Cars which have provided the authors with in-depth contextual understanding of the practices in use in the organization.

5. The Desirée project

This section is, unless otherwise stated, based on interviews as outlined in the methodology section.

5.1 Project initiation

Volvo Cars has a long-term and trustful relation with Aisin, a Japanese supplier of, among other things, automatic gear boxes, partly owned by Toyota. The collaboration includes bi-annual strategy meetings, where Volvo Cars and Aisin discuss current and future activities of common interest. In 1997, at one such meeting, one of the Volvo representatives noticed a product on display. It turned out to be a power-split hybrid transmission proposed to Toyota for their Prius project, but not selected as Toyota opted for an internal version of a power-split device. Aisin and Volvo agreed to initiate a joint project to test and demonstrate this power-split device.

A few months earlier, one of Volvo Car’s largest efforts so far in the hybrid trajectory had been halted due to costs. However, some people involved felt that Volvo Cars had to do something in the hybrid domain. An ambitious project manager was asked to organize a project around the Aisin technology and an initial budget was created. The project manager was not part of the previous hybrid history at Volvo Cars and realized during the preparation of the project that several engineers that had worked with electric traction were strongly committed to series hybrids. He also realized that management was not yet ready for this new technology - it was not possible to achieve a clear support at this stage. To avoid lengthy discussions, he recruited only a part of the engineers working with the project during approximately one year. As the project was not in the product plan, some departments were not at all represented, which contributed to a reduced administration of the project.

5.2 HEV demonstrator development phase

Two used vehicles, one S40 and one V40, were used as platforms for the Desirée powertrain. Relatively large batteries were selected, allowing for a certain range in electric mode at lower speed. The vehicles were also equipped with a battery charger (plug-in capability) and a small, three-cylinder combustion engine developed especially for Desirée. Several other innovations stemmed from the project (approximately fifteen patents), for instance an electric air conditioning system, which was installed but never made operational, as the fine-tuning would be too time-consuming.

After the main components and solutions were selected, and the system modelled and simulated, much work was carried out in the workshop. Due to the tight time and financial constraints, there was a limited use of drawings. This relatively high degree of freedom required high competence in the workshop and allowed a trial-and-error working method. There were few project meetings and the people involved in the project often met around the vehicles. The suppliers also participated, partly on site in Gothenburg, for instance Aisin had two resident engineers working with the project during approximately one year. As the project was not in the product plan, some departments were not at all represented, which contributed to a reduced administration of the project.

Closely related to the trial-and-error approach was a relatively large extent of testing. Apart from the obvious measurements of consumption and emissions, a lot of test driving in various environments was made. Among others, a direct comparison with the Prius was made in Japan, involving test drives with the two vehicles. These tests indicated a slightly better fuel efficiency of the Desirée with an energy efficiency improvement of approximately 40% compared to the conventional powertrain.

During the project, Toyota introduced the Prius. One reaction from European automotive companies was the argument that the Prius would never cover its own costs. Another response was the intensification of the hybrid development. The introduction of Prius made it possible for the Desirée project to free-ride on the interest and increased power-split hybrid knowledge that Toyota contributed to.

5.3 Project outcome

When approaching a relatively mature status, managers and other internal stakeholders were invited to test drive the Desirée vehicles, both as an evaluation of the vehicles and as a demonstration of the technology. Their response was positive. “I think the vehicle was very nice to drive and it appeared to be qualitatively close to market introduction.” (M7). It was decided to present the Desirée at the Geneva Motor Show in spring 1999.

The Geneva appearance resulted in a lot of attention. Among the persons very interested in Desirée in Geneva were several Ford managers. Directly after the Geneva
Motor Show, the Ford Motor Company acquisition of the Volvo car division was announced. Among the reasons mentioned for the transaction was the large requirement for resources in new powertrain development, where large volumes were considered necessary to carry the development costs. The Desirée project was noted during the due diligence procedures and it was later decided that Ford would lead the development of the full hybrid technology based on the Desirée project while Volvo Cars would focus on the industrialization of a light hybrid concept called Integrated Starter Generator (ISG). Consequently, the Desirée team was asked to hand-over the project results to Ford in Dearborn. Part of this knowledge transfer was made through the writing of a HEV handbook, summarizing the experiences from the Desirée project. Another part was a meeting in Dearborn, where the core Desirée team informed the Ford managers and engineers regarding the project and its outcome. The Desirée team noted that the Ford executives seemed amazed by the presented facts, especially that Volvo had produced these concept cars using so little time and resources. “We were quite effective, I guess.” (D2). The total budget for Desirée was USD 3.6 millions. As a part of the Partnership for a New Generation of Vehicles (PNGV), Ford had committed to launching a hybrid vehicle on the market (The Detroit News, 2006). The PNGV contract also implied demonstration vehicles and in the year 2000, Ford presented a diesel-electric light hybrid using a similar topology as the Volvo Car’s ISG concept. Estimates of the total PNGV budget, including governmental and industrial investments 1996-1999, give a total figure of approximately USD 4 billions for the three participating auto makers. HEV technologies account for the dominating part of the governmental investment (Commission on Engineering and Technical Systems, Transportation Research Board, 2000).

The Desirée hybrid solution required close collaboration with Aisin, a supplier that Ford did not have the same close relation to as did Volvo Cars, so they initially acted as a gateway in their relation. Even though the objective was to use the power-split device also in Volvo cars, the Ford project had soon altered the dimensions in a way that made it practically impossible to integrate in the Volvo cars. Ford carried out their part of the hybrid powertrain strategy with determination, targeting a small SUV, the Escape model. The up-scaling of the Desirée solution to work with this larger vehicle and the elimination of the all-electric range capability caused some problems but in the autumn of 2004, the first hybrid Escape was launched.

6. Core capabilities – used or challenged?

Using the core capabilities framework (Leonard-Barton, 1992) the two, partly parallel, HEV projects are compared and discussed below.

6.1 Employee knowledge and skills

In the mid-nineties, Volvo Cars and Toyota had a similar knowledge base, dominated by internal combustion engine related skills but, compared to other auto makers, also a relatively strong knowledge in the domains of battery electric vehicles and (series) hybrid electric vehicles. For both firms, the power-split technology and some other components such as the tractionary batteries represented a challenge to the existing knowledge base. Whereas Toyota opted for a solution focusing on the power of the batteries, Volvo Cars selected a solution closer to the series hybrid tradition with large requirements also on the energy storage capacity of the batteries. Toyota’s hybrid topology represents a larger break from the previously dominating electrification alternatives but is actually less radical than the Desirée solution, if considering the degree of electrification as a measure of radicalness. Both firms were quite confident about their knowledge and skills but acknowledged that the learning dimension of the HEV project was important.

6.2 Technical systems

Obviously, both firms had very strong capabilities in terms of vehicle development. Considering the powertrains, engine development was a dominating and well functioning process as illustrated by the Volvo Car project where a completely new engine was developed within the limited project scope and the new type of engine Toyota introduced in the Prius. Another important capability was the methods for simulation and testing. At a very early stage in the Desirée project, it was decided to use existing vehicle chassis and conventional components as much as possible. This was even used as a marketing argument for the concept; claiming a 40% improved fuel efficiency without using low friction tires or any other specific measures to save weight or reduce air resistance. Quite contrary, the Prius was designed from scratch and the project team was encouraged to make use of new technologies and design solutions.

6.3 Managerial systems

Even though, or maybe just because, the Desirée project was not initiated and executed according to formal procedures, it was a quite normal project in terms of management. The project team had a relatively large degree of freedom within the tight constraints of the budget and the time schedule. Several additional factors contributed to the positive and productive team spirit. One important factor was the geographical proximity of the people, often directly working together around the vehicles in the workshop, even involving the main suppliers. Another factor was the “skunk” dimension of the project. Even though it was not a top-secret real skunk project (Gwynne, 1997), it was a project outside the product plan and outside the mental notions of most people at Volvo Cars and elsewhere. A third factor contributing to the team spirit was
the tight time and budget frames, not allowing much deviation. The market introduction of Toyota Prius also influenced the Desirée project, as it both confirmed that the chosen technology worked in practice and sharpened the HEV competition among automotive firms. Toyota, on the other hand, used the Prius project as a vehicle to develop and test a new type of project management, including co-location of the project team in a separate room.

Another managerial difference was the extent of external networking. Whereas Volvo Cars based a lot of the core hybrid issues on knowledgeable suppliers, such as Aisin and Varta, Toyota decided to develop all core HEV technologies in-house.

Both projects were carefully documented but whereas the knowledge produced in the Prius project appears to have been further developed in other Toyota initiatives, the knowledge generated in the Desirée project was not systematically exploited, at least not inside Volvo Cars. Both companies seem to have succeeded in integrating the results from the two relatively isolated projects with the main operations, however in very different ways.

6.4 Values and norms

Both Volvo Cars and Toyota have much faith in the firm’s R&D capabilities, with the common standpoint that almost all challenges can be handled with technology improvement. The Prius project had a high status through the direct top management commitment and large freedom in terms of methods and budget. The clear role for the Prius vehicle in the Toyota vision also contributed to its status. On the other hand, Desirée was a rather low status project, with a skunk character, small resources and challenging some of the dominating values in the firm. For instance, at this time, few considered the green dimension to be an important aspect of premiumness (Willander, 2006). Also, decisions were mainly guided by legislation, especially in California, and as the Californian zero emission vehicle (ZEV) mandate became less demanding, projects with a clear ZEV dimension (like Desirée), lost some of its support.

Toyota used the Prius project to change values and norms. This strategy appears to have been successful at least in terms of branding. The Prius has assisted in linking the Toyota brand to high-tech and environmentally sounder products. When designing the Desirée project, another strategy was chosen. The main instrument to change the values and norms at Volvo Cars was the extensive test-driving exercise with key stakeholders. As this resulted in the managerial decision to push forward the technology as one of the key messages at the Geneva Motor Show, this strategy also worked quite well. However, when Ford Motor Company acquired Volvo Cars, management did not fight for a continuation of the power-split HEV technology development at Volvo Cars.

7. Conclusions

This paper set out to reflect on an alternative approach to the very demanding strategy applied by Toyota in the Prius project. An analysis of how the HEV projects related to respective firm’s core capabilities highlighted several similarities but also some key differences. The Desirée project was designed to maximize the use of the firm’s existing core capabilities while the Prius project seems to have been rather the opposite, as it challenged all four dimensions. However, although being a risky strategy, it also seems to have been a successful initiative to develop new capabilities and reduce the core rigidities of the firm. Today, Toyota is deploying its new capabilities at many levels and has a full spectrum of hybrid vehicles on the market, while Volvo Cars still does not have any HEVs on the market.

An interesting difference is that the Desirée project emerged from the organization while Toyota applied a clear top-down strategy, highlighting the importance of top management support when aiming at challenging core capabilities. This is in line with Leonard-Barton (1992) who argues that values and norms are the most difficult core capabilities to change. Since the Desirée project objective was concept development and demonstration, it did not radically challenge the values and norms of Volvo Cars. However, in hindsight, this also reduced the potential impact of the project, for instance in terms of foreseeing the demand for environmentally friendlier cars. It is possible that the Desirée project could have gained more long term impact in Volvo Cars if the setup had been different, but given the lack of a clear top management support it seems that the strategy not to challenge the organization on its core capability dimensions was rather wise, thus succeeding in surviving and achieving its goals.

The case study indicates that it is possible to manage development of rather radical technologies with only limited risk exposure and small resources, thus giving some contrasting insights to the much exposed Prius case. The transfer of the results to Ford Motor Company and the market introduction of a power-split based Ford Escape, confirms that the Desirée project succeeded in its mission, even though some team members would have preferred leading also the industrialization phase of the HEV technology.
9. References


GreatCarCongress (November 05, 2007) “Toyota has sold almost 1.2 million hybrids worldwide since 1997; Prius accounts for 72%.”


The Detroit News (June 29, 2006) “Ford bails out on hybrid promise”.

It is important to note that this is a plain text representation of the document, and it may not capture all the nuances and subtleties of the original content.


