Managing learning in the automotive industry – the race for hybridisation

Gerpisa 16th International Conference 2008

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Abstract
Hybridization is the main focus for most car manufacturers today – however it implies large changes both in terms of the vehicle itself (technology and integrated systems) but also in terms of usage and business models. In literature on discontinuous innovation, learning is put forward as a crucial capability but there are few empirical studies on how this actually happens in firms. This paper aims at discussing different learning mechanisms used in the aim of developing HEV capabilities. It also highlights that in this kind of broad innovation field, new mechanisms are emerging in the automotive firms, such as market experiments, exploratory partnerships and brand value experimentation. It also argues that overall learning strategies are necessary to guide the many learning mechanisms activated. It contributes to an increased understanding of how automotive companies deal with disruptive innovation.

1. Introduction
The impact of automobiles on the natural environment is well known, and the reduction of this impact is a priority issue on every car manufacturer’s agenda. Reduction of CO2 is one of the main drivers in technology development and also in focus of aggressive regulations. There are several ways of reducing CO2 emissions from cars with combustion engines such as new types of fuels (bio-fuels), low consumption engines and driver behaviour. There are also more radical technology developments, such as the hybrid electric vehicles (HEVs) in which two different sources of power are combined (OECD, 2004). Toyota’s first HEV project, the Prius, has substantially contributed to a large public and research interest (Magnusson and Berggren, 2001; Nonaka and Peltokorpi, 2006). However, it would be a mistake to restrict such innovations to their technological dimension. Hybridisation represents a very broad field of innovation, where for instance new marketing concepts, technological concepts and business model concepts are being explored by different car manufacturers.

This paper aims at discussing how different car manufacturers have used different learning mechanisms in their aim for developing HEVs. It also highlights that in this kind of broad innovation field, new mechanisms for learning (instruments, tests, experiments) are being developed in the automotive industry. It also argues that in the context of hybridization, overall learning strategies are necessary to guide the many learning mechanisms activated. It contributes to an increased understanding of how automotive companies deal with disruptive innovation. It also responds to a call for more research on disruptive technology as such (Daneels, 2004). This paper is based on five interviews with different car manufacturers, a

1 This paper is based on a study partly financed by R2DS Île-de-France and partly by Vinnova.
case study of a HEV project at Volvo Cars (14 interviews) as well as industry documentation and secondary sources.

2. Theoretical framework

2.1 Discontinuous innovation and innovative capabilities

Innovation is often related to the degree of novelty; it can be described as something 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; Christensen and Overdorp, 2000). 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).

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. 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 is underlined (Helfat et al., 2007; Nonaka and Kenney, 1991). Previous research on radical or discontinuous innovation (e.g. Henderson and Clark, 1990; Christensen, 1997; Leifer et al., 2001) describes a process characterized by uncertainty and new knowledge areas where performance criteria rapidly change. For firms, there is a difficult trade-off between short term returns and long term capability building (Bartezzaghi et al., 1997) that has been described as the productivity paradox (Abernathy, 1978), exploration-exploitation (March, 1991) or the ambidextrous organization (Tushman and O’Reilly, 1996; 1997).

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: “a collective capacity to permanently and simultaneously recreate new sources of value (products, concepts, patents, environmental values etc.) and competences (knowledge, know-how, professions etc.)”(Le Masson et al., 2006:21). Despite the theoretical discussions on innovative capabilities there are still few examples of how companies actually deal with innovations of a more radical nature and there is still a need to better understand how companies can prepare for and undertake such innovations.

2.2 The role of learning in innovative capabilities
Previous research has shown that organizational learning is a critical capability for firms aiming at being innovative (Madhavan and Grover, 1998; Lynn et al., 1998). It may be defined as “the ways firms build, supplement and organize knowledge and routines around their activities and within their cultures, and adapt and develop organizational efficiency by improving the use of the broad skills of their workforce” (Dodgson, 1993:377). Hatchuel et al., (2002) underlines the need for management of learning by proposing a type of design-oriented organization meaning an “organization favourable to collective learning cycles, which... [is itself] conducive to this simultaneous regeneration of objects, skills and occupations (Hatchuel et al., 2002:18). They claim that knowledge management is closely linked to the organization of actions within the firm and that the company must constantly reconstruct its collective learning process in terms of ‘concept objects’ and ‘embryonic occupations’ whose ongoing development will perhaps – but not always, generate more routinized occupations and practices (Hatchuel et al., 2002:18). Learning is thus important in a dynamic capability view of the firm because resource endowments are ‘sticky’, at least in the short run, and because firms often lack the organizational capacity to develop new competences quickly (Teece et al., 1997). In this perspective, as competences and capabilities are normally rather difficult to replicate, learning is the fundamental process by which capacities are built.

The literature contrast two fundamental learning processes: “single loop learning” (Argyris and Schon, 1978) which mainly consist in problem solving where routines in the organization is refined within an existing “theory in use” (Argyris and Schön, 1996) or “dominant logic” (Prahalad and Bettis, 1986) of the firm and “double loop learning” which not only detect and solve problems but also change the values and norms through questioning the underlying values and norms which involves a change in the “theory in use” (Argyris 1976; 1977; Argyris and Schön, 1996).

Transposed to innovation management in organizations, “single loop” learning would consist in the introduction of incremental changes within a dominant design (Utterback, 1994) and the exploitation of existing competences. This can be achieved internally or by developing the “absorptive capacity” of the firm (Cohen and Levinthal, 1990; Lane et al., 2006) that “refers to one of the firm's fundamental learning processes: its ability to identify, assimilate and exploit knowledge from the environment” (Lane and al., 2006). Also other authors have stressed the link between absorptive capacity and the firm’s capability to learn (Williander, 2007; Todorova and Durisin, 2007). By contrast, “double loop” learning would involve deeper changes in the knowledge and resource base of the organization. Innovative organizations are those that are able to explore, revise their routines and to mobilize new concepts and resources. In line with the design strategies proposed by Hatchuel, Le Masson and Weil (Hatchuel et al., 2005; Le Masson et al., 2006) this implies that a key-issue for companies is to combine their “absorptive capacities” with more “generative capacities” (Elmquist, 2007). In a “double loop” approach of innovation, neither the solutions nor the performance criteria pre-exist from the start but are to be designed and developed during the innovation process.

A focus on learning is all the more important when the outcomes of innovation work are uncertain, and there are potential “spill-overs”, i.e. unexpected or unintended outcomes. This phenomenon is often considered out of focus for managers but in innovation management the spill-overs are a key issue from a learning perspective. The implementation of instruments or mechanisms through which “spill-overs” can be identified and may feed the innovation process back is an important managerial task. As people, knowledge and stories circulate in the organization and between organizations, learning is likely to occur beyond existing boundaries in an “open innovation” scenario (Chesbrough, 2003; Chesbrough et al., 2006).
this perspective, organizations shall not only learn within existing boundaries or projects, but also try to leverage on external knowledge.

More important, several authors have stressed that learning can be managed in a long-term perspective, through repeated innovations (see Penrose, 1960, Hatchuel et al., 2003) and through learning between projects (e.g Maidique and Zirger, 1985; Rothwell and Gardinger 1989). Therefore, the innovation capability of the firm should not be measured within a project but need to be evaluated over a longer period of time within lineages of concepts and knowledge (Hatchuel et al., 2003). In this managerial approach, the idea prevails that organizational learning is not a natural process but, on the contrary, it is a process that needs to be managed, designed and guided through the selection of appropriate mechanisms that maximize the opportunities of learning and increase the resource base of the company (see Tidd et al., 2006).

2.3 Learning mechanisms in the automotive industry

What are the learning mechanisms available to support the development of innovative capabilities in the automotive industry? With an increasingly competitive climate, the process of new product development has become increasingly strategic for automotive firms (Magnusson and Berggren, 2001) and the main concerns have revolved around establishing more efficient structures and processes to reduce uncertainties associated with the process. In automotive firms, where R&D is mainly linked to a small number of very large and long-term projects, transferring and reusing knowledge between projects has been shown to be poor. The completion of the project is the main driving force and once the delivery is done the teams tend to break up and move on, leading to frequent reinventing-of-the-wheel (Coombs and Hull, 1998). Also on a more strategic level it has been shown that learning is difficult due to inherent inertia (Williander, 2006).

The early phases of the product development process are where there are most opportunities to test new ideas, since the costs involved with implementing changes are still relatively low (Reinertson and Smith, 1991). Intensive learning in the early stages or “front-loading” strategies has become a popular approach in the automotive industry (Thomke and Fujimoto, 2000, Thomke, 2003). Five main learning mechanisms have been identified in the literature:

— **Prototyping (virtual or physical)** - Intensive learning in the “fuzzy front end” of innovation processes can be achieved thanks to the use of new technologies like virtual prototyping and digital validation systems. These new experimental tools make it possible to speed up the detection of problems and validate alternative solutions at a much earlier stage (Thomke and Fujimoto, 2000; Thomke, 2003). As in the software industries, early deliveries of prototypes can also stimulate interactions with users to define product specifications more effectively (MacCormack, 2001). The physical prototypes are classic learning mechanisms in the automotive industry as they can help testing a new concept in front of a public (clay models) or demonstrators (mock-ups) which are used in the auto industry to evaluate and/or demonstrate the performance of a concept to a large audience. Concept cars are sometimes officially launched to test ideas with a larger audience (Backman and Börjesson, 2007).

— **Storytelling or Narratives** - In the organization literature, different works have stressed how learning from success or failure (Hamel and Prahalad, 1993) should be based on intended mechanisms like post-mortems or storytelling which can help revising routines and build a collective new sense-making (Weick, 1979) to develop a
critical view on past projects (Levitt and March, 1988). Some published examples are to be found on the development of the Volvo XC90 (Bragd, 2002) and the Renault Twingo (Midler, 1998).

— **Organisational separation or skunk-work projects** - It is often suggested that radical innovation projects should be organized separately from the NPD organization with dedicated teams, (e.g. Galbraith 1982; Quinn, 1985; Peters, 1997; Gwynne, 1997; Sharma, 1999; O’Reilly and Tushman, 2004; Govindarajan and Trimble, 2005). For instance the Toyota Prius project worked physically separated from the rest of the organization, among others to be able to work independently (Itazaki, 1999). The skunk work approach is described as advantageous since it protects and culturally separates the project for the purpose of innovation, often operating in near-total secrecy with strong top-management support (Gwynne, 1997). Much focus lies on the culture and enthusiasm created in such a sub-organization, based on a strong vision, autonomy, informal processes, collaboration and trust (Single and Spurgeon, 1996; Bommer et al., 2002).

— **Partnerships** – Literature on alliances, networks and inter-firm relationships are important in the building of innovative capabilities. Collaborations with external partners, in both research and development projects, is a well known mechanism to both share risk, create economies of scale and learn (e.g. Kogut, 1988; Powell et al., 1996; Birkinshaw et al., 2007). The automotive industry is well known for close collaboration with its suppliers and also alliances such as Renault-Nissan.

— **Customer involvement** - Learning mechanisms are not limited to technology and organizations. Recent work has also stressed the importance of involving consumers in product development, lead-user involvement (Von Hippel, 1990) and toolkits used for innovation and mass customization (Piller & Walcher, 2006). In the automotive industry, customer reference groups are often used (e.g. Dahlsten, 2004), but customers are mostly included in rather late phases, for instance through customer clinics and focus groups.

3. The race for hybridisation in the automotive industry

3.1 Drivers for eco innovation in automotive industry

The automotive industry is characterized by innovations, but most have been incremental and technological, remaining within the dominant design of the car. During more than a hundred years the propulsion has been based on the internal combustion engine (ICE). Recently, a focus on how to reduce the climate impact of cars has driven a strong development towards cars that use alternative fuels or power trains. Going from ICE towards more environmentally friendly solutions, such as hybrids, is an important technology shift and a challenge for car manufacturers.

For a long time, ecological innovation in the automotive industry has remained a matter of technological development driven by public regulations. In this perspective, environmental innovation should not be regarded in terms of absolute costs but in terms of relative costs. A classical example is provided by Du Pont de Nemours who proactively promoted a regulation of CFC in the 80’s, despite higher production costs for substitutes, as a means to gain a larger market share than its competitors who tried to prevent such a regulation. More generally, the latter argument is consistent with different empirical and theoretical works that show the importance of standard setting in business competition (see Garud and Rappa, 1994) and,
more generally, of studying the joint dynamics of innovation and institutionalization processes (Aggeri, 1999; Hargrave and Van de Ven, 2006).

The potential of eco-innovation for customers is an ongoing debate in the literature. Some authors argue that customers are increasingly interested in green products (e.g. Dagnoli, 1990) while others argue that there is no clear willingness to pay for the good of the environment (e.g. Diekmann and Preisendorfer, 2003). Except general arguments about why environment ought to be a strategic long-term issue for companies, the key question here is how companies may conduct eco-innovation processes that combine the private good (private value for customers), the public good (reducing the environmental impact) and a sustained competitive advantage for the company (e.g. Porter and van der Linde, 1995; Sharma and Vredenburg, 1998). Previous research on eco-innovation in the automotive industry has mainly focused on the possibilities of encouraging such developments on an industry level, that is through taxes, incentives and legislation (e.g. Porter and van der Linde, 1995; Sharma and Vredenburg, 1998), but there is less focus on the company perspective. Some results have shown that despite an awareness of the negative externalities of the current technologies, inertia to change is prevalent (e.g. Williander, 2006). This is especially apparent since there is an inherent contradiction in the values put forward in sustainable performance criteria, such as low consumption, and the criteria traditionally associated with car’s status such as powerful engines and large size (e.g. Luke, 2001).

However, recently three new drivers have increased the interest for climate related eco-innovations in the automobile industry. First, the acceleration of the public agenda with regards to climate change concerns – the anticipation of new regulations for CO2 emissions worldwide2 partly in combination with anticipated tax incentives with regards to vehicles with low CO2 emissions, as are already in place in for example France. However this variety of incentives systems and public choices is seen by large motor companies as an obstacle for the development of innovation. For instance, incentives strongly vary from a country to another with regards to diesel prices, to the promotion of electric vehicles or to the promotion of alternative fuels like natural gas or biogas. This heterogeneity may partly explain technological trajectories of car manufacturers. For instance, the strong focus on clean and efficient diesel engines by French car manufacturers relates probably to the fact that they are not addressing the US market, where diesel engines very seldom are used for passenger cars. Second, the brutal increase of oil prices has increased the car buyers’ concern about fuel consumption. Third, market competition is changing and first movers like Toyota have attracted the public eye and have received great media attention about their product innovations, like the Prius. This demonstration of how to actually combine a green, high status and performance image in one product has inspired competitors to outline and initiate their own hybridization strategies. All these elements have played an important role in the current race for eco-innovation that can be observed among car manufacturers. Finally, recent evolutions of the car market, characterized by a rapid decrease of big cars sales also reflect the urgency of developing more environmentally friendly cars.

3.2 Different initiatives on the automotive electrification path

Electrification of the vehicle and its propulsion system has always been an interesting alternative as it promises high energy efficiency in the vehicle as well as zero emissions of pollutants. Several obstacles have however delayed the introduction considerably. Whereas

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2 The forthcoming EU Directive on CO2 emissions will replace the voluntary agreement on CO2 emissions signed in 1998 whose targets will not be achieved by car manufacturers.
the electric vehicle has been promoted in various ways from the governmental side, the automotive industry has been more reluctant. The Californian Zero Emission Vehicle (ZEV) mandate introduced 1990 originally targeted electric vehicles but was later revised to also include other technologies such as hybrid electric vehicles (Fogelberg, 2000).

Around 1840 when sail ships gradually were outperformed by steam ships, hybrids using both sails and steam engines were used during a transition period (Geels, 2002). Following the same logic HEVs can be considered as an intermediate solution on the path towards full electrification of the vehicle. Hybrids can consequently be anything from a conventionally powered vehicle - Kirsch argues that the electric motor starting the engine makes it a specific type of technological hybrid, the “electrified gas car” (2000:75) - via several light hybrid topologies where the engine is dominant and the electric motor/generator assists in some situations through “full hybrids” such as the Toyota Prius with approximately the same power in the motors as in the engine to series hybrids and electric vehicles, where the propulsion is made by electric motor(s) and an engine, if any, only propels a generator of electricity on-board the vehicle. But, whereas this logic is quite clear technologically as illustrated in Figure 1, it has not always been followed in practice.

![Figure 1: The path towards electric propulsion](image)

From the governmental side, most initiatives have targeted full electrification at once. Maybe as a consequence, they have not yet resulted in any disruptive change in propulsion technology. Many car manufacturers responded in various ways to the Californian ZEV mandate, for instance Volvo Cars developed a HEV concept car (the Environmental Concept Car) in 1992 using a gas turbine generating electricity on-board, that had lower emissions than an electric vehicle using the average Californian electric power mix, thus providing tangible arguments against the narrow focus on full electrification of the vehicle (Interview at Volvo Cars, 2007). Another example is General Motors (GM) that responded as expected to the mandate, introducing the EV1, a ‘pure’ electric vehicle with a sporty image. A few hundred EV1 were leased to selected customers and when these vehicles after a couple of years were collected and scrapped by GM, it caused some debate and even a movie “Who killed the electric car?” (Woudhuysen, 2008). As expected, the Japanese manufacturers also responded with a limited introduction of electric vehicles, among them the Toyota RAV 4 EV and the Honda EV Plus, but they did also introduce some HEVs. Whereas Toyota was the first auto maker with a series production HEV, the Prius, Honda was the first one on the US market
with the Honda Insight. The Insight was a two-seater with a manual gearbox and a light hybrid topology named Integrated Motor Assist, IMA (Peter, 2004). Soon, deliveries of the Toyota Prius followed on the US market and partly because this vehicle was better aligned with dominating market preferences such as four seats and an automatic gearbox, it succeeded in selling in larger volumes. Honda’s next HEV was based on the same IMA technology but now introduced in an ordinary vehicle model, the Honda Civic (Honda, 2008a). Since the Prius, Toyota, on the other hand has another strategy and has mainly introduced hybrid powertrains in luxury high performance vehicles under the Lexus brand (GreenCarCongress, 2007).

Currently, there is a lot of interest in plug-in hybrids, i.e. vehicles with relatively large batteries that can be charged through a connection to the electric grid. GM has committed to deliveries of such vehicles, for example the Chevrolet Volt, within a few years (GM, 2008) and Volvo showed their ReCharge Concept in Frankfurt 2007 (Volvo Cars, 2007). Plug-in hybrids would be a significant step towards full electrification of the vehicle, as they are assumed to be driven on electric energy most of the time. The engine will probably only be used for trips longer than 50 – 100 kilometres and maybe also when heat for the passenger compartment is needed.

As outlined above, the logic of gradual electrification of the powertrain of the vehicles has not been followed in all parts, but when looking at the trend in general a pattern appears to be discernable. Honda is the auto maker that appears to be most consequent. The IMA hybrid offers almost the same energy efficiency as the full hybrid that Toyota uses in most vehicles, and it is probably considerably less expensive in terms of components. Now Honda is investing heavily in all-electric fuel cell vehicles with large field tests in among others California (Honda, 2008b). But in terms of impact on the market as well as the research community, the Toyota hybridization strategy has outperformed all other actors.

4. Addressing hybridization in different ways

In this section three different approaches to learning on hybridization will be briefly accounted for, via examples from Toyota, Volvo Cars and Renault. These examples are only single examples of different learning mechanisms but mirror how these companies have built competencies in this field.

4.1 Research method

Data on these three cases has been collected using multiple methods. We collected data on Volvo Cars though a case study research method (e.g. Eisenhart, 1989). 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 employed by 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. 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.
Data on the Toyota project (Itazaki, 1999; Nonaka and Peltokorpi, 2006; Williander, 2007 and the Renault project (Kiviat, 2008; Scheer, 2008) are based on secondary sources, complemented with two interviews at Renault and one at Toyota Europe. The data from Toyota and Renault is thus not validated by us but will rather be used as examples to illustrate the differences in approaches used by the different companies. A list of interviews can be found in appendix 1.

4.2 The case of the Desirée project at Volvo Cars

The Desirée project (Dual Hybrid Electric System for Increased Efficiency and Economy) started in October 1997 and involved approximately 20 persons from various departments. The objective was to develop two demonstration vehicles with substantially improved fuel efficiency that were to meet all regular emission and safety requirements and, apart from the powertrain, only contain standard components. It resulted in two demonstration vehicles 18 months later, using 40 percent less fuel than comparable cars. This remarkably high reduction was obtained through the introduction of a power-split hybrid propulsion system. No efforts were made to change the vehicle in other ways, for example by reducing the weight, streamline it to reduce air resistance or use low friction tyres. The technology demonstrated by the Desirée project was then further developed by the new owner Ford Motor Company and it is still used in the hybrid version of Ford Escape that was introduced to the market 2004.

The Desirée project was mainly initiated to test and demonstrate a power-split technology developed by the Japanese automotive supplier Aisin. It was a bottom-up approach without a clear mandate from top management. Much work was carried out directly in the workshop, partly because of a very tight budget and time schedule. Volvo Cars had a relatively strong HEV knowledge base to build on as several mainly series hybrid vehicle projects already had been carried out. This fact in combination with a strong reliance on technology partners such as Aisin providing the power-split device, Varta providing the nickel metal hydride batteries and Bosch the engine control module, made it possible to develop promising fully functional concept cars in 18 months.

Simulation and test driving were very important activities in the project, not only because the technology was new to the firm but also as the involvement of managers and other stakeholders as test drivers was considered a method to gain support for further HEV activities. Volvo Cars decided to show the Desirée vehicle at Geneva Motor Show 1999 but in the change of ownership that followed ensuite the project results were transferred to Ford, which took the lead of further development of the power-split hybrid technology (resulting in the launch of the Ford Escape). In recent years, Volvo Cars have launched a new hybrid centre, partly building on knowledge from the Desirée project and participate in several initiatives with partners and even competitors (such as the joint plug-in HEV project between SAAB, Volvo Cars and the Swedish energy company Vattenfall).

4.3 The case of the Prius project at Toyota

The Prius hybrid has received much attention and there are many things to learn from how Toyota has approached the field of hybrids (e.g. Itazaki, 1999; Magnusson and Berggren, 2001, Nonaka and Peltokorpi, 2006, Williander, 2007). If Toyota Prius is considered nowadays as a success, internal resource development and investments from Toyota shall not be underestimated. As the whole identity of the car and its architecture has been changed, the Prius is almost impossible to replicate, according to the experts. The knowledge and resource
base of the company is considered as a specific asset that is distinctive resource from its competitors.

Toyota’s project that led to the introduction of the Prius on the Japanese market late 1997 was strongly supported by the top management (Itazaki, 1999). One of the reasons behind the ambitious and in several aspects probably quite risky project was management’s perceived need to challenge the organisation and avoid “the curse of success” (Nonaka and Peltokorpi, 2006:93). Among the factors contributing to a risky profile were the decision to develop all new hybrid technologies in-house (Itazaki, 1999) and the methodology to focus on technological viability, and only as this goal was achieved change to cost reduction (Magnusson and Berggren, 2001). A minimum of prototypes and no back-up alternatives also contributed to the risk. It was “an extreme challenge for the senior engineers” (Williander, 2007:208). The project management was situated in the “red carpet room” separated from the rest of the R&D organization and simulation and tests were core issues in the project and test vehicles totalled five times longer distances than development of other new vehicles normally requires (Itazaki, 1999).

The initial production volume of 1 000 vehicles per month was soon doubled (Nonaka and Peltokorpi, 2006) and towards the end of 2007 an accumulated total of over 800 000 Prius vehicles had been delivered (GreenCarCongress, 2007).

4.4. The case of the Better Place project at Renault

In January 2008 it was announced that Renault-Nissan had signed an agreement to begin mass-producing electric cars together with a project in Israel, the Better Place project. The aim is to develop electric cars that have a driving range of 100 km driving in the city and 160 km highway driving and have a 110 km/h top speed. Israel was chosen since 90% of Israelis drive less than 70 km per day and all major cities are within 150 km from each other. The battery is being developed by NEC to be available in 2011 (Scheer, 2008). Renault has announced that the goal is to mass produce and sell electric cars in Israel by 2011 and also in other countries in Europe by 2012 (Renault homepage, 10/04/08). In March 2008, it was also announced that the project had signed an agreement with Dong Electricity to develop a similar infrastructure in Denmark (Lampinen, 2008).

The Better Place project was initiated by the entrepreneur Shai Agassi aiming at reducing oil dependency through building an electric vehicle infrastructure in Israel. The infrastructure is to be built on recharging points in the streets complemented by battery-swapping stations all over the country (Makeower et al, 2008). A pilot involving a few dozen cars will be launched during 2008 in Tel Aviv and a few hundred vehicles are expected to be on the road by 2009, with production scaled to the mass market by 2011. Early 2008, Israel slashed the tax rate on cars powered by electricity down to 10% in order to encourage consumers to buy such vehicles once they are available (Kiviat, 2008).

The Better Place project is a limited, initially small scale experiment very different from previous attempts with large scale public-private partnerships for electric vehicles in the 70’s in France (e.g Callon, 1980). Building a subscriber based ownership model this project is challenging one of the dominant logics of the car industry. A manager at Renault compared the Better Place project with the initiative Toyota took on the HEVs but said also that the uncertainty lies in the cost of batteries: “Asking people to buy an electric vehicle] “is like asking customers to buy fuel for the next ten years up front. We need another business model” (Interview Renault, 2008). Renault is part of the project for two reasons according to the interviewee, to learn on the technology but also to learn on the usage of the electrical car. The
main role of the car company is the role of integration both for the physical product and the software – designing the best compromise between performance and consumption.
5. Developing innovation through learning mechanisms

Using these three examples of learning mechanisms we will revisit the learning mechanisms described in literature on the automotive industry, then highlight some emerging learning mechanisms and finally address how they contribute to the building of innovative capabilities.

5.1 Classical learning experiments

In terms of prototyping, simulations and tests were crucial parts of both the Desirée and the Prius project, partly as the technologies were new and several different components and subsystems had to work together. It was also stated that simulations contributed to the short development time in both cases. The Desirée project at Volvo Cars resulted in two vehicles for test driving and demonstration, and, as the car was selected for the Geneva Motor Show, it also became an official concept car. In the Better Place project, early prototypes have been rapidly developed by Renault to test its properties and set requirements for mass production. The Toyota Prius is a good example of a narrative that has spread throughout the industry - a recently translated book also tells the details of the development work (Itazaki, 1999). People in industry often use the Toyota case as a reference case for having done the good strategic choice in terms of the hybridization. Renault has a link on its webpage pointing at the Better Place project homepage where interested people can follow each step in the project. The project also seems to have a strong media strategy, launching press releases and keeping a blog on news and events (www.projectbetterplace.com). The Desirée project has a reputation internally at Volvo as a success story that confirms the technology proficiency of the company, but it is not a story that is known to a wider audience.

In the case of the Volvo HEV project, the skunk profile contributed to a project with very limited administration and a tight project team. As the Desirée was used as a main message at the Geneva Motor Show in 1999, and as the team spent a lot of time involving managers and other stakeholder in the test driving of the demonstrators, the results were acknowledged by the rest of the organisation. It thus managed to avoid the risks often occurring when separating the more explorative activities from the core business, a set up that might lead to isolation and resistance against the ideas that are developed (Birkinshaw and Gibson, 2004; Moss Kanter, 2006). The Prius was not a skunk project; it rather had a strong top management support from the beginning, but was kept separated from the regular R&D organization. The Renault project also has a strong support from top management and CEO Carlos Ghosn can be seen on a photo with entrepreneur Agassi on the project homepage.

Partnerships are handled differently in the three examples. In the Desirée case, the partnership with technology partners was a key to the project success. Aisin was the main partner, supplying transmission and motor drives, but the relations to Varta for the batteries and to Bosch for the engine control module were also critical. Toyota had a different approach as they developed all technology in-house, convinced that this was the best learning strategy. In the Renault project, the partnership with the Israeli project has provided a strong platform for learning on both technology and customer uses. Furthermore, the success of the electric cars depends on the partnership with NEC on the battery technology.

In terms of customer involvement, the projects are all technology driven rather than involving customers in early stages of development. Customers are rather used in the final phases, reviewing the Desiree concept car, testing the Prius (at first release on the Japanese market) and they will also provide input to Renault once the electrical cars are released in Israel. All these projects thus contain parts that are quite conventional in the automotive industry, see summary in table 1.
Table 1. A summary of classical learning mechanisms represented by the projects.

<table>
<thead>
<tr>
<th>Project</th>
<th>Prototyping (virtual/physical)</th>
<th>Narratives</th>
<th>Skunkwork</th>
<th>Partnerships</th>
<th>Customer involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desirée</td>
<td>Demonstrators, concept cars</td>
<td>Internal success story</td>
<td>Protected from top mgmt in early phases</td>
<td>Important partnerships with Aisin, Varta Bosch</td>
<td>Only in final stage – Geneva motor show</td>
</tr>
<tr>
<td>Prius</td>
<td>Simulations</td>
<td>Reference case in industry</td>
<td>Supported by top management</td>
<td>Main development internal</td>
<td>Test market in Japan.</td>
</tr>
<tr>
<td>Better Place</td>
<td>Prototypes</td>
<td>Public site following development</td>
<td>Supported by top management</td>
<td>Partnership with Better Place project and NEC.</td>
<td>Test market in Israel.</td>
</tr>
</tbody>
</table>

5.2 New learning mechanisms:

Some learning mechanisms not previously covered in literature on the automotive industry can also be noted in these cases. The hybridization is a major technology shift in the industry and it seems that the classical approaches to learning are no longer sufficient. Some authors have argued that we are now in a context of intensive innovation where the identity of the object itself has become unstable (Le Masson et al., 2006) thus urging companies to redefine not only the product but also the values and the competencies of the firm to build innovative capabilities (Hatchuel et al., 2003). The high uncertainties (in all aspects; technology, market, customer preferences, regulations etc) make it difficult to develop all the needed competences in-house and companies are forced to renew also their learning processes.

One interesting aspect of the Toyota Prius project is that Toyota performed a full-scale market experiment using the Japanese market as a test before deciding if the technology shall be exported to other countries (which it was, in a refined version some years later). The Better place project in Israel is doing a similar thing, experimenting not only on technology and related usage, but also on the business model – redefining the ownership model. These market experiments seem to be another way of learning in more innovative situations. As mentioned earlier, the GM EV1 case also involved the customers in a relatively large extent. GM’s and Toyota’s experiments on the market produce massive learning but they are also very resource intensive and risky (as the bad-will from the EV1 case illustrates).

Also, new forms of partnerships can be seen, where uncertainties are much higher than in traditional alliances and partnerships. This has been called exploratory partnerships (Segrestin, 2005) – in such partnerships interests and the common purpose are discovered in the course of action, instead of defined initially. The more exploratory the partnership is, the more reciprocal commitments and contractual arrangements have to be managed to guide the learning process (Segrestin, 2005). For instance, in Sweden, so called distributed research centres have emerged where competitors come together at a neutral platform to grow competence. For instance, Saab Automobile collaborates with among others Volvo Cars in three such HEV related centres: Electric machines, Battery technology and Hybrid systems (Interview, Saab Automobile). In the three projects, the case of the Better Place is a clear example of an exploratory partnership – Renault could not define in the initial stages what the outcome would look like, but they are developing the value to offer and reinventing ownership models and thus also their own role in the mobility system.
Finally, there is an interesting mechanism around brands, a kind of brand value experiment. In the case of Toyota it is clear that the brand has been transformed due to the success of the Prius. The values of other brands have also been influenced by the lack of initiatives in the HEV area. GM argues that their image loss in terms of reduced sales were huge and the current testing of their plug-in hybrid VOLT is partly driven by the fear of not developing the right knowledge – according to Bob Lutz “GM won't make that error again, even if it means losing money on initial Volt sales” (Detroit News, 2008). Recent launches of different types of eco-labels is another phenomena in this area – for instance, Renault launched their Eco2 label in May 2007, signalling green production, recyclable materials and low CO2-emission levels. For Renault it is a way of communicating with the customers, of helping them make a more informed choice when buying a car and to put forward the work on environment that they are doing: “Before, we were the bad guys. We did not at all communicate on the environment – we lagged years. We needed to create our discourse” (Interview Renault 2008). An interesting aspect of this is that the development of labels is a way of putting forward the performance criteria to be used for eco-cars.

5.3 The impacts of learning mechanisms on innovative capabilities

In literature, it is argued that learning is a critical part in innovation (e.g. Lynn et al., 1998) and that learning can be managed in a long-term perspective, through repeated innovations (see Penrose, 1960, Hatchuel et al., 2003) and through learning between projects (e.g Maidique and Zirger, 1985; Rothwell and Gardinger, 1989). It has also been argued that to be innovative, companies need to manage learning strategies (Hatchuel et al., 2005). These learning strategies are then put into action through different learning mechanisms.

In this paper, the mechanisms that companies use as part of their learning strategies are discussed. The analogue of the double loop learning (i.e. changing the underlying logic) is valuable in this context of hybridization since it is an innovation field where not only the technology is radically different but where there seem to be a destabilization also of the market, customer use and the business model. To be able to explore this new area, companies need to develop both learning strategies (how to develop knowledge to be able to launch a hybrid) and the learning mechanisms that will help them reach their goals in a stepwise process of knowledge generation.

Two of the case projects, the Toyota Prius and the Ford Escape hybrid, have resulted in products on the market. The outcome of the Better Place project for Renault and other involved partners is not yet possible to depict. Toyota is the undisputed leader in the HEV market and the heavy investment in HEV technologies is now used in a portfolio of different products, all having a quite high profile. This reuse of HEV knowledge in a lineage of innovations (Le Masson et al., 2006) helps Toyota to maintain a dominating market position. It has also been stated that the project has generated a spill-over to the Toyota brand, rendering it an improvement towards high-tech and clean-tech. To state that the HEV learning strategy also has contributed to the growth of Toyota, now being close to over-taking GM as the world’s largest auto maker, would however be a bit speculative. The direct impact of Volvo Car’s Desirée project is not so easy to describe as the firm still has no HEV on the market. A clear spill-over however is the Ford Escape hybrid, which is partly based on the Desirée project. In the Renault case, the involvement in the Better Place project contributes, at this stage, to the positioning of Renault as a firm that engages in innovative ventures with a clear common good environmental dimension. In a longer term perspective it builds their knowledge not only on electric cars but also on the use and the potential business models to develop.
6. Conclusion

This paper aimed at discussing how different car manufacturers have used different learning mechanisms in their aim for developing HEVs. Addressing a disruptive innovation, such as hybridization, have also led to the emergence of new learning mechanisms in the industry, namely market experiments, exploratory partnerships and brand value experiments.

The hybridization in the automotive industry constitutes an interesting example since all companies are all forced to revisit the knowledge areas that have been linked to the dominant design of the car for a very long time. It seems that Toyota managed to develop a learning strategy very early where they have invested heavily in generating all the knowledge in house, using traditional learning mechanisms. Other firms have used less resource intensive strategies, learning step-by-step with partners, such as in the Renault case and the Volvo Cars case. Until a new dominant design of electric hybrid cars or pure electric cars, is developed, the focus on knowledge generation remains crucial.
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## Appendix 1 - Interviews

### Automotive firms

<table>
<thead>
<tr>
<th>Date</th>
<th>Company</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 2008</td>
<td>Toyota Europe</td>
<td>Marketing Manager</td>
</tr>
<tr>
<td>February 2008</td>
<td>SAAB Automobile</td>
<td>Senior R&amp;D Manager</td>
</tr>
<tr>
<td>February 2008</td>
<td>Volvo Cars</td>
<td>Marketing Manager</td>
</tr>
<tr>
<td>February 2008</td>
<td>Renault</td>
<td>Technical Manager</td>
</tr>
<tr>
<td>November 2007</td>
<td>Renault</td>
<td>Marketing Manager</td>
</tr>
</tbody>
</table>

### The Desiree case study

<table>
<thead>
<tr>
<th>Informant category</th>
<th>Number of interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desirée team member or leader</td>
<td>Five respondents</td>
</tr>
<tr>
<td>Manager at Volvo Cars</td>
<td>Seven respondents</td>
</tr>
<tr>
<td>HEV specialist at Volvo Cars not involved in Desirée</td>
<td>Two respondents</td>
</tr>
</tbody>
</table>