Project-based learning patterns for dominant design renewal: The case of Electric Vehicle

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Received 30 July 2009; received in revised form 15 October 2009; accepted 20 October 2009

Abstract

The increasing environmental concerns call for deep renewals in existing technologies and traditional design solutions in many industries. Electric Vehicle (EV) is emblematic of such a radical shift. Based on case studies and an action research within an on going project, this article analyses how project-based learning can question such a dominant design. After a brief history of past EV failures, we focus on what should be addressed to prevent the current projects from being just another bubble. We characterize the four projects-based learning patterns experimented in the 1990s and 2000s: concept car projects, derivative projects, vanguard development projects, and multi-projects concurrent programs. We analyse how the last two project-based learning patterns succeed to address the dominant design renewal challenges. We demonstrate that they develop different linkages between innovative projects and permanent departments of the firms. We show that multi-project concurrent program reduces dramatically the deployment lead-time of the new industrial paradigm.

Keywords: Electric Vehicle; Projects and programs; Organizational learning; Innovation management; Radical innovation; Sustainable development; Auto industry

1. Introduction

Environmental concerns call for deep renewals in existing technologies and traditional design solutions in many industries. The purpose of this article is to analyse how to renew a dominant design through projects. The empirical context we study is the automotive industry, an emblematic example of a heavy dominant design of the Internal Combustion Engine (ICE). Electric Vehicles (EV) or Hybrid Vehicles (HV) are challenging this dominant design. Although they are not totally new technological options, the numerous past attempts to introduce them as a competitive mass-market option have failed for nearly a century. Is the ongoing EV/HV revival just another occurrence of a “permanently emerging technology” syndrome, as characterized by Fréry (2000)? Or is it, at last, the beginning of a large scale roll-out of EV?

The literature on strategy has emphasized the importance of the dominant design concept to understand innovation trajectories on product as well as technology. A dominant design is embedded in product architecture, technology, usage specifications through regulations as well as design rules, customers’ practices or performance criteria. Utterback (1994) showed that dominant designs create collective patterns which facilitate the development of sustaining innovations and increase the value of previous investments. Therefore, breaking the dominant design has to be analysed not only as the result of a competition between fuel efficiency and alternative technologies, but as a deep renewal of the path dependant track including customers practices and values, designers competences, ecosystems perimeters, regulations, etc. To make an analogy with the analysis made by Kuhn (1963) of the scientific field, escaping from the dominant design can be seen as an industrial paradigm shift.

This implies analysing these shifts in terms of learning processes within the organizations and social contexts.
Our theoretical framework is based on literature on project-based organizational learning. This framework enlightens the learning routines and processes between the projects and the permanent organization: from the organization to the projects, within the projects, from one project to another, and from projects to organization of the firm. We use such a framework to analyse EV/HV projects in the 1990s and an ongoing European project. The comparison reveals very different project-based learning patterns, and significant differences in terms of scope and lead-time of the renewal process.

This paper is based on a methodology combining ex-post case study with longitudinal analysis of projects through an interactive research with Renault-Nissan, an OEM which develops an ambitious project on Electric Vehicles.

In the first section of this paper, we will define our theoretical framework and methodology. The second section will present the domain of electric mobility. After drawing a brief history of past ventures on the domain, we will focus on the key success factors preventing the contemporary attempts from being just another bubble. Then we will present in the third section the project-based learning patterns that firms experimented in the 1990s and 2000s in the domain. We will distinguish four different project-learning patterns: concept car projects, derivative projects, vanguard development projects, and multi-projects concurrent learning programs. The last section will compare how these different project-based learning approaches can meet the dominant design renewal challenge.

2. Theoretical framework and methodology

Since the mid-1990s, Lundin and Midler (1998) have emphasized the key role of projects in organizational learning and renewal processes. Learning within projects, learning from projects and cross projects learning have been identified as various complementary processes to implement deep transitions in firms as well as in public organizations. Ben Mahmoud-Jouini (1999) proposed an integrated model to grasp the links between product projects and learning processes within the design system of the firm. Then, Ben Mahmoud-Jouini et al. (2000) proposed a refinement which articulates the product project management, the competences creation and the strategy formulation process. In the same perspective, Frederiksen and Davies (2008) proposed a model of “Project Capability-Building” which occurs when a firm moves into a new technology and/or market base. The model focuses on the dynamic sequence between bottom-up project-led learning process and top-down business-led learning process which fully refines, exploits and expands the firm’s organizational capabilities and routines for a better execution performance. Brady and Davis (2004) addressed the important question of dedicating “vanguard projects” to breakthrough innovations that can be incorporated in the firm’s routines in a dynamic exploration to exploitation process.

Building on these project-based learning stream, Beaume et al. (2009) proposed an analytical framework to compare the innovation management practices within car makers. Fujimoto and Clark (1991) studied this new industrial context which lead, according to Midler (1995), to a “projectification” of the companies. Innovation management therefore appears as the interplay between product development projects and feature as technology projects (Beaume et al., 2009). Chapel (1997) emphasized the role of lineage management. LeMasson et al. (2006) analysed the organization of the cumulative learning processes through product lines.

Electric Vehicle analysis implies to extend this framework to a quite heterogeneous typology of projects. OEMs have addressed electric challenge through different patterns, from breakthrough concept cars or exploratory projects studied by Lenfle (2008) to development of electrified existing vehicles. This paper will compare these project-based learning patterns in their capability to escape from the Internal Engine Combustion dominant design system.

The research design is dual. First, a literature review on EV/HV projects, which had been launched in the 1990s and early 2000s. Second, an ongoing collaborative research with Renault on a major EV project started in early 2008. The researchers participate to weekly meetings of the project. They feed back their analysis every 3 months in research comities involving EV project director and high executives of the firm, from Strategic Planning, Research and Advanced Engineering departments.

3. Learning dimensions for a competitive mass Electric Vehicle development

The current context creates an opportunity for development of electric mobility. Will the ongoing attempts succeed in turning into a competitive mass-market alternative? To answer this question, we first make a brief history of past EV (unsuccessful) endeavours. Then, we point out the key issues that need to be addressed in order to escape from the Internal Combustion Engine dominance.

3.1. A brief history of Electric Vehicle

In the automotive history, EV/HV stood as a valuable option for more than a century, even if it lost the competition for automobiles mass-production at the beginning of the 20th century. The first EV appeared during the middle of 19th century and the famous « La Jamais Contente » was the first vehicle in history reaching 100 km/h (1899). At the end of the 19th century, a tough competition opposed EV, Internal Combustion Engine (ICE) vehicles with other concepts (steam, fuel cell, compressed air, etc.). During the 1890s, the first OEMs selling EV appeared, and from that time to the 1910s more than 20 OEMs competed on the EV market. Nevertheless, this number decreased to nearly zero during the 1920s, and remained marginal since. As a consequence, EV never benefited from...
any economy of scale: ICE vehicle began its large diffusion with Ford T (180,000 produced in 1913). The same year, only 6000 EVs were produced in the US. Moreover, EV lost in 1912 one of its main competitive advantages with respect to ICE vehicles: Cadillac began selling ICE vehicles equipped with an electric starter. These reasons explain why, at the beginning of the 20th century, EV began a decline. At the end of the 1920s, Hybrid and Electric Vehicles nearly disappeared. ICE became the standard of the automotive industry, which does not mean EV disappeared from the minds of men during the 20th century.

At the beginning of the 1960s, the researchers’ community felt fuel cells were very promising to store energy for EV, instead of lead batteries. Callon (1980) proved that the idea of fuel cell EV was strongly supported in the 1960s. An illustration is the data provided by Nicolon (1977) on public funding allocated by French State on fuel cells research: more than 26 millions of Francs¹ in less than 8 years. But this option quickly reached deadlock, and did not rebound on other markets.

During the 1970s, the two oil crises forced industrialised countries to stimulate energy savings. As a consequence, there have been several attempts to introduce EV between the mid-1970s and the mid-1990s. Fréry (2000) illustrated it by collecting data on several predictions made at different times by American institutions that tried to model an EV roll-out (see Fig. 1). Griset and Larroque (2006) noticed similar attempts in other countries.

All these different periods of “excitement” had rational motivations: high price of crude oil, at a time of growth for the nuclear power generation. Despite these projections, no take-off of EV market was achieved at that time.

During the 1990s, several countries, especially France and California, revived EV. In France, PSA and Renault introduced several EV models, adapted from their ICE vehicles. For example, PSA sold more than 10,000 units of its Peugeot 106 and Citroën Saxo, launched on the market in 1995. As sales proved to be low, they decided to abandon EV at the beginning of the 21st century. In California, EV had a similar destiny, but for different reasons. In 1990, the state of California created a legislation to create incentives for car manufacturers to sell at least 2% of zero emission vehicles by 1997, and then 15% in 2003. Pilkington and Dyerson (2004) showed that the mandate was gradually reduced, thanks to intense lobbying by OEMs, until it finally disappeared in 1998.

Analysing this EV history, three different key issues appear to be addressed to successfully overcome the pitfalls of previous attempts.

3.1.1. Achieving high “product integrity” for EV

For years, the dominant approach on EV/ICE competition was to cluster the problem on efficiency of specific electric component, for instance regarding batteries, as illustrated by TheEconomist (1997). The traditional available auto battery was based on lead acid technology. Even if cost competitive, the lead acid batteries never allowed satisfying autonomies (50 km). Until the 1990s, the automotive industry could not hope for some technology transfer because no other industrial sector was pulling for the development of mass-market, high-energy density batteries. Now the context is different. Consumer electronic devices led to large scale production of high-energy density batteries. Hybrid Vehicles market has also pulled the development of new automotive oriented batteries.

These components achievements are not enough to reach EV efficiency if they are “plugged in” a traditional ICE based vehicle. Electrification of ICE vehicles led to rather poor results. Such option embeds both the constraints of ICE and EV on one side, but do not value the specific advantages of electric motorisation on the other. To achieve EV “product integrity”, as defined by Clark and Fujimoto (1990), OEMs need to deeply revise the product architecture to adapt to new constraints (especially the battery location). They need to rethink the performance criteria, which drive the technical design choices on nearly every component of a car. For example, energy consumption is a key performance for EV as it has an immediate impact on vehicle autonomy. Thus redesigning more energy efficient lighting or heating is a key aspect of EV project.

The whole design system has thus to be reoriented on the new electric mobility paradigm. How to achieve such a migration while continuing to develop ICE cars, which will remain for years the core business of the auto industry?

3.1.2. New market strategy for electric mobility

Many authors who studied breakthrough innovation challenged the traditional technology competition paradigm. Bower and Christensen (1995) show that successful disruptive technologies generally do not over-perform the existing one on established performance parameters but generate breakthrough performances on new value parameters. Kim and Mauborgne (2004) characterize the “Blue

¹ One million of francs of then was 200 times the typical annual income of a worker.
Ocean” innovation strategies as a way to avoid the risk of frontal competition with strong incumbent and rival products but to gradually set up a strategy to create an uncontested market space. Moore (1991) stresses the importance of constructing a specific dynamic for identifying the customers and usages, in order to progressively establish the new dominant usage from early adopter to mass-market. We argue that such results can be fruitfully applied to Electric Vehicle.

Actually, the frontal competition between the ICE and electrified products turns out to the advantage of the dominant design. Taking the key criterion of autonomy, ICE vehicles have always proposed a five times higher autonomy than EV, even in the late 19th century. Nowadays, this remains true: 150 km for EV with good batteries, whereas a typical ICE vehicle has at least a 700 km range. Therefore, only small niches of fans or constrained customers will choose these products that clearly are second bests in such “apple to apple” comparisons.

“Blue Ocean” strategy would suggest that a successful introduction of mass-marketed EV would require:

- A marketing focus on users who will not consider the maximum autonomy as a key problem. Thus, the limited usage has always been one of the main reasons why EV has never been mass-marketed. Such a focus leads to urban and periphery commuting mobility usage.

- A high quality mobility service to prevent customers’ reluctance to EV because of the risks attached to buying such an innovation: reduced autonomy, technical reliability and investment depreciation. Even today, this autonomy problem cannot be solved if the scope of EV is not extended from a single product to a full service of mobility, integrated in a network. Two of the main niche markets that existed for EVs in the past prove it. Large company fleets, like utilities or postal companies, adopted EV as an efficient solution through significant operational economic gains. Blosseville et al. (2000) studied the EV car-sharing services that were implemented in many urban contexts, as, for example in France the Liselec and Praxile large scale experiments at La Rochelle, and Saint-Quentin-en-Yvelines. Both proved EV attractiveness when associated with a well maintained service.

- A design focus to maximize the specific value domains where the innovation can successfully compete with the dominant design. Of course, energy saving and “green mobility” is a rising concern for many customers in western economies. But other values such as silence, smooth driving are criteria where EV successfully competes with ICE.

3.1.3. New business model for electric mobility

EV development needs heavy investments for specific technologies and new infrastructures associated with electric mobility. Financing such investments requires innovative business models and risk sharing in the emerging phase of the market. Previous experiences demonstrated that traditional approaches lead to a circular problem:

- On one hand, with emerging markets, EV attempts have been considered as derivatives from ICE products, in order to minimize the additional investment and risk, and leading to poor comparative value creation for customer.

- On the other hand, electric technologies and recharge network remained expensive because nobody dared to take the risk of significant investment; therefore, EVs have always remained expensive compared to ICE vehicles, thus leading to a low demand.

Ongoing public concern about “green mobility” creates new opportunities. Public authorities can be considered as a key player in the customer system, as collective environmental values are clearly an EV strength. Such a public third party could give EV a significant incentive before scale effects and productivity gains make EV a real competitor for ICE vehicles in terms of end-user total cost of ownership.

Development of mobility services can create new business model opportunity for EV as a platform in a two-sided market. Following Rochet and Tirole (2003), we can argue that such a perspective calls for new cooperative strategies with services operators and energy providers.

4. Project-learning patterns on electric mobility

Based on our analysis of the previous decade experiences and ongoing experiments, we identified four different project-based learning patterns used by OEMs to renew the ICE dominant design: concept car projects, derivative car projects, vanguard projects and multi-projects concurrent learning programs.

4.1. Concept cars projects

Backman et al. (2007) studied concept car development project, a well-known activity in the auto industry. The project aims at developing a single unit of a car which is not designed to be sold on the market. In the past decade, almost all the manufacturers developed electric ones.

On the technology side, the concept car is an occasion to test innovative architectures and features such as the “Tulip”, designed by PSA in the 1990s or the “i-real” by Toyota in the 2000s. But this learning remains limited because of the gap between a technology working on one vehicle and a technology suited for mass-production.

On the market side, the learning gained through such a project consists in feedbacks that the OEM can get from people visiting motor shows, or participating to focus groups. This can be useful to test the image of innovative concepts, but it does not bring any learning on the usage conditions.

Finally, concept car projects do not bring any learning on business model possibilities because these initiatives
are limited to one vehicle, therefore not representative of mass-produced and commercialized business model.

This first learning pattern thus provides limited learning on market and technology dimensions, and can be considered as a pattern suited for testing the feasibility or the appeal of innovative concepts. This pattern stimulates learning in advanced departments of the company, such as Research and Advanced Engineering, the challenge being to transfer this learning to vehicle development projects.

4.2. Derivative projects

The word “derivative project” is generally used in the automotive industry to characterize a new vehicle development project, which marginally changes an existing vehicle. In the case of EV, this kind of project uses an already-existing ICE platform, and replaces the engine and the tank by an electrical engine and a battery. This approach reduces the financial risk: with respect to a newly-designed vehicle, the development costs of the project can be dramatically reduced. This approach was used for example by French OEMs Renault and PSA as by Toyota, Mitsubishi and several other OEMs in the 1990s. Griset and Larroque (2006) showed that all these attempts were disappointing, even the most committed OEMs such as PSA, which produced more than 10,000 units, gave up.

On the technology side, this approach provided learning on the battery and electric engine technologies. Mass-production conditions revealed the actual performance of different technologies for these components. But the learning was limited to these two components, although the whole vehicle reused the components developed and optimized for ICE vehicles.

On the marketing side, this failure of this kind of project proved than the market for EV did not exist if it simply copied the classical automotive model. Nevertheless, these vehicles were also used to test car sharing or innovative fleet management systems: these tests proved the end-user value of such schemes, and suggested a way to enlarge the customer system for EV, through the involvement of the public authorities in the EV ecosystem.

On the business model side, many experiments using derivative EV where supported by local public authorities and the question of infrastructure was not fully taken into account by these projects.

4.3. Vanguard development projects

We identified a third learning pattern, based on the use of a “vanguard project”, concept introduced by Brady and Davis (2004), to initiate the learning process on a new vehicle concept. This has been used notably by Toyota in the 1990s, for developing HV, and has also been tried (unsuccessfully) by General Motors. Toyota started in mid-1994 the development of a HV vehicle, studied by Morgan and Liker (2006), by using a vanguard project named Prius I.

This vehicle was first marketed in mid-1997 then a second generation of Prius was developed and released in mid-2003, still on the vanguard pattern. This second generation Prius introduced a new version of the Toyota Hybrid System, with innovative features such as an “all electric driving mode”. After this first phase, the company started to roll-out this HV concept on several vehicle models, and marketed four new vehicles on two different segments of the auto market by the beginning of 2006. In 2008, Toyota (2008) established a specific engineering division for Hybrid Vehicle engineering field, and has gained a great commercial success with more than 1,000,000 sales in 10 years. In 2009, Toyota continued to enrich the HV lineage with new plug-in version for the Prius.

On the technology side, Toyota has used the vanguard project to reconsider all the engineering design rules. The use of a specific and dedicated new product development allowed it to design an HV well fitted with the overall concept of energy frugal vehicle: the aerodynamic of the vehicle is maximized thanks to an egg-shaped styling, the consumption of gasoline is minimized by the development of an engine with a specific thermodynamic cycle, etc. The company used the vanguard project to learn about the new HV architecture, and how to optimize it in accordance with the new constraints posed by the huge batteries space needed.

On the market and usage side, Toyota chose to dedicate a specific vehicle for its innovative concept: the vanguard Prius. According to May (2006), it has a very specific exterior egg-shaped styling and the company has emphasized new values brought by this vehicle, such as silence or eco-mobility, in order to prevent a frontal competition with ICE vehicles.

On the dimension of business model, the Toyota approach did not include any revision to the auto industry business model. Actually, the company is just beginning to tackle the question of infrastructure for EV recharge: it is testing a plug-in version of the Prius, and has partnered with several utilities to test such technology.

4.4. Multi-projects concurrent learning programs

In this section, we discuss the data from the collaborative research initiated with Renault and argue that this case reveals new learning patterns for managing renewal projects. First, we characterize the learning scope of the Renault Nissan EV project. We then we show that this learning happens through a revised coordination process between projects, Research And Advanced Engineering. Finally, we highlight the learning pattern of the EV program, which is managing the learning effort across the different EV projects.

4.4.1. Expanded learning scope within a project

This project is managing an enlarged learning scope, on the three key dimensions of vehicle technology, marketing and business model.
On the technology and vehicle side, the design process of cars is deeply reframed to minimize the energy consumption of car components. The firm adopted an original solution – named “quick drop” – to answer the autonomy challenge by quickly exchanging the battery of the EV. Knowing that such batteries weight at least 200 kg, such a solution called for a deep architectural redesign of the car, in order to fit easy plug in battery package: this is an architectural innovation as defined by Henderson and Clark (1990).

Moreover, the OEM does not focus only its design effort on the car itself but enlarges its design perimeter from the development of a product to the development of telematic services that will be embedded into the vehicle. The driver will use these services to manage its autonomy, the charging operations, etc. Then, Lenfle and Midler (2009) showed that this approach leads the OEM to open up the project to telecom and service providers.

On the marketing side, the EV project is testing a new market creation method. Although customers of the automotive industry are individuals (or fleet managers), here Renault–Nissan is shifting to a “customer system” approach involving public entities.

Second, it is reversing the marketing routines of the auto industry. Usually, an OEM develops mass-market projects and then explores the possible niche markets they can access, for example through derivative vehicles. In the case of the EV project, the OEM is choosing to learn on the opposite path: following the Burgelman and Siegel (2007) and Moore (1991), it first identifies all the possible niche markets, and creates what Burgelman and Siegel (2007) define as “minimum winning games”. Moore (1991) studied such strategies in the case of high tech. ventures. One distinctive feature of the EV case we observe is then that “bowling alley” strategy guides the EV strategy of the program, which is quite unusual for automotive industry.

Then, on the business model side, this EV project is reframing the business model of the whole auto value chain. The EV project introduces new relations. Traditionally, in the automotive industry, the business model of the OEM and the one of the gasoline supplier are completely decoupled.

Moreover, the OEM generally does not involve the stakeholders in its development projects. In the Renault case, it is exactly the contrary, because the OEM involves at least utility companies, electric mobility service providers, and public entities such as states or local authorities in order to value all the external effects related to the EV program.

4.4.2. Concurrent learning processes between projects and R&AE divisions

This enlarged scope of learning is proceeding through a quite unusual process involving the projects and the research or advanced engineering divisions.

In the automotive industry, as in many project-based companies, the innovation learning process within the company is usually sequential, starting from research or advanced engineering departments, which prepare innovative features. This knowledge is then implemented in product development projects in order to be valued on the markets. This learning path is usually very efficient in a dominant design context, and allows companies to prepare and mature in advanced innovative feature that can then be deployed across several lines of products.

On the EV case, Renault–Nissan is facing the renewal of the dominant design. The classical approach would have been to first reconfigure its Research and Advanced Engineering divisions to address the electric mobility learning challenges before getting involved into development projects. On the contrary, the firm chose a concurrent learning process between development projects and transition in technical permanent departments: the top managers of the company first decided to initiate projects, whereas the Research and Advanced Engineering divisions were not yet reconfigured (see Fig. 2).

For the company, this EV project is thus modifying the roles of both development teams and research or advanced engineering departments. Development projects are not only the recipients of knowledge created at R&AE departments, but they have to stimulate and favour the learning process at these departments. This call for intense coordination between these different entities, in order to manage the risk associated to such radical innovation.

4.4.3. Multi-projects concurrent learning program

A key problem in managing such concurrent learning processes is to coordinate the different time perspectives of actors involved. In order to meet the development project perspective, it is necessary to eliminate risky long-term breakthrough. But to meet the dominant design renewal challenge needs to explore beyond the short-term development perspective.

To address this problem, the firm adopts a multi-projects program approach that gives the opportunity to coordinate ambitious technological learning roadmaps with various lineage and generation of products.
5. Time to renewal: vanguard project sequence vs. multi-projects concurrent program

In the previous paragraph, we characterized four different project-based learning patterns. Our analysis shows that the first two patterns cannot address properly a dominant design renewal such as Electric Vehicle.

Concept car projects miss to address learning in business model as well as breakthrough in users’ mobility behaviour, which are key steps to reach the mass-market.

Aiming at minimization of the investment risk through important reuse of existing ICE platforms, Derivative projects do not create enough differentiating value to prevent or win a frontal confrontation with ICE dominant design. These 1990s unsuccessful trials anyhow led to an important learning. They revealed the necessity to enlarge the scope and radicalism of the innovation step to a deep redesign of the vehicle, a renewal of the classical business model and development of valuable mobility services targeted to specific customers.

The last two learning patterns implemented by Toyota on its Hybrid Vehicles and by Renault–Nissan on his Electric Vehicle program address this enlarged innovation challenge. They then appear as good candidates to escape from the dominant design trap of ICE vehicles.

In this last section our aim is to compare learning patterns 3 and 4, on the criteria of the renewal deployment speed.

The Prius case is typical of what Brady and Davis (2004) describe as sequential learning in vanguard projects.

In their analysis of the Toyota HV case, Morgan and Liker (2006) show how from 1993 to 1995 the project was thought as an extensive learning space aimed at “21st century car”, exploring various technologies and vehicle concepts. The Prius is then the result of the convergent phase, through an impressively fast 17 months vehicle development.

After this “within-project” learning phase, a “project to project” phase occurs from first generation of Prius to second generation. On the product and technology, Prius II introduces significant enhancements in terms of styling, driving and environmental performance. On the commercial side, this new project introduces a wisely targeted marketing effort in USA, where the scale of the program really takes off (see Fig. 3 below).

In the Toyota case, the deployment of the hybrid technology to the other products of the Toyota and Lexus brands occurs only after the second generation of Prius, through a third “project to firm” learning sequence.

Comparatively to this Prius vanguard project learning sequence, the multi-projects concurrent learning program implemented by Renault to address dominant design renewals looks promising both in terms of flexibility, risk management and time to market:

- First the learning scope is enlarged. Through differentiated projects portfolio, the firm can explore a larger variety vehicle concepts, related services, business models and customer targets.
- Second, the risk of the global program venture is reduced, compared to a single focused trial. Each project supports a focused and limited part of innovative risk, which facilitates its management. Flexibility in cross projects learning's from market feedback is enhanced, and so the global risk is reduced.
- Last but not least, due to permanent and tight links between Research, Advanced Engineering and Development departments, the dissemination of learning from project to permanent skill-based organization is occurring simultaneously with the implementation of projects, whereas it is sequential in the vanguard project learning sequence. This makes possible an anticipated coordination between technical roadmaps and the lineage deployment strategy through the EV program.

Fig. 3. The three generation Prius sales. (Source: Toyota)
To compare this two cases on the “time to renewal” performance criterion, we define three main milestones:

- **The “New Product Development launch” milestone:** When the company officially launches the new product development process for the 1st vehicle.
- **The “1st market launch” milestone:** When the firm markets the 1st vehicle.
- **The “roll-out” milestone:** When the company rolls-out the innovation at least on three segments.

Fig. 4 compares the resulting lead-times on the Toyota HV and Renault EV cases.

This comparison reveals a significant difference. Although the different learning approaches perform quite a similar lead-time for first reaching the market with their innovative product, they need very different lead-time to roll-out the innovation.

### 6. Concluding remarks

This article addresses the question of project-based learning when a firm or an industry has to renew a dominant design. We developed the case of EV, an emblematic case of such a transition.

We developed a framework to analyse project-based learning processes. Four different patterns have been characterized on this case: concept cars projects, derivative projects, vanguard development projects, and multi-projects concurrent learning programs.

We showed that the first two patterns could not succeed in addressing the important and various challenges of the transition from traditional Internal Combustion Engine vehicle to electric mobility. On the contrary, vanguard project approach, as exemplified by the Toyota Hybrid Vehicle project, and multi-project concurrent program, as exemplified by the Renault Nissan EV program, showed to implement deep and large scope of the learning. Our comparison of this two cases suggests that the lead-time to roll-out dominant design breaking innovations could be dramatically reduced by a concurrent multi-projects learning process. Such a result is due to the specific articulation of project pulled learning within Research and Advanced Engineering permanent departments, and innovation push generation of new products, according to the learning rhythm within Research and Advanced Engineering.

Such results can inspire many sectors, which are nowadays confronted to such transition necessity, according to the environmental constraints.

Finally, we want to highlight the main limit of our research. Some of the conclusions are derived from the analysis of the ongoing research on the EV project. Then, our conclusion related to the better time performance of concurrent multi-projects learning should be confirmed by the actual success of the project, which will happen by the beginning of the 2010s.

### Acknowledgment

We thank Remi Maniak for his fruitful comments on a previous version of this paper.

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