PLATFORM RE-USE
LESSONS FROM THE AUTOMOTIVE INDUSTRY

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ABSTRACT

Firms move from the management of unique projects to multi-project management based on a platform strategy that reduces lead-time and development cost, enhances reliability, allows mass customization and increases manufacturing flexibility. While the major challenges of the platform design have been highlighted, the management of the platform lifecycle was under studied. We address this missing point by considering the evolution of the platform during its life cycle. For that purpose, we have carried out a field methodology research at a car manufacturer six years after the successful setting of the platform strategy. We analyzed at a fine-grained level the development of a second generation product on this existing platform. Using a model that traces the design decisions taken during this development, we have identified that in order to reuse the platform over two generations, the engineers implicitly apply, besides the design rules that correspond to the very definition of platform strategy as presented in the literature such as the carryover and the lean design, a learning routine that challenges these rules. We designated this routine by "*smart reuse*" because it enables the reuse of the platform from one generation to another. We highlight the interplay between the products and the platform that co-evolve. We point out the reciprocal prescription relationships between the products and the platform. This co-evolution operates through two levels: between the product planning and the platform on one hand and the product development and the platform on the other. It has organizational implications that point out the central role of the Platform Director in the platform reuse. Eventually, we outlined the platform architecture issue, mainly its modularity, and its impact on the platform progressive renewal. This research that addresses the sustainability of the platform is exploratory: it reveals ideas that need to be validated and tested through other methods and in other industrial contexts.

Keywords:

Multi-project management, Platform Strategy, Modularity, Design rules, New product development, Reuse, Automotive Industry

Research paper and Case study

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INTRODUCTION

More and more, companies face the double challenge of replacing products at an increasing rate along with satisfying very diverse customers. These two requirements lead to the multiplication of new product development projects (Wheelwright and Clark, 1992; Cusumano and Nobeoka, 1998). In order to be competitive, the cost and time of these projects must be kept under control. Furthermore, the project teams have to innovate, in order to put on the market attractive products while keeping under control the underlying risks. Hence, competing in this context necessitates to move from a management of unique projects leading to "hits products" to the management of product families based on a multi-project management (Cusumano and Nobeoka, 1998). The platform strategy is one way to implement the multi-project management approach. One can find in the literature many different definitions for the platform. At this stage and in order to articulate our research question, we will consider a platform as a large set of product components with standardized interfaces that are physically connected as a stable subset of a larger product and that can be shared among different final products. The concept of building product families based on platforms to create variety economically has been widely accepted in the literature where several authors (Cusumano and Nobeoka, 1998; Muffatto and Roveda, 2000; Simpson & al, 2006; Jacobs *et al.*, 2007) pointed out the advantages of the modularization in general and of the platform strategy specifically. It reduces the lead-time and the development cost, it enhances the product quality and reliability, it allows variety and mass customization and finally it increases manufacturing flexibility. Adopting a multi-product approach based on a platform strategy has proved to be successful in many sectors: appliances (Meyer and Lehnerd, 1997; Worren *et al*. 2002), electronics (Sanderson and Uzumeri, 1990), software (Cusumano, 1991), automotive (Cusumano and Nobeoka 1998), etc. The question is not anymore about whether to invest in a platform or not but it is about the design of the platform. We believe that the literature misses a detailed analysis of the platform design process, its evolution during its life cycle and the interplay between the platform and the products reusing it. We intend to address these issues.

The major challenge of the platform design is to balance commonality and product differentiation: emphasizing the commonalities will reduce the design and production cost and delay as well while it will hamper the diversity of the products that will use this platform. According to Robertson & Ulrich (1998) the design of a platform is based on the preliminary planning of the range of products that will use this specific module or platform, since the design of a product is based on the "modular reuse" (Ettlie and Kubarek, 2008) of the platform and on the development of the differentiating components. Hence, one major challenge of the platform design lies in the optimal time span of the product planning. Indeed, in order to achieve the expected advantages of the modularization, the tendency would be to consider a long period of time during which the platform will be reused. But, this will hamper the mass customization and diversity, which are among the main objectives of the platform strategy. Furthermore, in dynamic competing environments, the product planning that generates the platform could be rapidly inaccurate. How to make possible the design of unplanned product on an existing platform? How an existing platform can host an unplanned product that will reuse part of the components platform?

These issues highlight the fact that the management of a platform lifecycle could be critical. By this we mean the management of the evolution of the platform after its initial design and introduction on a first family of products and its reuse for the next generation of products. Indeed the main part of the literature on modularity focus either on the adoption of this strategy and the analysis of the conditions under which it is efficient, or on the evaluation of this strategy once it was adopted. The analysis of the dynamics of the platform strategy is therefore under studied. We intend to address this missing point by considering the evolution of the platform during its life cycle, what we call platform reuse. For that purpose, we carried out a field methodology research at a car manufacturer six years after the successful setting of a platform-based organization. We analyze one moment during the life cycle of a platform consisting of the first phase of the development of a second-generation new product re-using this platform. This development raises question about the renewal of the platform, the management of its lifecycle and its architecture. While articulated differently, these questions were considered by Muffatto[1] (1999) as critical issues: (i) the relationship between platforms and the development of new ones, (ii) the number of models should be derived from a single platform, (iii) the expansion or reduction of platforms. We intend to contribute to the understanding of these open issues.

This analysis led us to the following result. Engineers implicitly apply during the development process of a product on a platform, two design rules that correspond to the very definition of platform strategy as presented in the literature: the carry-over (R1) that favours the commonality, and the lean design (R2) that avoids overdesign. However, the analysis of the development process of a product reusing the existing platform shows that these rules suffer many exceptions. We thus suggest that the reuse of the platform relies on the existence of a learning routine that challenges R1 and R2. We designated it by "*smart reuse*". We discuss (i) the organizational implications on the relation of the platform management with the strategic planning on one hand and with the project management on the other, and (ii) the impact on the platform architecture.

The paper is organized as follow. Section 1 reviews the existing literature on platform strategy and product design. In section 2, we present the research setting, the method adopted for the data collection and analysis. The pre-development process of a product on an existing platform and the underlying design thinking is presented in section 3. We then turn to the analysis and discussion (section 4) before concluding.

THEORETICAL BACKGROUND

From the platform design to the platform renewal

In an intense and dynamic competitive environment, the reduction of the product life cycle and the increasing variety of customer demands lead firms to offer a big variety of products with an efficient use of resources. For that purpose, they leverage investments in design and

[1] On the basis of his analysis of the platform strategy of the five major Japanese automobile companies

manufacturing by adopting modularity. Product modularity is the use of standardized and interchangeable components that enable the design of a wide variety of end products (Schilling, 2000). Product modularity is a multifaceted concept with little consensus on a stabilized definition. However, based on a review of the numerous definitions of product modularity found in the literature, Jacobs et al. (2007) suggest a common understanding about this construct: product modularity incorporates building blocks that can be combined to provide a comparatively large number of product configurations (Langlois & Robertson, 1992; Sanchez and Mahoney, 1996; Baldwin and Clark, 2000; Schilling, 2000).

One of these blocks is the platform. Muffatto and Roveda (2000) identified two types of platform definitions among the wide literature about this subject: (i) the production oriented stream of literature that stress the physical commonality paying more attention to the manufacturing and assembly process than to the other performances such as the lead time reduction and (ii) the multifaceted stream of literature represented, for example, by Robertson and Ulrich (1998) that consider a platform as "a collection of assets that are shared by a set of products". In this definition, besides the production and the logistics processes, the assets could be the development process, the project organizational structure and the knowledge.

According to Muffatto (1999), a platform approach is (i) a technical issue because it is related to product architecture, (ii) a strategic issue because it affects product development performances (reduction of cost and lead time and increase in flexibility), and (iii) an organizational issue because it affects product development and especially the coordination between the team platform and the advanced engineering activities.

Like modularity, platform strategy has to deal with architecture (Ulrich, 1995), standardization (Meyer and Lehnerd, 1997), mass customization (Worren *et al.*, 2002) and interfaces (Sanchez and Mahoney, 1996).

Platform strategy corresponds to the process of identifying and exploiting commonalities among a firm's products, its target markets and the processes for designing and producing these products (Meyer and Lehnerd, 1997). This strategy is an answer to the « fat design » phenomenon identified by Cusumano and Nobeoka (1998) and Fujimoto (1999) as the down side of the heavy weight project management organization. These authors pointed out that it is useful for firms to overlap the projects that share the same components: in that case the engineers can design components for more than one project. By coordinating chronologically overlapping projects a firm can transfer a design from a base project to a new one and facilitate task sharing among engineers as well as mutual adjustments and communication between the interdependent projects. They show that this approach is beneficial for both the speed and the effectiveness of technology leveraging between projects.

Several research have showed that implementing the platform strategy increases the launch speed of a new product developed on the platform by reducing the lead time, it reduces the development cost, it increases the quality by using pre-tested components and it enhances the variety of the products range (Sanderson and Uzumeri, 1995). The advantages of the platform strategy have been widely accepted in the literature. The question is not anymore about whether to adopt a platform strategy or not but about the design of the platform because many firms are adopting the concept with different interpretations and degrees of implementation.

The literature pointed out the importance of the strategic planning of the sequence of products that will be developed on the platform in order to design it. According to Cusumano and Nobeoka (1998), it is more efficient for companies to make advance plans during the platform development (or base project) for its future reuse. Robertson and Ulrich (1998) propose a structured process for platform design based on three plans: the product plan in a first place, than the differentiation and the commonality plans. It is on the harmonization of these three plans that the success of the platform strategy depends. Following these approaches, the platform may be regarded as a "planning tool" (Muffatto, 1999). However, this preliminary product planning presents some limits. Cusumano and Nobeoka (1998) pointed out that even with an advanced plan, "*it is difficult for engineers in the base project to predict problems future projects may have in reusing the platform*". Furthermore, this product plan could be ineffective in dynamic competing environments where a product plans change. In these industries, the period of time during which the product planning remain accurate becomes increasingly short and it is common to design products not planned when the platform was initially designed. This issue highlights the question of the time span for which a platform is designed, its evolution and the number of models that will be developed on the platform, etc. Will the platform generate a burst of products before being renewed or is this renewal progressive along the products developments?

New generation of products can either be based on an entirely new platform or a partial renewal of the existent platform. According Halman *et al.* (2003), a new platform is developed when basic architecture changes are necessary. Meyer and Lehnerd (1997) pointed out that long-term success and survival require continuing innovations and renewal. They analyzed the renewal of the platforms of HP in the printer business and proposed metrics to monitor the evolution of the platform (Meyer et al. 1997). For Halman *et al.* (2003) « *this is not a one-time effort. New platform development must be pursued on a regular basis, embracing technological changes as they occur and making each new generation of a product family more exciting and value rich than its predecessors* ». According to these authors, the partial renewal concerns one or more subsystems that undergo major changes in order to allow new features necessary for the second generation of products planned on the platform. This issue has been highlighted by Garud and Kumaraswamy (1995) "*in rapidly changing environments, (…) upgradability becomes important. If a system is not upgradable performance improvements may involve its complete redesign*". Simultaneously, several authors (Halman et al. 2003, Krishnan and Gupta, 2001, etc) pointed out the lack of indication in the literature on the moment when firms have to renew their platform. Hence, some authors address the renewal issue, but they do not specify how this evolution is managed simultaneously with the products development.

The number of models that should be derived from a single platform has not been addressed by the literature. Literature has focused mainly on the initial platform development that will generate enough derivative products to gain back the investment and less on the implementation of a succession of product families on a platform. A clear gap in literature exists when it comes to implementing successive product families on platform and we intend to contribute to fill this gap.

Product Design in a Platform-driven Environment

The leading principle in the design of a product on a platform is to decide which components of the product will be the differentiating elements and thus will be specifically designed for the product and not reused from the platform. This trade-off is strongly linked to the question of the product architecture, which is the way in which the components are organized and interact (Ulrich and Eppinger, 2004). Since the mid 1990s, studies of the interest and impact of modular structures have paid particular attention to questions of architecture (Ulrich, 1995; Baldwin and Clark, 2000). Platform design has also been the subject of many publications aiming mainly to propose methods to manage the commonality / differentiation dilemma by considering technical, marketing, industrial and economic constraints (Ulrich & Eppinger, 2004; Simpson & al., 2006). However, these studies pay relatively little attention to the design process of a product on an existing platform. It is as if it is perceived as not being fundamentally modified by the platform approach. Yet, as highlighted by Muffatto (1999), "*when there is a platform strategy, the development process must include the possible options that a platform can offer from its early stages*". This missing point is probably consistent with the static nature of these studies looking into the question of the design of the first-generation platform, i.e. starting from scratch (or almost). However, when seen from a dynamic point of view, the question changes. As Fisher *et al.* (1999) mention it, "*in most industrial situations, there already exists a portfolio of products and the managerial problem is to decide which components to re-use, which components to replace, which to develop. This problem is complex and deserves further research attention*" (p. 313).

Therefore we believe that there is a missing link in the literature. Indeed, when platform reuse becomes an important concern for designers and managers, the question of platform architecture, and specifically its modularity, could be fundamental. As demonstrated by the literature (Ulrich, 1995; Langlois and Robertson, 1992; Sanchez and Mahoney, 1996; Baldwin and Clark, 2000), modularity enhances the product flexibility by allowing designers to change some parts of the system without having to redesign the whole. It is thus possible to imagine a modular platform that will evolve according to environmental and technical changes on some of its parts, while being able to keep its core unchanged. This raised however two fundamental issues that we will keep in mind while studying platform lifecycle management, and therefore platform architecture:

- The design rules (Baldwin and Clark, 2000) that govern the architecture and the management of the platform;
- Most of the cases used in the literature on modularity comes from the electronics and computer industry which represents perfect examples of modular product architecture allowing the "*firm to accelerate its learning about markets by enabling the firm to leverage many different variations of a product [mix and match] more quickly and at reduced cost*" (Sanchez and Mahoney, 1996, p. 72). However the question of the transferability of this strategy to other kind of products remains open. Whitney (1996) for example, argues that some structural characteristics (e.g. high power transmission between components and systemic effects) of electro-mechanical products such as cars, planes, cameras, etc prevent them from being modular.

Our work contributes to addressing the question of product development in a platform environment when the platform already exists, what we call the platform reuse.

RESEARCH SETTING AND METHOD

In order to contribute to a better understanding of the life cycle of the platform and its reuse from a products generation to another, we decided to conduct a field-based study and to analyze the first phase of the development of a new product on an already existing platform in a leading European automotive manufacturer, Platcar (pseudonym), which adopted the platform strategy six years ago (1998). This strategy led to the reduction of the lead-time and cost of the developments and the increase of the models diversity compared to the performances of the firm before this strategy. Data were collected during 15 months (between April 2004 and July 2005). The method adopted for this research is an exploratory case study, which is the most appropriate method (Yin, 1994) to reveal or induce ideas that should be tested in other contexts and environments using other research design. The product development analyzed revealed issues about the renewal of the platform, its life cycle and its upgradeability. Below, we will present our research setting and the method employed for the data collection and analysis.

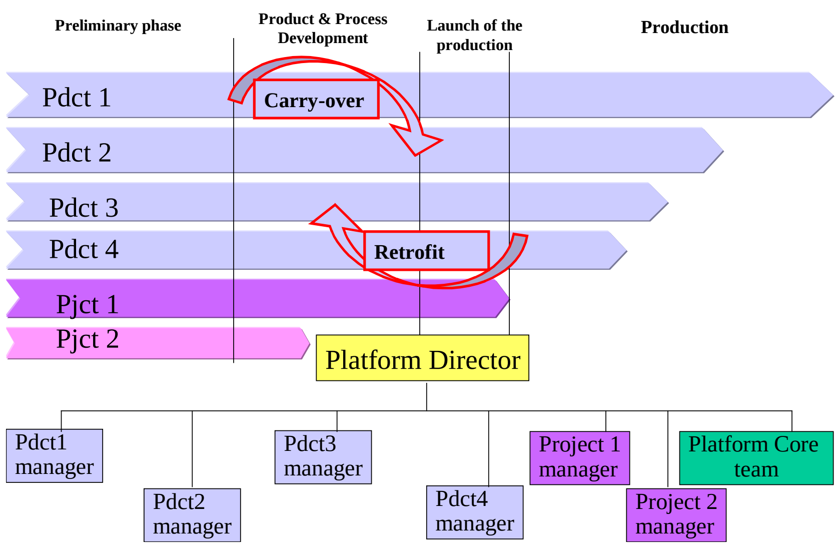
Research Setting

The automobile sector being one of fierce rivalry, the competitive advantage of car makers (OEM) resides in their ability to control development and manufacturing costs, to meet a variety of customer needs as efficiently as possible and to reduce development delays in order to replace models frequently. The impact of the new product introduction rate on market performance may be particularly great in the automotive industry because technology is improving steadily and customer expectations are fragmented and change at a rapid pace. Fresh styling and model introduction in addition to functional performances have a significant influence on sales (Clark and Fujimoto, 1991; Nobeoka and Cusumano, 1997). Furthermore, the platform strategy in the automotive industry has been studied by several authors such as Cusumano and Nobeoka (1998), Robertson and Ulrich (1998), Muffatto (1999), Becker and Zirpoli (2003).

Platcar is a medium-sized generalist OEM (200,000 staff and 3.5 million vehicles sold around the world in 2005). It is among the top three in Europe (14.5% market share) and the seven biggest in the world (5.5% market share). Since the end of 1980s, the automotive sector in Europe was marked by an increasingly intense and widespread price war, leading to severe pressure on OEM margins. In this context, Platcar adopted the project management principles as analyzed by Clark and Fujimoto (1991). It led to the strong empowerment of the project managers. But as described by Becker and Zirpoli (2003) at FIAT, by Fujimoto (1999) at Toyota and by Cusumano and Nobeoka (1998) at several other car makers, the increasing number of models, the growing complexity of coordination of the development tasks, the continuous pressure on costs and lead time and the difficulty to share and capitalize knowledge issued from developments projects challenged this strategy. Hence, in 1998 like many other OEMs in the world, Platcar structured its products around four platforms: one for small cars, one for medium, one for big and the fourth one is a platform in collaboration with a competitor. The platforms were not only a technical object combining common components to several vehicles, but correspond also to an industrial organisation as these vehicles are manufactured in the same plants. In this research, we focus on one platform: the smallest (referred to hereafter as PF) representing 34% of Platcar sales in 2005. Competition is particularly fierce in this market segment occupied by the main European generalist OEMs. Furthermore, in this company, this segment has always served as a pilot unit for implementing organizational innovations. Our choice of PF as a field study is therefore justified by the competitive industrial background in the automotive industry in general and the specific situation of PF in Platcar, as it can be considered as being ahead of the rest of the firm, in particular.

In order to achieve an efficient and effective multi-project strategy, simultaneously to the platform design, a specific organization was settled. Each platform was managed by a platform director who has the role of coordinating the current projects under development (crossover and carryover) and the life cycle of the products developed on the platform emphasizing the renewal of some components when neeeded (retrofit). For that purpose, the platform director has under his responsibility the project managers who are in charge of the new products developments, the product managers who are in charge of the continuous improvements of the existing products and a core platform manager who develops and maintains the platform. This core platform manager is in charge of a team composed mainly of technical engineers, plant and purchasing managers and cost controller. The core team is in charge of the constant fitting of the products developed into the platform. Each project manager has to focus on his specific car concept generation and implementation. He customizes the available technology to the product under development. For that purpose, he cooperates tightly with the platform core team. Each product manager interacts with the core team as well, because the feedback from the customers and the manufacturing could be integrated in the platform to benefit to the current and future projects. On the other hand, the modifications made by the core team to the platform may also benefit to the existing models by retrofitting updated platform components on the existing products. This enables the monitoring of the commonality components level, the improvement of the performances and the reduction of the costs (See Fig N°1)

Figure 1. The organization of the platform PF at Platcar



The platform director belongs to the engineering department that comprises, the technical divisions, the purchasing and the support functions (costing, quality audit, prototypes, homologations, nomenclatures). The technical divisions, the purchasing and the support functions provide the platforms and the projects with the skills, expertise and services (quality management, budget monitoring, IT and communication) required to achieve their objectives. The engineering department and the strategy department (in charge of the product planning) report to the CEO.

An evaluation study conducted by the firm in 2005 showed that in six years, the lead-time has been reduced by 17% (from 260 weeks to 215 weeks). The numbers of models tripled moving from one new model each 2,5 years to one model each 9 months: Platcar launched on PF (the smallest platform) 7 models in 5 years. The platform cost development represents 40% of cost development of the first model that was developed on the platform. For the following 6 models, the platform cost development represents 10% on average of the models cost development. The 90% remaining cost is relative to the development of the differentiating components and the upper body of the car.

PF was planned to be the basis for two product generations and hence should last about 10 years. However, six years had passed since the design of PF, and new requirements in terms of regulations and consumer expectations had emerged. These new requirements emerged form the analysis of the product planning of the second-generation products suggested by the strategy department and that are supposed to be developed on the existing platform. This could lead to the evolution of the platform. In order to analyse this evolution, we have chosen to focus on the development of one of these second-generation vehicles scheduled on PF.

The Platcar product development process comprises 4 phases: the pre-project phase ends once the market target has been specified and the main characteristics of the product defined. At this point, the project manager and his core team are appointed: this is the project launch. During the second phase that follows, this small team has to define the concept, the architecture, the style guidelines and the initial product specifications. This is followed by the third phase that freezes the style, the specifications and the suppliers. Finally, the fourth phase (the longest) brings the product design process to a close. We will focus more particularly on the first phase of the development process: the pre-project phase prior to the official project launch. The fact that the vehicle is being developed on the platform leads to the fact that a small team from the platform core team is appointed in order to analyze the compatibility of the product with the platform during this first phase. We will focus on the work of this team.

This research setting is particularly relevant to our research question, which is the reuse of an existing platform, its impact on the product development process and vice versa.

Method: data collection and analysis

Our research requires in-depth analysis of the designers' practices. To be able to analyze the development process empirically, we used a field-based methodology (Glaser and Strauss, 1967; Yin, 2003). As we've shown in the research setting section, the field was selected by theoretical sampling (Eisenhardt, 1989), meaning that it was not chosen for statistical reasons but because it was particularly relevant to the question of the product design on an existing platform. Hence, our findings are not universal and do not reveal any statistically significant phenomena. They shed light on the development of the product on an existing platform and by this way reveal issues about the platform reuse and evolution and its life cycle management. Our method relies on an inductive inquiry that generates theoretical insights from a single in-depth case. It is relevant because our aim is to provide new insights rather than to verify established theories.

The data was collected over a period of 15 months and were mainly composed of two types: (i) historical data such as the minutes of the quarterly platform meetings and the documents presented during these meetings covering 5 years since the launch of the platform in 1998 and (ii) fresh data created for the purpose of the research such as interviews and participation to design meetings that were held during the research duration (15 months). These data were gathered for one part by the researchers and for the other by two research assistants (RA) that were students in the last grade of a Master Degree in Engineering. The researchers conducted ten interviews with the platform director, the core team manager and the manager in the strategy department in charge of the product planning of this family. Each interview lasted almost two hours. The research assistants attended all the design meetings that were held within the platform core team during the research duration. They especially attended the meetings held by the members of the small team that were in charge of the compatibility analysis of the new product developed on the platform and of the analysis of the new requirements induced by the new regulations and the customers feedbacks. By being involved in these meetings, the RA thus had a wide access to documents and people. They were in close collaboration with the team in charge of the first phase of the design process. They conducted interviews with different members of the platform core team as well. The RA worked under the supervision of the authors: they met on a regular basis (once a month during all the research duration) and each time the RA asked for it as well. Regular meetings (every two months) were held involving the critical resources of the platform, the research assistants and the authors. The purpose of these seven meetings, that lasted two hours on average, was to validate the understanding of the phenomenon under study and to discuss the research progress. (See Table N°1 for an overview of the data sources).One of the authors had previously conducted a research over a period of three years on different but adjacent subject relative to the design processes in this firm. This past relation provided two strengths: (i) a stable relationship that secured the access to the data within the firm during this research, and (ii) a historical and accurate understanding of the management practices of the firm especially the design process. This previous knowledge of the firm and the design practices makes the interaction with the research assistants rich and enhances the reliability of the analysis they suggest.

Table N°1: Overview of the data sources and collection process

Source of data	**Number Frequency**
Interviews	
PF director	10
PF core team manager	
Manager in charge of the product planning of this family in the strategy department	
Pre-development team at PF	On a continuous basis
Meetings	
Design meetings involving the pre-development team attended by the research assistants	Monthly and when a specific question in raised
Research meetings involving PF director, PF core team manager, the research assistants and the authors	7 (every two months)
Research meetings involving the research assistants and the authors	15 (monthly)

During the interviews, the interviewees were asked to focus on the design decisions they take during the predevelopment phase of the product on the existing platform. During the meetings, the RA were asked to trace these decisions and to investigate the stakes and the impacts of each of these decisions after the meetings with the engineers. Considering their engineering background, the research assistants were able to understand the debates and the stakes of the discussions that occurred during these meetings. This approach is similar to the decision perspective adopted by Krishnan and Ulrich (2001), because it “helps get a glimpse inside the black box of development". Hence, the unit of analysis was the decisions taken during the very early phase of product development by the platform core team. In order to trace the design process, the authors and the RA used a design theory proposed by Hatchuel and Weil (2003) and called C-K model. According to these authors, the design process is the creation of new concepts from an initial one by adding or subtracting new properties. For that purpose, the designer mobilizes knowledge, either it already exists in the firm or it needs to be developed or acquired. Hence, this theory proposed a way to trace the design process by tracing this back and forth movements between the Concepts and the Knowledge.

During the interviews and the meetings, the authors and the RA focused on the type of knowledge mobilized and its origin (whether it already existed in the firm or was specifically developed for the design decision purpose). Hence, the knowledge was clustered into four categories as recommended by Strauss and Corbin (1998). Three are relatively traditional in new product development: technical knowledge (product and process engineering), market knowledge (meaning everything perceived by the customer such as style and performance, for example) and economic knowledge (aiming to maintain project profitability). A fourth category emerged from the analysis related to the reuse of the platform. It will be highlighted in the data presentation (next section) and analysed in the discussion section.

This way of representing the design process highlighting the design decisions, the movement between the knowledge and the concepts and the type of knowledge involved was not the one used in the firm. It is a grid of analysis adopted by the researchers. It represented a powerful tool of communication and was extensively used during the regular interactions between the engineers and the researchers. Using this grid, the researchers presented at several stages the design process to the informants (members of the platform core team) that commented and validated it.

Hence, in line with the paradigm of grounded research (Glaser and Strauss, 1967; Miles and Huberman, 1994; Eisenhardt, 1989; Suddaby, 2006), the analysis draws on interview notes, transcripts of meetings and company documents. Because qualitative analysis is an inherently dynamic, ongoing process, the authors conducted multiple readings of their field notes, the meeting minutes, and the documentation. They proceeded iteratively, such that the early stages were more open-ended than later stages. In addition, the authors remained open to both the use of existing theory and looked for evidence that might inform it, and any emerging constructs that might complete and enrich it.

As mentioned above, the orientation with regard to the data analysis is inductive, with the aim of generating insights into the platform reuse for a second generation product and the impact on the product and on the platform. Following this inductive approach, it appears that the engineers apply different types of rules in their design decisions. These "design" rules were confronted to the theory. This analytical comparison (Yin, 1994) showed that the development process revealed issues that not pointed out in the existing literature on product development. Considering these issues could be helpful to understand and put light on the reuse of the platform and its evolution during its lifecycle.

PRE-DEVELOPMENT PHASE OF A PRODUCT ON AN EXISTING PLATFORM

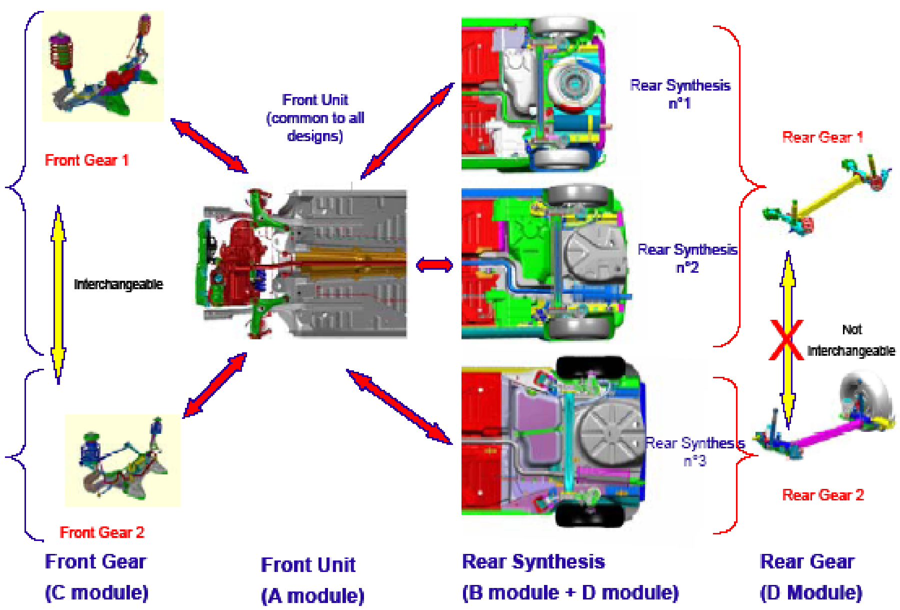
This section is divided in two parts: in the first part the data relative to the design process are presented. In the second part, these data are analyzed. The design decisions reveal issues that will be discussed in the next section.

DATA

In the following, the design decisions taken during the first phase of the project development called the pre-development phase held by members from the platform core team will be presented.

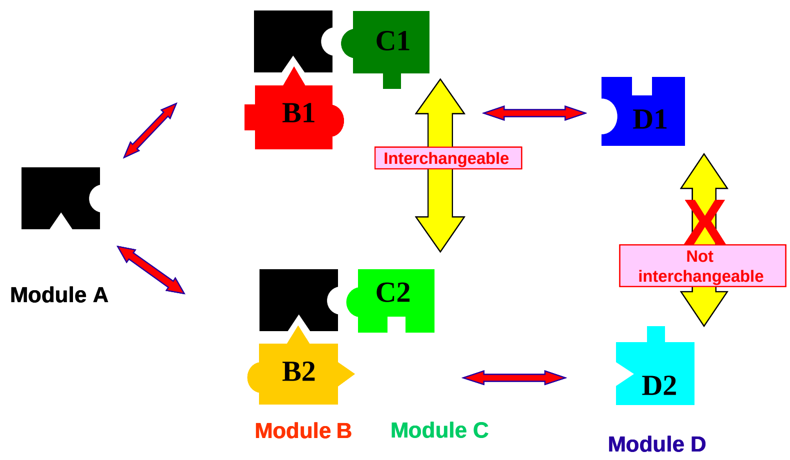
At the beginning of the research, seven models have already been developed on PF (the smallest platform of Platcar). At this moment, PF was composed of the engine area, the suspensions, the driver cockpit, the passenger compartment, the front unit, the front gear, the rear gear and the rear synthesis. Hence, PF represents 60% of the value of the vehicle and is invisible to the customer because it does not have a great influence on the silhouette (upper body) and the style of the vehicle. Note that this is not specific to Platcar because one can find more or less the same elements in other car manufacturers platforms (Simpson & al., 2006). For simplicity reason, not all the design decisions taken during the pre-development phase of the product on PF will be considered. The focus will be on the decisions relative to: the front unit (A), the rear synthesis (B), the front gear (C) and the rear gear (D). Figure N°2 shows the image of these modules.

Figure N°2 – Images of the modules of the platform considered



Except for A, these modules exist in different versions (B_1 and B_2, C_1 and C_2, D_1 and D_2) corresponding to different performances in terms of cost and functionalities. B_1 and B_2 are interchangeable. C_1 and C_2 as well. However, D_1 and D_2 are not. Figure N°3 shows the representation that we will adopt in the following: A, B, C and D, are represented by different geometric shapes. They are connected by interfaces, which are represented in the form of notches of varied geometric shapes. A is common to all the vehicles. The two versions of B (B_1 and B_2) are connected to module A via the same interface (represented by a triangular connector) because they are interchangeable. The two C modules (C_1 and C_2), are connected to module A via the same interface (semicircular connector) because they are interchangeable as well. On the contrary the two D modules (D_1 and D_2) that are connected to the B and C modules via specific interfaces are not interchangeable. D_1 goes with C_1 and B_1 while D_2 goes with C_2 and B_2.

Figure N°3 – Model for the part of the platform considered



The design processof the elements A, B, C & D are analyzed through the grid of analysis presented in the method section (Krishnan & Ulrich, 2001; Hatchuel & Weil, 2003). The design reasoning is thus analyzed as back and forth movements between the knowledge and the design options. The type of knowledge mobilized, either it already existed in the firm or was specifically developed on that purpose, is highlighted. As we mentioned it earlier, four types of knowledge were distinguished: technical (product and process engineering), market (meaning everything perceived by the customer), economic (aiming to maintain project profitability) and the reuse of the platform. The design process that occurred during the pre-development phase lasted almost one year. It is decomposed in three stages. Each stage will be presented and will end by a table that highlights the main design options considered, the decision taken at this stage and the knowledge used.

The First Stage

The decision to build the new model on the existing platform supposes that it is constructed starting from the front unit (A) that is common to all the cars on PF. The second design decision concerns the Rear Unit (B), which exists in 2 versions (B_1 and B_2): designers have to choose between A/B_1 and A/B_2. In taking such a decision, they favour the reuse of the platform and they mobilize the technical knowledge about B_1 and B_2. Considering this knowledge, it appears that on a given function, the performance of A/B_2 is excessive regarding the product under development. The characteristics of this product are specified by the product-plan provided by the strategy department. Hence, on the basis of the market knowledge, adopting B_2 will lead to confusion in the market segmentation. Furthermore, on the basis of the economic knowledge, adopting B_2 will lead to an overdesign. Hence, the option A/B_2 is rejected. The possibility of a new, lower-performance and cheaper module developed starting from B_2 is therefore envisaged (B_3). But this option is soon abandoned mobilizing the design rule “reuse existing part”. And finally the option A/B_1 is selected.

Design options	Evaluation of the module B	Design Decision	Knowledge mobilized
A/B_2	On a given function, the performance of A/B_2 is excessive regarding the product-plan provided by the strategy department	Rejected	Market knowledge: adopting B_2 will lead to confusion in the market segmentation. Economic knowledge: adopting B_2 will lead to an overdesign.
A/B_3	A new, lower-performance and cheaper module	Rejected	Market and economic knowledge
A/B_1		**Selected**	**Reuse platform elements rule**

Second Stage

The decision design then turns to the front gear (C) that exists in two versions (C_1 and C_2). The technical knowledge indicates that the two modules have different characteristics leading to different performances. Discussions therefore started with the strategy department that had planned this product in order to identify its performances regarding this functionality: market knowledge has to be developed. For manufacturing issues (technical and economic knowledge), the utilisation of C_1 seems problematic and necessitates further exploration. Besides that, if C_2 is selected, it goes only with D_2 that does not go with B_1 (technical knowledge). Technical studies are therefore launched to study the possibility of combining B_1 and D_2. Shortly thereafter, technical studies revealed that C_1 could not be used. It is therefore ruled out. As a result, the design selected is $A/B_1/C_2$.

Design options	Evaluation of the module C	Design Decision	Knowledge mobilized
$A/B_1/C_1$	What are the performances of this product planned by the Strategy Department regarding the functionality monitored by C?	Rejected	Technical knowledge: C_1 could not be used
$A/B_1/C_2$		**Selected**	**Market knowledge and Reuse platform elements rule**

Third Stage

The stake is to specify the Rear Gear (D). The reuse of the platform rule leads to the utilisation of either D_1 or D_2.Technical knowledge shows that D_2 is not technically compatible with B_1. The design [$A/B_1/C_2/D_2$] is therefore ruled out. The design of a new module D_2* that is compatible with both modules B_1 and C_2 is envisaged leading to [$A/B_1/C_2/D_2$*] combination. But this possibility costs a specific development. In order to avoid this considering the reuse platform rule, D_2 should be selected. Bu D_2 goes with B_2. Hence, the design A/B_2 that was ruled out during the first stage because B_2 overshoots the performances of the product planned by the strategy department is reconsidered. A/B_2 favours the commonality and avoids the development of a new module D_2*. Hence, there is a trade-off between the application of the reuse platform on one hand and the market and economic issues on the other. The design [$A/B_2/C_2/D_2$] is then considered.

A careful analysis by the core platform team of the global product plan proposed by the strategy department shows that C_1 that was rejected at the third stage for technical reasons regarding this product could be reused on other models of the product plan. This lead to consider it with a new view. Hence, the design including C_1 is again envisaged. But C_1 is necessarily associated with D_1 that has a high production cost because it uses an old technology. The possibility of designing a new module D_1* with the same interfaces as the D_1 but a lower manufacturing cost is therefore considered. Hence, a third possibility is revealed: the design [A/B_1/C_1/D_1*]. Here again the trade-off is between developing a specific elements D_1* or accepting high manufacturing cost.

Design options	Evaluation of the module D	Design Decision	Knowledge mobilized
A/B_1/C_2/D_2	D_2 is not technically compatible with B_1	Rejected	Technical knowledge (platform modularity)
H1: A/B_1/C_2/D_2*	**A new D_2* compatible with both modules B_1 and C_2**	**Selected**	**Technical knowledge (platform modularity)**
H2: A/B_2/C_2/D_2	**D_2 goes with B_2 B_2 overshoots the performances of the product planned by the strategy department**	**Selected**	**A trade-off between the reuse platform rule and the market and economic issues**
H3: A/B_1/C_1/D_1*	**- C_1 (rejected at the third stage) could be reused on other models of the product plan - C_1 goes with D_1 but D_1 has a high production cost because it uses an old technology - A new D_1* with the same interfaces as D_1 but a lower manufacturing cost**	**Selected**	**A trade-off between the reuse platform rule and the economic issues**

At the end of this pre-development phase of the design process, and before the official project launch, three solutions are thus considered: H1 [A/B_1/C_2/D_2*], H2 [A/B_2/C_2/D_2] and H3 [A/B_1/C_1/D_1*]. No single design is completely satisfactory. Each stakeholder defends its preferred criteria:

- The core platform players favour the commonalities and the reuse of the platform.
- The Strategy Department favours the coherence within the product range and the segmentation between the products of the product plan.
- The project team members who have just been affected, before the official project launch to facilitate the knowledge transfer with the core platform team favour the customer performances, the style and the project profitability. However, they are concerned by the risk reduction and using existing modules, could limit the project drifting.

The debate is therefore open, with each stakeholder defending the hypothesis that favours his own key criteria.

The Project team design

Finally, at the project launch, the platform director who has to reconcile the platform principles and the project objectives, selected H1 [A/B_1/C_1/D_1*] and H2 [A/B_1/C_2/D_2*]. H3 is thus rejected because the B_2/C_2 combination: B_2 overshoots the performances targeted and raises product positioning problems and C_2 raises economic issues. The project team that explored the two hypothesis H1 and H2 more carefully, found that adapting B_1 to make it compatible to D_2 is less risky than developing a new D and therefore a fourth design was considered: $[A/B_1*/C_2/D_2]$.

ANALYSIS

The pre-development of the product on an existing platform by the platform core team is based on the mobilization of four categories of knowledge: market knowledge, economic knowledge, technical knowledge and platform-related knowledge. The mobilization of these categories was identified at each stage in the design process. The first three categories of knowledge are traditionally involved in every development. However, the fourth category designated by “reuse platform design rules” deserves a discussion.

Detailed analysis of the mobilization of this category throughout the design process described in the data section above, leads to the distinction of two different issues: design rules on one hand, and a learning routine that affects these design rules on the other hand. Indeed, the data show that the engineers implicitly apply during the design process two rules that correspond to the very definition of platform strategy as presented in the literature. These rules are: R1 or Carry-over that favours the commonality and R2 or Lean design that avoids overdesign. R1 corresponds to the reuse for the new product of as many elements of the platform as possible to limit development cost, reduce lead-time and benefit from the knowledge and the industrial infrastructure. R2, or lean design, means that the design process is conducted using undersized elements and scaling them upwards, rather than oversized items that increase performance and costs needlessly. R2 is applied in the stage one of the pre-development studied, for example, when B_2 was rejected because it overshoots the performances of the planned product. R2 favours a “bottom-up design” approach and avoids the overdesign (Krishnan & Gupta, 2001) that is one of the risk of platform strategy. These rules represent the vector of integration of the multi-project management approach into the design of a single product on an existing platform. They enable the integration of the platform approach that is by essence a multi-product one into the single-product design process. This category of knowledge, combined with the other categories traditionally mobilized in new product development (market, technical and economic) represents the embodiment of the platform strategy in the organization.

What is relatively noticeable in this reuse approach during the development of the product on an existing platform is the stage at which these rules are mobilized. In fact, the platform-related rules are brought into play at the same time as the market knowledge at the very beginning of the design process. It is conducted by the team in charge of the core platform in interaction with the strategy department before the project team is appointed. This settles the platform as one of the main drivers of the product development.

On the other hand, the analysis of the design process shows that these two rules suffer many exceptions. R1 and R2 can be brought into question by different type of knowledge either marketing or technical or economical. Hence, we suggest that the reuse of the platform supposes, besides the two rules highlighted previously, a learning routine that challenges R1 and R2. We designated it by “*smart reuse*”. Indeed its main role is to transgress R1 and R2 in order to allow an efficient platform reuse. Following the evolutionary framework of new product development proposed by Loch & Kavadias (2008), “*smart reuse*” can be considered as a retention or inheritance routine. Its role is to “*maintain the selected features into the next generation of artifacts and enable the cumulative capability of the system*” (ibid, p. 4). Hence, “*smart reuse*” allows a continuous adaptation between the existing components of the platform and the requirements of the new products. The example extracted from the case studied below illustrates the operating of this learning routine. Let us consider the 4th stage: after opting for B_1 and C_1 (by applying R1 and R2 rules), it is therefore D_1 that should be chosen. But as the existing D_1 has an excessively high production cost, the design of a new D_1* is considered, thereby violating rule R1. The application of this rule is therefore brought into question by an economic criterion. The case studied show many other examples like this one.

It also revealed that the rules R1 and R2 were transgressed because some elements of the platform were not interchangeable (which is characteristic of a non modular architecture). Let us consider the 3rd stage of the design process. The application of R1 and R2 leads to the adoption of B_1 and C_2, leading necessarily to the re-use of D_2. But the existing D_2 is not compatible with B_1 because D1 and D_2 were not interchangeable. The process thus resulted in developing a new D_2* compatible with B_1 and thereby violating rule R1. The same goes at the end of the design process when the design of a new interface for the B_1 (B_1*) to make it compatible with D_2 is considered, thereby challenging R1 and R2. These examples highlight the limits of re-using a non-modular platform for several products over a long period of time.

DISCUSSION

The literature dealing with platform design highlights the importance of a prior planning of the products to be developed on the platform. The issue is to determine what will be common to the different products and that could represent the core of the platform. Ulrich and Robertson (1998) thus stress the need to ensure iterative consistency between three plans: product, differentiation and commonality. It is on the harmonisation of these three plans that the success of the platform strategy depends. In this way, the life cycle of the platform needs to be consistent with the period of time covered by the product plan. Furthermore, what is implicit in this literature is that the design of the platform leads to freezing some technological options that could not be easily modified throughout the platform lifecycle. Considering this, one can ask if the platform strategy is efficient in dynamic sectors in which technologies and/or product plans evolve rapidly to answer to evolving client preferences. Cusumano and Nobeoka (1998) had pointed out this issue "*especially when the time lag between the completion of the base design and the transfer to a new project is long*". This leads the engineers to develop new components, thereby extending design cost and lead-time. We can therefore wonder what is the scope of relevance of a platform strategy? Does the advantage of platform strategy reside only in the fact that it makes it possible to design, more quickly and at lower cost, a wide variety of products *for a relatively short period of time* over which it is possible to foresee the trends of the customers needs and the technologies? To address this issue, Krishnan and Gupta (2001) suggest targeting the optimal lifespan of a platform by comparing empirical data and theoretical models. In such an approach, platform strategy would only be effective if the platforms were renewed regularly. The problem of platform renewal would then be posed in the same way as product renewal, but on a different timescale.

Smart reuse: acknowledging the platform and new product co-evolution

Our research, based on the detailed analysis of a product development on an existing platform designed six years ago, addresses the long lifecycle platform reuse over two generation of products. This strategy, envisioned by Meyer & Lehnerd (1997), presuppose to define beforehand both the products to be designed on the platform and the evolution of the platform itself. Our case shows that this possibility is probably out of reach in dynamic environments especially when there are several years between each generations of products. Indeed our analysis demonstrates that the design of a new product on an existing platform raises strategic, marketing, technical and economical questions, providing an illustration of the difficulties pointed out by Fisher & al. (1999). Therefore the platform does not totally constraint the product development that would has no other choice than to adopt the platform components. We showed through our analysis of the development process, that when the platform has a long life cycle, the products developed on the platform impact the platform components. The *"smart reuse"* that we highlighted enables this. It is a mean to ensure the upgradability highlighted by Garud and Kumaraswamy (1995). That is what we refer as interplay or a co-evolution of the platform and the products (Loch & Kavadias, 2008). The prescription relationships between the products and the platform operate in both ways. In other words the planning process described by Ulrich & Robertson as an interaction between product / commonality/ differentiation does not take place only at the beginning of the platform design process. It has to continue throughout the platform lifecycle. Thus in the case of platform reuse neither the traditional *top-down (proactive platform) approach* wherein a company strategically manages and develops a family of products based on a platform, nor the *bottom-up (reactive redesign) approach* wherein the company redesigns a group of distinct products to standardize components (see Simpson & al., 2006 chap. 1 p. 5-6 on this distinction), are suitable. Acknowledging this interplay between the platform and the products that use it, leads to renewing the approach of the platform planning which, in most of the literature, takes place first and foremost at the beginning of the design process in a top-down manner. This echoes the deliberate vs. emergent debate that pervades the strategic management literature (Mintzberg, 1978; Mintzberg & Waters, 1985; Burgelman, 2003). In this perspective the role of the "*smart reuse*" routine in the sustainability of the platform over several generations of products highlights two links that need to be considered: one between the new product development process and the platform and the other between the platform and the product planning. This raises important issues relating firstly to the organization of the development process and secondly to the architecture of the platform. We now turn to these issues.

Organizational implications of the smart reuse

Let us first consider the organization. The reciprocal relation between the existing platform and the new products deeply modifies the logic of the development process and, therefore, its unfolding and organization. To analyze the transformations involved, it is useful to keep in mind the traditional V model originated from the theory of Systematic Design. Pahl and Beitz (1996) divided the design process into two broad stages: a specification stage (from the top to the bottom of the left-hand side of the V) and a validation and synthesis stage (from the bottom to the top of the right-hand side of the V). In this classic design approach, the design process begins by an analysis of needs followed by the search for a concept and then a feasibility study resulting in specifications. Architectural design and detailed design can then begin on this basis, and validation follows. It is therefore *what we want and what we can do* that serves as the sole entry point of the design process. The issue consists in finding the best response to the specific question asked at the beginning of the process. However, when the product is developed on an existing platform, some components are imposed to the project team. The V model is thus fundamentally modified. Now, *what we want and what we can do* is no longer the sole starting point. There is a second entry point that is *what we have and what we re-use*. The design process must thus take into account elements that already exist. The design starts from the top and the bottom of the V cycle as well. Therefore, designing a product on an existent platform necessitates a continuous dialogue to negotiate trade-offs between what we have and what we want, especially in cases where the firm decided to use the platform on several generations of products. This has implications since it supposes an evolution in the organization of the design process. Indeed traditionally the actors of the "top" of the V cycle, typically Strategy and Marketing departments, are in a prescription relation with product developers. They define the requirements that engineers have to translate into working products. In our case the relationships evolves to a situation of reciprocal prescriptions where actors from the "top" and the "bottom" of the V cycle have to negotiate trade-offs around the evolution of the platform and its associated products. More precisely, we can identify two organizational implications associated to the *smart reuse* process:

- - Between the platform core team and the projects teams. This micro level deals with the trade-off between the requirements of the new product and the existing platform. We can infer from our data that the older the platform, the more intense this interaction will be since the fit between a "new" product and an "old" platform will be difficult to reach. This is illustrated by our data. It is the platform core team that was in charge of the evolutions considered regarding the platform. Our analysis recognizes the need to organize a continuous debate *during* the platform lifecycle between the players involved: the platform core team and the projects teams. However this micro level is only the last step of a longer planning process and, as we have seen, it frequently raised strategic questions;

- Between the platform and product planning. While the micro level of interaction modifies the product development process, this macro level modifies the organization of the product planning process. It corresponds to what we have argued before, that this process is neither a top-down nor a bottom-up approach. The question is to organize the prescription relationships between the platform and the product planning players during the platform lifecycle to ensure its sustainability.

In both cases the platform director is a central figure. Indeed he is the one who has a global understanding of the platform and the projects developed on it. He is in a typical middle-management position, in-between strategic and engineering questions. The first level is his raison d'être: ensuring a fit between the platform and the new products under development. But, during this process, he gets an understanding of what is possible on the platform and what is not, and thus of when it should be renewed. The challenge for firms is thus to recognize this role first by empowering him and secondly by involving him as early in possible in the strategic planning process to trigger the debate around smart platform re-use.

Toward a modular platform architecture

The second issue refers to the architecture of the platform itself. The growing research on product architecture (Baldwin and Clark, 2000; Sosa *et al.* 2004; Mc Cormack *et al.* 2006) demonstrates the benefits of a modular architecture in highly dynamic environments in terms of technical and market issues. Indeed, modularity greatly increases the range of options available to designers. As demonstrated by Baldwin & Clark (2000) it allows engineers to substitute one component for another, to eliminate certain elements, to add new components and so on (see Baldwin and Clark, chap. 5). Thus, when confronted with dynamic environments they can adapt (mix-and-match according to Sanchez & Mahoney, 1996) the product without having to redesign the entire system and without occurring the associated costs and delays. Modularity thus plays a key role in component re-use (Simpson & al, 2006). Platform modularization thus appears to be a straight solution to increase the platform flexibility overtime. However while literature on product modularity is plentiful, that on platform modularity is less so. The question is therefore to determine the extent to which the design of a modular platform could contribute to the progressive renewal and upgradeability of the platform during its life cycle. This is a very complex question in the automotive industry. Indeed, as pointed out by Whitney (1996 & 2004) mechanical product like an automobile has characteristics that reduce the possibility of modularization. To address this question we have used the Design Structure Matrix proposed by Eppinger (1991) to assess the degree of modularity of the platform at Platcar. This is an exploratory work but the results, shown in appendix, are very interesting. It appears that the Platcar Platform is not very modular. For example, changing elements of the Suspension leads to modifications all over the vehicle except the trunk floor. Moreover we have reason to believe that the DSM does not document all the interactions of the systems since it neglects, for example, functional interaction. In our case for example, even if there is no physical relations between the front gear and the rear gear (see the Suspension/Rear synthesis box of the DSM), it is impossible for functional and physical reasons (width between the wheels) to match different types of front and rear gear. This lack of modularity very probably explains part of the difficulties encountered during the platform re-use design process we have studied. It furthermore raises important managerial questions insofar as the modularization of the PF is not only an engineering problem. Indeed, the relevant question is not "can we modularize the platform" but rather "what parts are the most interesting to modularize". This supposes close interactions between engineers on one side and strategic and marketing departments on the other. No doubt that the question of platform modularization deserves further research in the future.

CONCLUSION

We intended to address the evolution and the renewal of the platform in firms that have adopted a platform strategy and that use the same platform for several generations of products. The questions of the renewal of the platform, the management of its lifecycle and its architecture were considered by Muffatto (1999) as critical issues: (i) the relationship between platforms and the development of new ones, (ii) the number of models should be derived from a single platform, (iii) the expansion or reduction of platforms.

For that purpose, we conducted a fine-grained analysis of a product development on an existing platform that has been designed six years ago. We developed an in-depth analysis of the development process by tracing the decisions taken during this development and the type of knowledge involved. This approach gives us a unique understanding of the challenges of the platform re-use, an understudied topic in the existing literature. The analysis of the design process revealed that when designing a product on an existing platform, specific design rules regarding the platform are mobilized, besides the traditional knowledge used in every development such as the market, the technical and the economical knowledge. These rules are at the heart of the platform strategy since they integrate the platform approach into the design of a single product on this platform. These rules implicitly applied by the designers are R1, the Carry-over that favours commonality and R2, the lean design that avoids overdesign. They are brought into play at the same time as market knowledge at the beginning of the product development, highlighting that platform considerations take on the same importance as product ones.

Furthermore, the case shows that these rules are transgressed and challenged by a learning routine that ensures a *smart reuse* of the platform. We believe that this issue constitutes the key contribution of this paper. Indeed the literature is generally focused on the planning and design of the first generation of platform, assuming the possibility to anticipate its evolution over time. Our research demonstrates that this assumption needs to be challenged especially in dynamic environments when the firm decides to re-use the platform on two generations of products or more. We showed that when the platform has a long life cycle, the products developed on the platform and the platform itself co-evolve. Thus rather than a one-step planning process we observe a continuous interaction between technical, marketing, economical and strategic question during the platform lifecycle. Ulrich and Robertson's (1998) framework thus could be extended towards a continuous planning process. The *smart reuse* routine highlights the interplay or the co-evolution between the products and the platform. It points out the reciprocal prescription relationships between the products and the platform. This operates through two levels: between the product planning and the platform on one hand and the product development and the platform on the other. It has organizational implications that point out in both cases the central role played by the Platform Director to ensure these relations and bridge technical and strategic questions during the life cycle of the platform. The *smart reuse* routine has implications on the platform architecture as well.

The research reported here is exploratory. It draws on one case within a single research setting. We have to mention that these results and ideas were presented to the platform director of another platform in the firm studied that launched four platforms. Here again, the platform director and the platform core team validated the results and the ideas highlighted. However, these findings should be treated with healthy caution since the characteristics of the case probably affects the research findings. Specifically the low modularity of an automobile greatly increases the problem raised by platform reuse. Other studies, in different environments, with more modular products making possible modular platform may contribute to a better understanding of platform reuse both from a technical and an organizational perspective.

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Appendix: The Platform Design Structure Matrix

The modularity of the platform could be analyzed through a widely used tool: the design structure matrix or (DSM) that represents the dependencies and relations between elements. This tool, first proposed by Stewart (1981) and further developed by Eppinger (1991) is used to map the architecture of a product i.e. the nature of the links between its components. In a DSM, the product is thus divided into components, represented in row and column. The DSM is a square matrix (n x n) where n is the number of components considered. The cells in the matrix represent the links between two components. If there is no link the cell is empty, if there is a link there is something in the cell. More precisely we distinguish here, following Sosa *et al.* (2003) three types of interdependencies between components:

- Interface (I): the two components are attached together (weld…)
- Space (S): due to limited space there is an interaction between the component
- Transfer (T): there is a transfer (of information, fluid, energy) between the components

The remaining question then becomes: how to evaluate the degree of modularity, and thus flexibility, of a product's architecture? A first approach is visual: the more the marked cells are concentrated along the diagonal, the more modular the product. Another solution, proposed by Mc Cormack et al. (2006), is to calculate a *change cost*. This metrics evaluate the "*degree of "coupling" it exhibits, as captured by the degree to which a change to any single element causes a (potential) change to other elements in the system, either directly or indirectly (i.e., through a chain of dependencies that exist across elements)*". Formally the change cost is calculated by dividing the number of marked cells by the total number of cells in the DSM.

We use available documents to build ourselves a first version of the DSM. Then we discussed it with two Platcar experts on architecture. They proposed the division of the platform in 31 modules (50 for the entire vehicle) following their usual design methodology. The result is the matrix in Fig N° 13. If we limit ourselves to a visual analysis, the DSM seems not very modular. This result is confirmed by the change cost which is, in this case, nearly 30%. This seems to indicate an "integral" architecture. Indeed, we can compare this figure with the, sparse, available data on DSM. For example, Mac Cormack et al. (2006) found a 6,63% change cost on Linux and a 2,78% on Mozilla after its redesign, which constitutes very good examples of modular software. Of course we have to be very careful on this kind of comparison since we are very far from apple-to-apple comparison. Software and automotive platform are intrinsically of different nature.

Figure 14 The DSM of the PF platform

Three types of interactions:

Interface between modules,
Spatial (volume constraints)
Transfert (fluid, energy and/or informations)

		Engine area								Suspension								Front Unit	Drinving post / Cockpit				Passenger compartment			Rear synthesis						Rear unit
		Engine	Accessories	Gearbox	Air feeding	Cooling	Exhaust	Powertrain suspension	Electricity/electronics	Transmission	Engine craddle	Steering mechanism	Front gear component I	Front gear component II	Front gear component III	brake	Wheel / tire	Front structure	Pedal board	Main cable	Steering column	Electronic control box	pipes / cables	Underfloor protection	Passenger compartment floor	Fuel tank	Rear axle	Rear gear component I	Rear gear component II	Rear gear component III	Wheel / tire	Trunk floor
Engine area	Engine		IT	I	IT	IT	IT	I	IT	IT						ITS		S	T				IT									
	Accesories	IT		IT		IT	S	S	IT			IT						S														
	Gearbox	I	IT		S	IT	S	I	IT	IT		S				S	S	S	IT													
	Air feeding	IT		S			IT		IT									I														
	Cooling	IT	IT	IT			S		IT			IT				S		I														
	Exhaust	IT	S	S	IT	S		S	ITS	S	IS	S				S		IS														
	Powertrain suspension	I	S	I			S			IT	I	S						I														
	Electricity electronics	IT	IT	IT	IT	IT	ITS					IT	IT			IT		I	IT	IT	IT	IT	IT			IT						I
suspension	Transmission	IT		IT			S	IT			S	S		I			S	S														
	Engine craddle						IS	I		S		I			I		S	I														
	Steering mechanism		IT	S		IT	S	S	IT	S	I			IT		T	S	S			IT											
	Front gear component I								IT					I		S	S	IS														
	Front gear component II									I		IT	I		I	IT	I															
	Front gear component II										I			I			S	S														
	Brake	ITS		S		S	S		IT			T	S	IT			S	I	IT	IT	T	IT	IT						IT			
	Wheel / tire			S						S	S	S	S	I	S	S		S			T					S						
Front Unit	Front structure	S	S	S	I	I	IS	I	I	S	I	S	IS		S	I	S		I	I	S		IT		IT							
Drinving post / Cockpit	Pedal board	T		IT					IT							IT		I			S	S			I							
	Main cable								IT							IT		I				IT			I	IT						
	Steering colum								IT			IT				T	T	S	S			IT			S							
	Electronics control box								IT							IT			S	IT	IT											
Passenger compartment	Pipes / cables	IT							IT							IT		IT						IT	I	IT	I	IT				I
	Underfloor protection																						IT		I	I						I
	Passenger compartment floor																	IT	I	I	S		I	I		I						I
Rear Synthesis	Fuel tank								IT								S			IT			IT	I	I		S	S				
	rear axle																						I			S				IT		S
	Rear gear component I																						IT			S			I			I
	Rear gear component II															IT												I		IT	I	
	Rear gear component III																										IT		IT			I
	Wheel / tire																												I			S
Rear Unit	Trunk floor								I														I	I	I		S	I		I	S	