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**MAPPING THE DETERMINANTS OF TIME TO MARKET
IN THE AUTOMOTIVE INDUSTRY:
A LITERATURE REVIEW
AND A MULTIPLE CASE STUDY ANALYSIS**

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Part I

Introduction

Chapter 1

Introduction:

**A Resume of the Project
Italian and English Version**

1.1 Introduzione

IL progetto di tesi che proponiamo riunisce tre articoli basati sull'analisi del processo di sviluppo dei nuovi prodotti (NPD) nel mercato automobilistico utilizzando come performance fondamentale il Tempo di Sviluppo (Time-to-Market, TTM).

Il lavoro é progettato cosí da poter essere letto consecutivamente o suddiviso nei tre paper a seconda delle necessità, e quindi dá adito ad alcune ripetizioni necessarie al completamento della struttura logica autonoma di ogni singolo paper; gli articoli sono caratterizzati da una forma classica, nella quale si tratta il tema di riferimento attraverso un'introduzione teorica iniziale, un'approfondita sezione analitica corredata da considerazioni e dimostrazioni (posizione rispetto alla letteratura precedente ed alle evidenze empiriche del caso studio), ed infine una parentesi conclusiva, nella quale si riportano anche suggerimenti per approfondire od ampliare l'analisi fin qui realizzata. Per evitare di appesantire il lavoro, abbiamo unito le appendici e la bibliografia, generando due sezioni separate nella parte finale del testo.

Rispettivamente, il primo paper struttura un'ampia presentazione teorica, che sfocia in un'alternativa ai due modelli tradizionali presentati in letteratura, mentre i due successivi evidenziano la relazione tra il TTM e parametri specifici, rispettivamente *l'integrazione dei fornitori* nel processo di sviluppo dei nuovi prodotti e *l'analisi delle soluzioni di prototipazione rapida e virtuale* nel corso della fase di design e test. Abbiamo quindi realizzato un caso studio nel mondo automobilistico tra due produttori europei, dimostrando gli effetti delle sostanziali differenze nel loro approccio organizzativo e tecnico allo sviluppo dei nuovi prodotti.

Il nostro lavoro si prefigge un doppio obiettivo: da un lato si cerca di provare, attraverso un'ampia analisi teorica, l'importanza della durata (TTM) della fase di sviluppo dei nuovi prodotti; dall'altro si evidenziano le differenze prestazionali dovute all'utilizzo di tecniche pratiche e soluzioni organizzative differenti, con l'aiuto di un caso studio specifico. In particolare, vogliamo dimostrare come due produttori (limitando le differenze nel tentativo di comporre un quadro quanto piú chiaro possibile) abbiano affrontato diversamente il dilemma relativo al TTM, inteso come la principale fonte del vantaggio competitivo dell'azienda, e come differenti parametri possano pesantemente influenzare i risultati finali ottenuti.

Nel corso dell'analisi da noi condotta, abbiamo optato, tra tutti i metodi qualitativi possibili, per una ricerca basata sulla tecnica del *multiple case study*, in quanto si é dimostrata estremamente valida quando si tratta di studiare fenomeni contestualizzati in casi attuali, dove si uniscano contemporaneamente approcci di tipo induttivo e deduttivo. Il lavoro si basa sull'utilizzo di variabili di controllo (rispettivamente caratteristiche dell'OEM e del modello di riferimento) che hanno indirizzato la scelta dei casi studio, e parametri prestazionali (il TTM inteso come performance principale e la sicurezza del modello come misura di qualità). I risultati fanno riferimento alla contemporanea analisi della letteratura ed

all'acquisizione dei dati attraverso un questionario strutturato ed interviste dirette libere, rispettivamente ai direttori del settore tecnico e commerciale di entrambi i progetti presi in considerazione. Questo metodo a doppia entrata permette un confronto dettagliato tra punti di vista sia internamente (funzioni diverse) che esternamente (pratiche diverse) all'azienda.

Le conclusioni che abbiamo raggiunto si sono dimostrate innovative e fondamentali nella definizione di un nuovo percorso di ricerca: abbiamo infatti determinato che, in un ambiente caratterizzato da un continuo rinnovamento, dove la conoscenza é ampiamente suddivisa tra tutti gli attori coinvolti, lo sviluppo congiunto (co-development) non é solo fonte di grandi vantaggi, dati dal coinvolgimento di diverse imprese in uno stesso progetto e dallo sfruttamento delle competenze di partner nello sviluppo di attività che l'azienda non é piú in grado di realizzare autonomamente (outsourcing), bensí rappresenta un utile ponte nella condivisione di conoscenze tali da aprire alle imprese le porte di scambi biunivoci sia tecnologici che metodologici. In particolare, non solo siamo stati in grado di fornire importanti indicazioni sull'effetto che nuovi metodi e strumenti di sviluppo possono avere sul TTM, bensí abbiamo dimostrato che i vantaggi riscontrati nel NPD devono essere interamente ascritti al rafforzamento delle relazioni buyer-supplier. Possiamo quindi concludere che le aziende in grado di sfruttare nel miglior modo possibile il loro rapporto con i fornitori (piú dal punto di vista metodologico che puramente produttivo) si trovano sicuramente un gradino sopra tutti i concorrenti diretti nel mercato.

Si evidenziano qui di seguito alcuni dettagli relativi ai risultati ottenuti, capitolo per capitolo, utilizzando come indicatore fondamentale l'abstract dei tre paper, in modo tale da chiarificare l'evoluzione del nostro lavoro ed il contributo che questo si propone di fornire.

1.1.1 Paper 1

New Product Development and Time to Market: a Literature Review

IL panorama letterario relativo allo sviluppo dei nuovi prodotti (NPD) si é ampliato sempre piú nel corso degli anni, come risultato della crescente attenzione destinata all'argomento. Questo lavoro si basa su una rivisitazione iniziale della letteratura sul NPD in termini generali e quindi, attraverso una progressiva focalizzazione, tratta l'evidente dilemma relativo al tempo di sviluppo (TTM): affermiamo, infatti, che il TTM sia stato (e *debba essere*) visto come l'indice prestazionale fondamentale nell'intero processo di sviluppo per due ragioni: prima di tutto, rappresenta il punto di contatto tra gli approcci destinati al miglioramento del processo e le performance economiche principali, ed in secondo luogo é un indicatore fondamentale in riferimento allo "stato" del processo. Questo lavoro ottiene un duplice risultato: da un lato, fornisce al lettore una rivisitazione della lettera-

tura riguardo NPD e TTM, strutturata ed allo stesso tempo semplice, alla quale si aggiungono diversi suggerimenti bibliografici con lo scopo di ampliare i riferimenti del testo; dall'altro, viene qui fornita un'interpretazione personale del panorama letterario: si dimostra infatti l'esistenza di due linee di pensiero principali nella letteratura moderna che fa riferimento al TTM, l'una fortemente legata ai vantaggi che la riduzione del tempo di sviluppo può fornire all'azienda, l'altra dedicata alle debolezze di questo approccio, ed alle zone d'ombra ancora da coprire. Noi suggeriamo la possibilità di ridefinire queste due linee di pensiero riducendole ad una, consegnando all'impresa le chiavi della scelta di campo: le aziende che tendono a concentrarsi solamente sulla riduzione del tempo di sviluppo, tendono infatti a ricadere in una spirale discendente fatta di riduzione della qualità, investimenti più elevati, processi imprecisi, mentre le compagnie che si impegnano su tutta la catena del valore (miglioramento dei processi, eliminazione degli sprechi e così via) imboccano una strada ascendente di miglioramento continuo. La concreta esistenza di entrambe queste possibilità sembra essere la ragione dell'esistenza parallela di due linee guida contrastanti in letteratura. In poche parole, è il modo di procedere che determina la bontà dei risultati finali, e non il contrario.

1.1.2 Paper 2

Mapping the Determinants of Time-to-Market in Automotive New Product Development: a Multiple Case Study Analysis

CONSIDERATO l'aumento in tempi recenti della pressione per ridurre sia i tempi che i costi di ricerca e sviluppo, le imprese hanno dedicato gran parte dei loro sforzi a modificare le loro abitudini organizzative. Nel corso di questo lavoro, cerchiamo di evidenziare i principali parametri coinvolti nella sfida per ottenere i migliori risultati, utilizzando come parametro prestazionale fondamentale il tempo di sviluppo. Ci spingiamo alla ricerca delle determinanti che consentono la riduzione delle tempistiche, fornendo una linea guida per le imprese che si sforzano di raggiungere il successo competitivo concentrando i loro sforzi al miglioramento di questa performance. Utilizziamo qui una indagine qualitativa, basata sulla metodologia di ricerca *Multiple Case Study*, ponendo a confronto due produttori europei nel mercato automobilistico. Il paragone viene realizzato su due indicatori, rispettivamente il Time-to-Market e la Qualità del nuovo prodotto, visti come prestazioni fondamentali nello sviluppo dei nuovi modelli, mantenendo costanti nel corso dell'analisi delle caratteristiche del veicolo (definite variabili di controllo), per ridurre l'incertezza intrinseca dell'analisi. Mettiamo in luce, inoltre, l'influenza che diversi parametri esogeni, quali ad esempio l'esperienza precedente dell'impresa nel mercato di riferimento e la sua struttura organizzativa, possono avere sulla volontà di rinnovamento della struttura e della metodologia utilizzata. Lo studio evidenzia come, nel segmento specifico da noi analizzato –vettura familiare di medio/piccole dimensioni–, la determinante fondamentale per quanto riguarda la riduzione del tempo di sviluppo sia la gestione della relazione diretta con i fornitori.

In particolare, la cooperazione con un numero ristretto di fornitori selezionati può sfociare non solo in vantaggi temporali con pari risultati qualitativi, bensì anche in nuove pratiche metodologiche da adottare. Infine, si studia l'effetto della posizione competitiva attuale in riferimento alla tensione verso l'innovazione: il nostro caso studio prova come, contro intuitivamente, le imprese in posizione competitiva peggiore siano quelle che maggiormente tendono all'innovazione, in un certo senso avvalorando le teorie che evidenziano i vantaggi delle imprese entranti nel mercato (incumbent advantage theory). La domanda relativa a quali siano i parametri fondamentali coinvolti nella competizione basata sui tempi di sviluppo trova qui una risposta sia in elementi organizzativi interni (cooperazione di lunga durata con i fornitori) che esterni (esperienze passate). Questo lavoro fornisce quindi sia un suggerimento pratico su come affrontare la pressione continua alla riduzione del TTM, che un avvertimento per evitare che le imprese di successo ricadano in uno stato di torpore, facendosi sfuggire il vantaggio competitivo accumulato a causa di una crescente inerzia organizzativa.

1.1.3 Paper 3

Time to Market as the Final Performance in the Rapid-Virtual Prototyping Challenge: A Case Study in the Automotive Industry

SEMPRE come conseguenza dell'incremento della pressione organizzativa sulle aziende (tempi e costi), queste hanno rivolto la loro attenzione all'utilizzo di tecnologie ed approcci innovativi nel tentativo di sviluppare competenze tali da stabilizzare il vantaggio nei confronti dei diretti concorrenti. Consolidata l'idea che le informazioni raccolte influenzino direttamente ed in profondità le prestazioni del prodotto, intese come tecnologie necessarie, interesse sul mercato e tempistiche di sviluppo, le imprese hanno apportato profondi miglioramenti alla fase di test del prodotto, attraverso l'introduzione di nuove metodologie e strumentazioni. Questo lavoro si propone di dimostrare come l'utilizzo di tecnologie informatiche abbia modificato le modalità d'azione delle imprese nei confronti dei test sui nuovi prodotti, sia dal punto di vista tecnico che commerciale. Ci riferiamo alle tempistiche di sviluppo come variabile dipendente, ed evidenziamo, attraverso l'utilizzo del confronto tra due casi studio nel mercato automobilistico, il possibile bilanciamento tra l'uso esteso di tecniche di prototipazione virtuale (VP) e quello delle più note tecnologie di prototipazione fisica fortemente migliorate dai metodi informatizzati nell'accezione di prototipazione rapida (RP). Sugeriamo un contemporaneo avanzamento nella ricerca: da un lato, affermiamo che l'utilizzo di tecniche di VP facilita la rapidità del processo di sviluppo dei nuovi prodotti, mantenendo allo stesso tempo prestazioni identiche per quanto riguarda la qualità del prodotto finale, mentre dall'altro lato ci soffermiamo sull'importanza di altre variabili nel processo decisionale che porta all'adozione di metodi di VP. La soddisfazione del cliente, l'immagine dell'azienda sul mercato e la storia recente della stessa rappresentano variabili fondamentali nella scelta delle tecniche da adottare. Ci soffer-

miamo inoltre sulla forte opposizione che si riscontra in letterature tra i sostenitori di una o dell'altra tecnologia, e proponiamo la nostra posizione. Basandoci sui risultati ottenuti, é nostra ferma convinzione che le imprese debbano focalizzarsi esplicitamente sulle tecniche di prototipazione virtuale, in quanto queste consentono maggior rapidità nel NPD, riducono le spese di sfruttamento dei due processi in parallelo e consentono di ottenere risultati qualitativi perfettamente confrontabili. Nella sezione conclusiva del nostro lavoro, vogliamo far presente che una "regola d'oro" deve ancora essere definita, in quanto risultato doveroso di un mix tra fattori esogeni ed endogeni, e quindi necessariamente riadattata a seconda del mercato e dell'impresa di riferimento. Il risultato che otteniamo é quindi da considerarsi una prospettiva sugli strumenti da utilizzare nel processo di sviluppo dei nuovi prodotti, insieme a considerazioni generali per quanto adattate ad un ambiente di riferimento assolutamente specifico.

1.2 Introduction

THE project we focused on is clustered into three chapters, lying on Time-to-Market (TTM) as the main performance in New Product Development (NPD) in the Automotive Framework as the leitmotif.

We built up our work in three semi-freestanding papers, such that they can be get through consecutively or separately according to the readers' needs; the final structure grounds on some necessary redundancies, as we fulfilled each paper of all the needed information to work as a stand-alone analysis; they are all structured on a classical shape, made of a theoretical introduction, an in-depth analysis with personal findings and considerations, and conclusions with suggestion for further analysis. In an attempt to render the entire structure more manageable, we tried to rule out any redundancy on the appendices and the references, thus building two joint sections at the end of our work.

The first paper aims at highlighting the theoretical point of view concerning the topic, while the others evidence the influence of two specific parameters, respectively *supplier integration* in NPD and *virtual vs rapid prototyping techniques* during the design and testing stage, on TTM. To test our theoretical intuitions, we built up a case-study in the automotive framework between two European OEMs, evidencing strong differences in their organizational and technical approach to NPD.

The aim of our work is twofold: on one side, we try to prove theoretically the importance of Time-to-Market in the Development stage, specifically focusing on the automotive framework; on the other, we show through our comparative case-study analysis how different organizational and technical solutions could take to different results as regards TTM, all the rest being equal. We evidence, thus, how the OEMs worked to face TTM dilemma, and how different parameters could influence the final performance of the firm.

In the evolution of the comparative case-study we opted, among the qualitative methods, for a *multiple case study* research design, as it proved to gain advantages when the researcher aims to study contemporary phenomenon within some real-life context, with both a deductive and inductive approach. Thus, we structured our work grounding on some control variables (respectively OEM and model characteristics) and on performance parameters (TTM as the fundamental one and safety as a check of the final quality of the model). The results are based on an in-depth analysis of literature and the data acquiring both through a structured survey and free direct interviews both to the technical and the marketing chief directors inside the OEMs. This double-check method helped us to focus on different points of view inside the firm, thus working on a double comparison, inside and outside the OEM.

Our conclusions proved to be innovative and fundamental as they are able to build a new path in research: we proved, in fact, that, in a fast-changing environment, where knowledge spreads all over the involved actors, co-development

not only provides great advantages in connecting different firms and outsourcing practices that the OEM is no longer able to afford, but it can also bridge over methodological knowledge, thus providing the OEMs of new methods and tools to be used in the NPD stage. We were able to prove the great influence new methods and tools could have on TTM, and we found out that their derivation was to be totally ascribed at the strength of the buyer-supplier relationship. We could state, then, that the firms that are able to exploit in its entirety the strong relations with their suppliers will find themselves on the leading edge of the market framework.

I will provide here some hints concerning the results we gained in the three papers, with the aid of their abstracts, such that it can be made clear the evolution of the work and its evolutionary contribution.

1.2.1 Paper 1

New Product Development and Time to Market: a Literature Review

THE literature on New Product Development (NPD) continued to grow during years, as the result of the increased attention posed on the topic. This paper builds up firstly a brief literature review about NPD in general sense, and then, in a progressively focusing shape, deals with the Time-to-Market (TTM) Dilemma: we state, in fact, that TTM has been (and *has to be*) considered as the main performance concerning the entire NPD process for a couple of reasons: first of all, because it represents a contact point between approaches aimed at improving the process and the main performance measures, and secondly because it is one of the indicators concerning the “state” of the process itself. The aim of this paper is twofold: on one side, it provides the reader of a well-structured, simple and organized literature review both about NPD and TTM, including some suggestions about future readings to be useful as deepening the analysis on the topic; on the other, it depicts a personal interpretation of literature: we prove, in fact the existence of two mainstreams in modern literature concerning TTM, one referring to its advantages, while the other exploiting the presence of some weaknesses and shadows. We suggest, then, that these two streams could be both resumed in one, as we “give” firms the chance to decide: firms concentrating mainly on time reductions seem to fall down in a black hole built up of quality decrease, higher investments, imprecise processes, while companies working on the whole value stream (better processing, eliminating wastes and so on) resemble to get into a good-for-good spiral. The parallel existence of these two real solutions seems to be the reason for the parallel existence in literature of two contrasting mainstreams. In a word, it is the way things are done that determines final results, and not the opposite.

1.2.2 Paper 2

Mapping the Determinants of Time-to-Market in Automotive New Product Development: a Multiple Case Study Analysis

As pressure to lower both time and costs of research and development (R&D) increased in recent years, firms strived to change their working habits accordingly. In the course of this analysis, we try to evidence the main parameters involved in this struggle to gain better results, specifically focusing on the Time performance. We devote our effort to identify the determinants of a shorter TTM, thus providing a guideline in the effort firms should pose as they will strive for competitive success. We use a qualitative analysis, based on the Multiple Case Study Research Method, between two European OEMs in the automotive market. We compare, thus, two performance indicators, respectively Time-to-Market and Quality, as milestone performances in the development of a new model, holding constant some characteristics of the vehicles (namely control variables), to reduce the variance in the analysis. We further highlight the influence exogenous parameters such as the previous experience of the firm in the market framework and its organizational structure could have on its willingness to innovate. The study shows that in the specific segment we analyzed –small family car– the main determinant as regards TTM advantages resulted to be supplier co-development management. In particular, the co-operation with a thin base of selected suppliers could come out not only in TTM advantages and equal qualitative results, but also in new methodological practices as realizing new product development. Moreover, we highlight that, counter-intuitively, firms in a worse competitive position are willing (and are able) to innovate more than successful ones, thus confirming the incumbent advantage theory. The question about which are the main parameters involved in the Time based competition, thus, finds here an answer both on internal organizational elements (long-lasting, relational knowledge and practices interchange with suppliers) and on external ones (past-experience). This study will thus provide the readers both a practical hint to solve the TTM pressure matter, and also a warning to quit the risk of slipping out of their successful position squeezed by their own inertia.

1.2.3 Paper 3

Time to Market as the Final Performance in the Rapid-Virtual Prototyping Challenge: A Case Study in the Automotive Industry

STILL fixed on the time-cost pressure matter, firms embraced many novel technologies and approaches in an attempt to develop new capabilities that would give them an advantage over competitors. As information collected deeply influence product performances, intended both as technical requirements, market appeal and timing, strong improvements were brought to the testing phase, with the introduc-

tion of new methods and tools. This paper shows how IT instruments changed the way firms act with respect to testing new products, both on their technical and market side. We will refer to the timing of projects as our dependent variable, and we will show, with the aid of a comparative case study in the automotive market, the possible trade-offs between the extensive use of virtual prototyping (VP) and the old-fashioned method of physical ones, aided by great improvements in rapid prototyping (RP) techniques. We suggest a parallel advancement in research: on one side, we state that VP allows for the fastening of the entire NPD process, still maintaining the same performance as regards the quality of the final product, while on the other we refer to the importance of other variables in the decision of the firm whether to implement VP methods. Customer satisfaction, the image of the firm and historical matters should be a further base in the decision process. Along with these considerations, an important aspect actually dominating research framework is the challenge between rapid and virtual prototyping as opposite testing technologies. We will state, grounding on our results, that firms should focus explicitly on VP techniques, as they can both speed up the NPD process, reduce parallel-processing expenses and gain same-level qualitative results. In the conclusive section of the paper, we aware, though, that a “golden rule” is still under definition, as it is the results of a mixture of endogenous and exogenous factors, thus should be re-adapted every time market or firm conditions change. The result is, thus, a waving perspective on NPD tools, with the shape of the general conclusion and the features of the specific framework.

Part II

New Product Development and Time to Market

Chapter 2

New Product Development and Time to Market a Literature Review

2.1 Abstract

THE literature on New Product Development (NPD) continued to grow during years, as the result of the increased attention posed on the topic. This paper builds up firstly a brief literature review about NPD in general sense, and then, in a progressively focusing shape, deals with the Time-to-Market (TTM) Dilemma: we state, in fact, that TTM has been (and *has to be*) considered as the main performance concerning the entire NPD process for a couple of reasons: first of all, because it represents a contact point between approaches aimed at improving the process and the main performance measures, and secondly because it is one of the indicators concerning the “state” of the process itself. The aim of this paper is twofold: on one side, it provides the reader of a well-structured, simple and organized literature review both about NPD and TTM, including some suggestions about future readings to be useful as deepening the analysis on the topic; on the other, it depicts a personal interpretations of literature: we prove, in fact the existence of two mainstreams in modern literature concerning TTM, one referring to its advantages, while the other exploiting the presence of some weaknesses and shadows. We suggest, then, that these two streams could be both resumed in one, as we “give” firms the chance to decide: firms concentrating mainly on time reductions seem to fall down in a black hole built up of quality decrease, higher investments, imprecise processes, while companies working on the whole value stream (better processing, eliminating wastes and so on) resemble to get into a good-for-good spiral. The parallel existence of these two real solutions seems to be the reason for the parallel existence in literature of two contrasting mainstreams. In a word, it is the way things are done that determines final results, and not the opposite.

Index terms- New Product Development, Time to Market, Literature Review, Improvements in the Value Stream.

2.2 Introduction and Scope

THIS paper is a review of literature about New Product Development (NPD) and specifically about the relation occurring between NPD and Time to Market (TTM), commonly used in literature both as a parameter and an indicator [23]. This “*double role*” is the key of its importance in the market framework, as it represents both a factor to work on, involving increasing effort and skills, and a performance to evaluate, establishing part of the success of firms’ new products on the market.

We will define here NPD as the transformation of a market opportunity and a set of assumptions about product technology into a product available for sale [110]. We must say that the literature on the topic is vast and complex to be reduced into a single stream of analysis, in that the importance of NPD has grown dramatically over the last few decades, and it is now the dominant driver of competition in many industries [174], if not in all of them. Researchers, according to this consideration,

strive to understand the factors that drive product outcome [235], having in mind that NPD is intrinsically a dilemma [6,177]: going back of many years, we can already see that NPD was considered one of the main activities, and at the same time one of the most dangerous for the firm; a study of over 700 Fortune 1000 companies estimated that new products would provide over 30 percent of these firm's profits during a five-year period from 1981-1986, growing to 40 percent for technology driven firms [19], and more recently, it was estimated that in industries such as automobiles, biotechnologies, consumer and industrial electronics, computer software, and pharmaceuticals, companies often depend on products introduced within the last five years for more than 50 percent of their annual sales [174]. At the same time, new products failure rates are still very high, covering an enormous volume of new products introduced in the market. With data running after one another, estimates have been made in many reviewing papers [9,36,55,174] showing an intriguing situation where not only the striving for success is hard, but also the striving to survive sometimes could be necessary. As Griffin (1997) says, a firm is born by successfully commercializing one new product. To remain profitably in business over the long term requires the firm to go along developing and commercializing additional successful products as fast as possible without corroding the internal capabilities of the firm, or at a minimum keep re-developing current products to better meet customer needs as technologies and competitors change and improve [79].

Our research will be in some sense *trumpet-shaped*: this structure will help us to progressively center on niches of the entire NPD approach, as intended in literature. Our aim is to focus on NPD studies, in an attempt to show how their evolution increasingly took firms to work on the time-to-market dilemma, as it proved to represent a huge part of new products success. The shape of the paper will thus help us in our attempt to focus on a detailed analysis with a time-based approach to literature: in section 2.3 we will center our attention on the general theme of NPD, with the aid of five milestones reviewing studies concerning a period of about 15 years (since 1987 to 2001). The aim of this structure will be to start examining the NPD process as it was intended to be at the end of the 80s, thus evolving our analysis according to the principal debates in the next 10–15 years, as they are reported in the reviews we focused on and on the rest of the literature we analyzed; in section 2.4, we provide evidence of the evolution of the time-to-market theme: during the development of NPD projects, in fact, many researchers understood the stronger effort posed on the reduction of cycle time, due to the faster obsolescence of products and the need of replacing them with newer ones, as soon as the market asks for innovations, and tried to center their works on this matter; we will expose how TTM was intended to be, since the beginning, i.e. as a final performance of the entire process, in a word something to assess to be successful on the marketplace, till its revolutionary definition, i.e. the idea that lead time could be an intermediate performance between variables and performances of the products; a firm could strive to reduce its cycle time, understanding the factors acting on it, to get better economic results on the market [46,128]. This part of the research will thus focus on the approaches concerning TTM, citing some empirical studies, with the purpose to confirm or even provide discussion elements about the topic, with an effort posed on the classification of literature. We will finally highlight

our position concerning the relation between TTM and the NPD process, to report both on the importance TTM concern gathered in the last decade and on the relation between a better NPD process with shorter TTM. Our work will depict some examples on the NPD process and TTM evolution using as a framework the automotive market. The use of this setting is mainly due to its maturity and innovative features, creating a perfect environment for our dissertation proofs.

Our contribution in this paper is, thus, twofold. First, we provide a structured review of the NPD problem, as intended in literature, citing some examples regarding works already published, and trying to understand the evolution of the different researches on the topic during a long period of time. We will try to give a sort of map of the most cited articles citing the reviews starting from the year 1995, in order to create a framework where to start coming up to the NPD theoretical approaches¹. Second, we center our research focus on TTM, providing the reader of some hints about the present-time studies, while suggesting the importance this topic gained in the actual market framework. We will, at the same time, justify the strong effort researchers and firms are devoting in reducing development process lead times, and suggest an interesting starting point to work on when structuring a new research on the topic: is time to market a fundamental indicator when talking about product success? We will show how many researches during these years stated it *really* is.

2.3 NPD Theoretical Background

BRINGING new products successfully to the market is the lifeblood for most organizations, but it is also a complex and difficult task [9]. Over the years, many authors posed the attention on NPD, as it became the most important task for all the companies involved in the competition. Product development is critical because new products are the nexus of competition for many firms [34] and, even if at the beginning of the 90s literature was neither as large nor as systematic as research in manufacturing [48], it was developing faster than all the other topics in economic literature, soon including complete and good reviews [9, 23, 48, 69, 70, 86, 110, 177, 179], and influencing articles covering even small niches of the NPD competition and process. If it is hard to classify literature, even harder it is to identify pioneering studies, defined as the first efforts on innovative paths of study. An interesting starting point could be that of Brown and Eisenhardt (1995), looking at the innovation research as it was split in two broad areas of inquiry: the first, involving the differences in the patterns of innovation across countries and industrial sectors, the evolution of particular technologies over time, and intra-sector differences in the propensity of firms to innovate, called economic-oriented tradition [77, 78, 117], and the second, focusing on *how* specific new products are developed [34, 48, 177, 235] called the organization-oriented tradition. Our work will thus be an underbody analysis of single subunits of the entire literature. This methodology, that obviously do not permit us to create a complete general re-

¹See section 2.3 for details and Appendix A for the complete references

view of all the topics covered by researchers, could help us to focus on specific details of the NPD dilemma, and also to understand the evolution of the literature understatements during years. In our attempt to reduce the entire analysis to a funnel-shaped work, we will focus only on the “physical” component of NPD, meaning the latter of the two options. This technique obviously reduce the entire study framework, but enables us to center the attention on the main “real” matter firms are actually facing on the marketplace [23].

The main research question we would like to ask in this section can be resumed as follows: *what was the development of the NPD studies during this period, since about 20 years ago till now, and how the main question of NPD (i.e. what are the influencing factors in NPD) has been solved in years?* To answer this question we structured a work based on some literature reviews across a long time line, and then focusing on the concepts we found to be fundamental for our analysis. Literature has grown in a way that is hard to present schematically, soon including factors that a few years ago were impossible to foresee, due to great technological improvements and market changes. This meant simply that many different paths were built, during years, according to the reduced life cycle of products and sometimes also of the companies themselves. As a proof, we entered in our study (see Figure 2.1, 2.2 and 2.3) the number of citations of the main reviews: it is easy to highlight its yearly exponential growth, along with the high number of papers citing one of the three chosen reviews (Source: ISI Thompson Web of Knowledge).

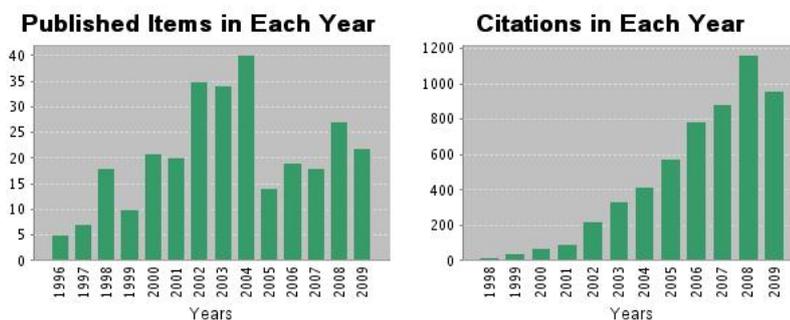


Figure 2.1: Articles Citing Brown & Eisenhardt, 1995

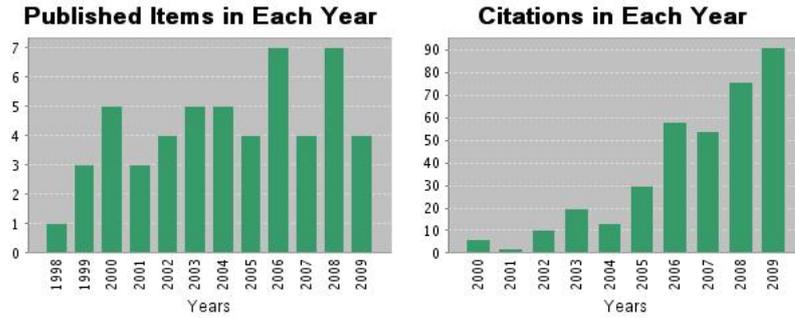


Figure 2.2: Articles Citing Balachandra & Friar, 1997

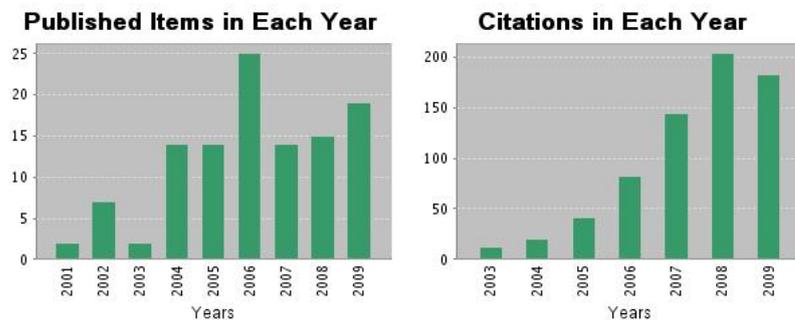


Figure 2.3: Articles Citing Krishnan & Ulrich, 2001

This is the symptom of a stable if not increasing interest about NPD and the possible solutions to its entrepreneurial dilemma (i.e. is it possible to find out a unique best solution to gain higher performances by the products firms introduce in the market?).

We supposed it to be useful to provide readers with an overview of the evolution of the research contents. In our attempt to order literary contributions, our first step was to pose some milestones on the overall framework, so as to use them as coherent summaries of the main evolutions recurrent in literature. In particular, we focused on:

1. Clark, K.B. Chew, W.B. and Fuimoto, T. *Product Development in the World Auto Industry*, Brookings Papers on Economic Activity 729-781 (1987)
2. Cusumano, M.A. and Nobeoka, K. *Strategy, Structure, and Performance in Product Development: Observations from the Auto Industry*, Managing Product Development 75-120 (1992)
3. Brown, S.L. and Eisenhardt, K.M. *Product Development: Past Research, Present Findings, and Future Directions*, Academy of management review 343-378 (1995)

4. Balachandra, R. and Friar, JH *Factors for Success in R&D Projects and New Product Innovation: A contextual Framework*, IEEE Transactions on Engineering Management 44:3 276-287 (1997)
5. Krishnan, V. and Ulrich, K.T. *Product Development Decisions: a Review of the Literature*, Management Science 1-21 (2001).

We then fulfilled the “milestone approach” with other fundamental papers, in an attempt to deepen the analysis with recent works examining the possible evolutions of the topic (nb: with paper we will mean every scientific publication) written during the period 1987-2001 [34, 174, 177, 194, 235] *et al*². We found the use of some reviews challenging to keep the length of the paper manageable when used for an introductory work. As our survey is by no means exhaustive, and is intended to serve as a pointer for future integrations, the ideal contribution of it will be to provide researchers of a wide framework of in-depth recent (2000–2008) works, and of a solid base of previous analysis summaries. Any evolution in literature, in fact, should come along with a vast knowledge of previous studies.

2.3.1 Approaches to the NPD dilemma: a brief review of literature

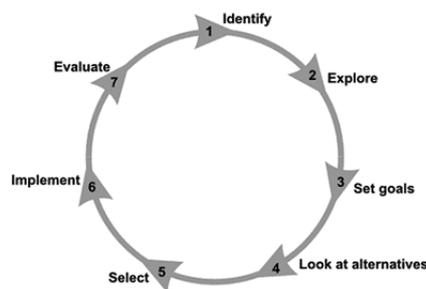
THE method we are proposing here is a sort of time-line evolution of the literary framework about NPD. We will analyze the first milestone contribution [36] we identified³, as if we were placed at the end of the 80s, and we were trying to portray the “actual” NPD pattern. We will highlight its strengths and then center on its weaknesses, so as to show how more recent works evolved during years to dissolve these shadows. We decided to take into account this paper as a pioneer study principally because it represents both an introductory analysis to the entire NPD process, related to a vast and complete review of literature, but also because it delve the topic with a full-bodied statistical dissertation from the industrial world. The parallel evolution of research and “real-world” examples, helped us to join the advantages of a direct comparison between theory and practice, so as to fulfill the general framework about the topic. Moreover, the work seems to be a strong base for following researches, and the recurrence of the idea of the problem-solving cycle was one of our primary mean of choice, along with the attention posed on the trade-off decision making between cost and time: this seemed to be a forerunner for a new generation of studies, during the 90s. Finally, as it serves as one of the milestones for the revolutionary contribution by Clark and Fujimoto [34], it could be intended to be one of the main works about the automotive industry. The importance of this work, though, representing one of the main reasons to consider

²To find a complete bibliography we will refer to Appendix A, comprehensive of the most cited papers citing Brown and Eisenhardt (1995), Balachandra and Friar (1997) and Krishnan and Ulrich (2001), and to the final bibliography of the paper

³See Section 2.3

it a pioneer for a broad range of the following literature, is that it refers to NPD as a complex trade-off between Strategic and Organizational decisions, meaning with the first ones the number of unit tasks and the complexity of their interactions, and with the latter the capability of the organization to create and process information [36]. All the resulting performances of the process depend on the inter-relation of these two broad areas. “Time” is here intended as a performance to achieve, at the same level of costs and quality. Interestingly, the elapsed time is affected by the way in which the unit tasks are interrelated, thus in a word by the internal structure of the firm. The chance to solve tasks in parallel is then referred back to the problem solving capabilities of the firm. The authors, while crossing over this topic, left for further analysis the hint that time at any cost is not the proper way to manage a firm: internal skills, in fact, should not be lost, as the firm still needs to control resources. Twenty years later, the same concept was expressed clearly in an interesting book, showing how research kept working on the same topic so far [219]. The auto industry seems to be a perfect environment in which to develop this sort of analysis in that there is the possibility to analyze these contents in many different countries and in big, somewhat stable organizations, full of historical data sets. In synthesis, what gives product development the power to affect competition is the long life of the design; depending on the product, changing from one design to another entails significant adjustment costs and time [36]. The interesting model proposed by Clark, Chew and Fujimoto, recovered in recent researches [174, 177, 194] *et al.*, poses its attention on the *problem-solving cycle* (Figure 2.4), as it has been defined in previous studies [163]: the idea that successful product development is surrounded by a balancing act between relatively autonomous problem solving by the project team and the discipline of a heavyweight leader, or a strong top management, will be accepted later on with the economic success of Toyota and its model all over the world [122].

Figure 2.4: Problem Solving Cycle



The proposal is mainly centered on a repeated 5-point process, i.e. setting goals, generating alternatives, building models, testing and selection, starting from some initial base considerations that should be faced by the firm: the organization must solve a steady stream of problems to attain its goals [37, 141], and solving these problems requires new knowledge and information, creative ideas, and collective implementation [141]. Both pioneering and relatively new studies faced the

underlying question about the best organizational and strategic solutions to win the competition, splitting into two mainstreams of analysis: on one side the idea that generating high quality ideas and in depth knowledge was a matter of pure individual action supported by a generalized lack of constraints [99,148], on the other a vast section of literature convinced that individual knowledge creation by itself wasn't enough, and an effective structured process was necessary to integrate the "*wild spirit*" of individual ideas into collective action [115,205]. Similarly in the two approaches, an important goal of the business plan must be to continually produce and build on new knowledge. At the same time, although creative and collective action are not mutually exclusive, the structure and processes they require do appear contradictory and difficult to combine. To resume the interesting aspects of the starting point of our analysis, we could say that the paper by Clark, Chew and Fujimoto (1987), and also other works by the same authors, jointly or separated, between 1987 and 1989 [35–37], offers us a perspective on NPD research principally based on:

1. the problem solving cycle [36,163], as the structural base of the NPD process;
2. the division between strategy and organization, the first intended as the choice of the market, the differentiation between products offered, the tasks to be destined to specific project groups, and the latter intended as the organization of the single processes, e.g. parallel processing, managing of mistakes;
3. the relation of both strategy and organization with specific performance of the firm, intended as financial and process performance;
4. the definition of the cost-time dilemma, intended to be one of the main challenges of the actual market framework.

At the same time, though, it shows some shadows that have been discussed in more recent papers, and gave new lifeblood to the debate on NPD development during the following two decades.

To understand the main research questions left unsolved by this paper, we decided to cluster our time-line analysis on a topic-based-scheme: in this way, we intended to help the reader to focus on the specific aspects of the entire work and to help researchers to easily find literary answers to specific questions they are trying to refer to. We strove to build this sub-section in the common paper-way giving birth to an introductory sub-section, underlying some general ideas about the topics we illustrated during the following paragraphs.

Introduction: Strategy, Structure and Performance

As the entire work is based on some hypotheses, researchers found themselves involved in a strong debate concerning their effectiveness in a complex structure. Explicitly, the dilemma they tried to solve at a glance concerns the whole structure of Clark, Chew and Fujimoto (1987), as it refers to the variables to take into account, and can be easily represented as: "*is it possible to fix a model with these*

kind of variables?" The question seems to be quite easy in its structure, but finds out to be extremely complex. To let the entire model being stable, in fact, these three assumptions should bear:

- the existence of a causal relationship between the variables;
- the possibility to look primarily to individual projects [48, 146];
- the chance to use time-to-market as a final performance of the entire system.

Implicitly, instead, other two important subjects had been only mentioned, without a stronger analysis of their implications. Firstly the idea that NPD process and its outcomes depend on a firm's decision makers' level of perceived uncertainty regarding the external environment [26, 235] had been expressed, with different level of elaboration, but past research⁴ did not precisely explain how organizations adapt the NPD process when the external environment is perceived to be highly uncertain [183]; and finally, an intrinsic hypothesis in the model [36] is the focus on new concepts of an established product in a market in which the firm already competes. Even if the new product will search for open spaces, or niches, in the market itself, the firm needs not to search for a totally new knowledge about the environment in which it is going to operate. Not so far away in the time-line, a strong attention was given to the successful development of new products for new markets. Research, in fact, evidences that the commercial success of new products depends on how well the market opportunity has been identified, analyzed, and incorporated into the product's design [55, 124].

To have a deeper view of the hints expressed here, we will proceed splitting the analysis in brief paragraphs, the aim of which is to introduce the debate and to open some space for further investigations in the actual literature, whenever interested in in-depth elaboration. We won't deal with time-to-market, as deeper analysis will be developed in the next section.

U The effect of uncertainty

UNCERTAINTY has been a central concept in the organization theory literature, particularly in works which seek to explain the nature of the relationship between organizations and their environment [115, 189, 204].

In his classic book, *Organizations in Action*, Thompson [204] asserted that

Uncertainty is the fundamental problem with which top-level organizational administrators must cope

Thompson, J.D.,
Organizations in Action, (1967)

A classical distinction in organizational thinking is between situations that can be described as certain, predictable, well understood, or routine, and situations that are characterized as unpredictable, intractable, or uncertain [25, 180]. An

⁴before the year 1995, and, with a few exceptions [184, 186–188], also till the year 2000

implication of this distinction is that when conditions are certain or predictable, then people can plan and organize their activities to rely on routine and bureaucratic organization [73]. When uncertainty reigns, then people adjust to this lack of information by being more experimental, flexible, and even improvisational [63]. Uncertainty directly affect firms' decisions and results, such as time-to-market and the definition of the boundaries of the firm itself [29, 52, 94, 98, 175]. Past research suggests that there are various type of perceived uncertainty about the environment, including technological uncertainty, consumer uncertainty, competitive uncertainty, and resource uncertainty [58, 98, 134]. Milliken (1987) debated the chance to find a useful conceptualization of environmental uncertainty, and concluded that it was a concept too vast to be useful in literature. As our focus is on product [23], we will center our attention specifically on the effects of technological uncertainty, still considering that the presence of the other "kind" of uncertainty influences in some way all the decision process. The interactions between the different kind of uncertainty need to be considered when developing a complete work about the topic. Perceived technological uncertainty refers to an individual's perception that he or she is unable to accurately predict or completely understand some aspect of the technological environment [134]. As we analyze literature we can often face determinist papers where the idea of uncertainty is in some way left to future debates. If we refer to one of the best reviews in literature [23], even if it has been passing much time since it was published, we could identify a strong emphasis in NPD given equally to the necessity of an organized planning of activities, with the support of management (*rational plan*), on the need of an integrating function able to connect and transfer information (*communication web*) and on the balancing between autonomy and discipline in action (*disciplined problem solving*)⁵. The idea of a successful product intended as a deterministic combination of both planning information exchange and clever solutions is ever present also in other reviews and papers [9, 174], and has been strongly contended during years [183–185]. An interesting and necessary evolution of the theory, often evoked between 1995 and 2001 and never tested before, is the extent of the rational plan perspective by explicitly addressing the moderating effects of perceived technological uncertainty [183]. Another possible perspective suggested by researchers is that product development is consisting of information-processing activities⁶ [23, 34]. The step further suggests that certain organizational approaches and uncertainty combine synergistically to additionally influence work effectiveness (either positively or negatively) [194]. This stream of research took literature another step forward, involving the adaptive process into the NPD machine. The historical debate on whether the organization was inertial and in some way unable to change or it was malleable and can realign with evolving conditions, shifted from *whether* adaptation happens to *when* it occurs [63, 75]. For a wider overview about a debate which is broadening its boundaries ever more, we suggest here (Figure 2.5) some articles, referring to Song and Montoya-Weiss (2001), published in the major international journals (i.e. *Journal of Marketing*, *Strategic Management*

⁵for a complete analysis of the topic and for the complete bibliographic references, we suggest to get back to Brown & Eisenhardt, 1995

⁶The core research approach can be considered here the Information Processing Theory (IPT)

Journal, Journal of Product Innovation Management, Academy of Management Journal et al. between 2001 and 2008, arranged in accordance to the citation level Source: ISI Thompson Web of Knowledge). This work structures a theoretical model examining the moderating effects of perceived technological uncertainty on NPD, and is able to provide an interesting empirical test over more than 500 Japanese projects. An obvious matter is intended to be the geographical confinement of the analysis. At the same time, though, it serves as an interesting explorative and confirmative study that can be considered as one of the most qualified works to spread the analysis on the recent years' research.

Figure 2.5: Best-Cited Articles referring to Song & Montoya-Weiss, 2001

Record 1 of 7

Author(s): Im, S; Workman, JP

Title: Market orientation, creativity, and new product performance in high-technology firms

Source: JOURNAL OF MARKETING, 68 (2): 114-132 APR 2004

ISSN: 0022-2429

Record 2 of 7

Author(s): Song, M; Droge, C; Hanvanich, S; Calantone, R

Title: Marketing and technology resource complementarity: An analysis of their interaction effect in two environmental contexts

Source: STRATEGIC MANAGEMENT JOURNAL, 26 (3): 259-276 MAR 2005

ISSN: 0143-2095

Record 3 of 7

Author(s): Thieme, RJ; Song, M; Shin, GC

Title: Project management characteristics and new product survival

Source: JOURNAL OF PRODUCT INNOVATION MANAGEMENT, 20 (2): 104-119 MAR 2003

ISSN: 0737-6782

Record 4 of 7

Author(s): Atuahene-Gima, K; Li, HY

Title: Strategic decision comprehensiveness and new product development outcomes in new technology ventures

Source: ACADEMY OF MANAGEMENT JOURNAL, 47 (4): 583-597 AUG 2004

ISSN: 0001-4273

Record 5 of 7

Author(s): Cooper, LP

Title: A research agenda to reduce risk in new product development through knowledge management: a practitioner perspective

Source: JOURNAL OF ENGINEERING AND TECHNOLOGY MANAGEMENT, 20 (1-2): 117-140 MAR-JUN 2003

ISSN: 0923-4748

DOI: 10.1016/S0923-4748(03)00007-9

Record 6 of 7

Author(s): Chen, JY; Reilly, RR; Lynn, GS

Title: The impacts of speed-to-market on new product success: The moderating effects of uncertainty

Source: IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT, 52 (2): 199-212 MAY 2005

ISSN: 0018-9391

DOI: 10.1109/TEM.2005.844926

Record 7 of 7

Author(s): Naveh, E

Title: The effect of integrated product development on efficiency and innovation

Source: INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH, 43 (13): 2789-2808 JUL 1 2005

ISSN: 0020-7543

DOI: 10.1080/00207540500031873

Market Knowledge competence

MARKET knowledge is defined as an organized pool of knowledge about the market (or markets) in which the firm acts (or would act in the future) [119]. Market knowledge competence is thus a measure of the ability of the firm to analyze its markets in terms of customer needs and the competitive market in general, specifically defined as “*the capability of the firm to develop a better understanding of customer needs and their evolution and of the competitive environment in target markets*” [100]. Past research suggests that the commercial success of new products depends on how well the market opportunity has been identified, analyzed, and incorporated into the product’s design [55]. For a new product to achieve significant and rapid market penetration it must match such customer requirements as new features, superior quality and attractive pricing [174]. Moreover, a rapid penetration of the market could reduce uncertainty about new products, help the definition of faster development and raise the advantages of time-to-market with respect to the commercial success of the product. Despite the ascertain importance of this imperative [41, 129], research evidences that new product developers often fail in understanding the market [43]. In 1990, Deborah Dougherty wrote:

Improvements in both the theory and practice of product innovation will be limited until the problems with understanding new markets are clarified and solved

Dougherty, D. *Understanding new markets for new products*,
Strategic Management Journal 59-78 (1990)

In literature, this has been one of the hot-topics during 1980s and 1990s, indeed the first empirical demonstration of the influence of market knowledge competence on new product success came in 1990 [235]. Recent empirical research into the concept of market orientation has also shown a positive effect on product success [7, 220], although due to other factors, this relationship may not extend to profitability and market share [8]. Interestingly, the definition of the term “market” is not universally the same in literature. The “market” connotes many issues, including specific technical parameters users want [212], competitors [160], segments defined by their industry, buying habits, or growth, and preferences, features and prices. Depending on how issues are emphasized or combined, a number of market definitions are possible [55]. What lacks in many works is the possibility to clearly signal a common understanding for “*market*”, cause every definition conveys a different meaning, and could require different solutions to be faced.

An interesting evolution of the topic focused on the timing of the market studies: the improvements in the technological settings gave this stream of literature new lifeblood and made it extremely actual. As all products must serve some need of the customer in order to be successful, a product developed either as “push” or “pull” based may indeed fulfill such needs. However, companies that understand these needs prior to market entry (i.e. developing their market knowledge competence) will increase the probability of success [100]. Many authors focused their attention in understanding the right moment in which to begin market studies, depending on their competence not only concerning the specific action of defining needs, but also on their speed-to-market, meaning with it the possibility to get products to the market earlier. The milestone approach [17] slowly left its place

in the literary content to parallel approaches, and to many considerations about readiness to marketplace.

As the competition on taking products that better fit customer needs faster to the market increases, the importance of better understanding customer needs before competitors, and, later on, of faster transforming them into new products, increases. A useful overview of the topic will be given in section 2.4. In an attempt to provide some interesting literature about Market Knowledge Competence, we found that Dougherty, 1990, was a focal point from which to start the analysis of the recent literature. We then recreated a list of recent articles (Figure 2.6), written between the year 2000 and 2008, citing Dougherty (1990), organizing it according to the number of citations they had during time. Citation analysis is based on the premise that authors cite documents they consider to be important in the development of their research, so frequently cited papers are likely to be the most influential on the discipline, with respect to less cited papers [192]. The highly cited documents seemed to have special symbolic significance, standing for specific discoveries, methods, or ideas that were shared by citing authors [181]. As a base to split the entire sample we used the h-index [93]⁷. We decided to refer to ISI Thompson Web of Knowledge as a complete data set concerning the topic⁸ (Figure 2.6).

⁷A scientist has index h if h of [his/her] N_p papers have at least h citations each, and the other $(N_p - h)$ papers have at most h citations each

⁸Web of Knowledge was found to have strong coverage of journal publications, but poor coverage of high impact conferences [133]

Figure 2.6: Best-Cited Articles citing Dougherty, 1990, years 2000-2008

Record 1 of 14

Author(s): Miner, AS; Bassoff, P; Moorman, C

Title: Organizational improvisation and learning: A field study

Source: ADMINISTRATIVE SCIENCE QUARTERLY, 46 (2): 304-337 JUN 2001

ISSN: 0001-8392

Record 2 of 14

Author(s): Wiklund, J; Shepherd, D

Title: Entrepreneurial orientation and small business performance: a configurational approach

Source: JOURNAL OF BUSINESS VENTURING, 20 (1): 71-91 JAN 2005

ISSN: 0883-9026

DOI: 10.1016/j.jbusvent.2004.01.001

Record 3 of 14

Author(s): Sherman, JD; Souder, WE; Jenssen, SA

Title: Differential effects of the primary forms of cross functional integration on product development cycle time

Source: JOURNAL OF PRODUCT INNOVATION MANAGEMENT, 17 (4): 257-267 JUL 2000

ISSN: 0737-6782

Record 4 of 14

Author(s): Davila, T

Title: An empirical study on the drivers of management control systems' design in new product development

Source: ACCOUNTING ORGANIZATIONS AND SOCIETY, 25 (4-5): 383-409 MAY-JUL 2000

ISSN: 0361-3682

Record 5 of 14

Author(s): Franke, N; Piller, F

Title: Value creation by toolkits for user innovation and design: The case of the watch market

Source: JOURNAL OF PRODUCT INNOVATION MANAGEMENT, 21 (6): 401-415 NOV 2004

ISSN: 0737-6782

Record 6 of 14

Author(s): Sethi, R

Title: Superordinate identity in cross-functional product development teams: Its antecedents and effect on new product performance

Source: JOURNAL OF THE ACADEMY OF MARKETING SCIENCE, 28 (3): 330-344 SUM 2000

ISSN: 0092-0703

Record 7 of 14

Author(s): Brockman, BK; Morgan, RM

Title: The role of existing knowledge in new product innovativeness and performance

Source: DECISION SCIENCES, 34 (2): 385-419 SPR 2003

ISSN: 0011-7315

Record 8 of 14

Author(s): Iansiti, M

Title: How the incumbent can win: Managing technological transitions in the semiconductor industry

Source: MANAGEMENT SCIENCE, 46 (2): 169-185 FEB 2000

ISSN: 0025-1909

Record 9 of 14

Author(s): Nambisan, S; Wilemon, D

Title: Software development and new product development: Potentials for cross-domain knowledge sharing

Source: IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT, 47 (2): 211-220 MAY 2000

ISSN: 0018-9391

Record 10 of 14

Author(s): Dougherty, D; Borrelli, L; Munir, K; O'Sullivan, A

Title: Systems of organizational sensemaking for sustained product innovation

Source: JOURNAL OF ENGINEERING AND TECHNOLOGY MANAGEMENT, 17 (3-4): 321-355 SEP-DEC 2000

ISSN: 0923-4748

Record 11 of 14

Author(s): Dong, A; Hill, AW; Agogino, AM

Title: A document analysis method for characterizing design team performance

Source: JOURNAL OF MECHANICAL DESIGN, 126 (3): 378-385 MAY 2004

ISSN: 1050-0472

DOI: 10.1115/1.1711818

Record 12 of 14

Author(s): Maltz, E; Souder, WE; Kumar, A

Title: Influencing R&D/marketing integration and the use of market information by R&D managers: intended and unintended effects of managerial actions

Source: JOURNAL OF BUSINESS RESEARCH, 52 (1): 69-82 APR 2001

ISSN: 0148-2963

Record 13 of 14

Author(s): Sheremata, WA

Title: Competing through innovation in network markets: Strategies for challengers

Source: ACADEMY OF MANAGEMENT REVIEW, 29 (3): 359-377 JUL 2004

ISSN: 0363-7425

Record 14 of 14

Author(s): Zhang, QY; Lim, JS; Cao, M

Title: Innovation-driven learning in new product development: a conceptual model

Source: INDUSTRIAL MANAGEMENT & DATA SYSTEMS, 104 (3-4): 252-261 2004

ISSN: 0263-5577

DOI: 10.1108/02635570410525799

Causal Relationship between variables

SINCE the end of the 80s (as we are considering that period as our beginning milestone for the entire time-line), research showed a strong correlation between variables such that: (1) product strategy determines the product-development agenda and thus task requirements; (2) task requirements directly or indirectly affect the structure and processes a firm might use to organize and manage product development; and (3) overall product strategy and task requirements, as well as the management structure and process for individual projects, directly or indirectly affect project performance and market responses to products [48]. Interesting proofs come from the automotive market, as it suffered for an evolvment due to its global framework and its complex internal structure [71, 138, 146]. The main problem was to define the macro-factors these studies brought to light: one could come away with the conclusion that there is a plethora of factors deemed critical for success or failure of NPD projects [9], included into the macro-areas firstly defined [35, 36] *et al.* Many studies found different ways to classify influencing factors, or to define them out of specific domain areas. For further information about the empirical studies about the topic we refer to Zirger and Maidique [235] with their interesting report on an entire set of works between 1972 and 1974 (SAPPHO studies [170, 171]) and 1987 [44], relating on the possibilities of conceptualization of the research. The growing complexity of the relation between internal and external variables opened some space to further research, driven by the contradictory empirical results about many influencing factors, both market related, technology related, environment related and organization related [9, 235].

To resume, we could say that two are the main critical points in the assumption of the causal relationship between variables: first of all, that it could be extremely hard to limit the number of internal and external factors affecting the single macro-variable; second, that causal relationship among even a selected group of variables may still be unclear because of interdependent effects. At the same time, though, it is our interest to group the variables into macro-areas, so that they could be more easily managed by researchers or managers working on them.

2.3.2 Clustering Variables: some ideas

As the entire framework still showed some shadows to be better defined, and research can be ideally represented as an on-going process aimed at identifying the best solution as a problem arises, we found it interesting to conclude the general analysis of the NPD process experimenting our ideal clustering method of variables, such that they can be easier manageable during research. Our aim is to define an explorative way to depict variables depending on the viewpoint of analysis and on the referred action-point (i.e. the level of the decision-making in the firm). Supported by literature, we found four central clustering methods: the *research stream method* [23], the *environmental method* [9], the *action method* [177] and finally the *functional method* [110]. We gave these methods names that could easily recognize the idea on the basis of their structure, so as to help their research deployment. We suggest to get back to the reviews cited for further analysis, and

we will provide here in brief the concepts underlying each approach.

1. *research stream method*: to follow the streams of research so as to focus on the proposed factors: three main streams of analysis which center respectively on (i) product features, markets and organization, (ii) internal and external communication, and (iii) disciplined problem solving to gather higher economic success in NPD projects. The center of the analysis are some pioneering studies [4, 5, 141], from which these different streams evolved. Interestingly, in the work, it is suggested also a common perspective, which condensate the whole theory in one complete scheme.
2. *environmental method*: the possibility to split the analysis on the basis of four environmental super-structures, respectively market⁹, technology, environment¹⁰ and organization¹¹, has been well developed here in an interesting scheme including many studies with contradictory results, offering in this way some space for further research. The point of view could be considered as external, “super-partes”.
3. *action method*: with the term “action” we would like here to resume the relation between the different factors and the NPD performance, intended in the paper as time, cost and quality of the new product. The factors are grouped in two different sub-structures, respectively centrifugal¹² and centripetal¹³ forces. The point of view is at a process level, meaning that the grouping method is on the effect different processes and structures could have on the specific performance. Managers, thus, could easily access influencing factors knowing the relation between them and the environment, combining their efforts on the perfect mix of effort on the whole system.
4. *functional method*: the emphasis here is on the distinction between the point of view of different functions inside the firm (namely: marketing, organizations, engineering design and operations management) with respect to the same parameters. In a word, while productive solutions differ not only across firms but within the same firm over time, the decision process seems to remain fairly consistent at a certain level of abstraction [110]. This means that the best point of view is not over the firm, but inside the boundaries of the firm itself. The innovative idea is that the distinction occurring between functions of the firm is also the driver for different decisions over time. This means also that structuring decisions with a particular attention on a function specific view is fundamental for the success or failure of the NPD activity. An equilibrium between the functions is the determinant of the

⁹meaning the knowledge of the market and of the customers that could be affected by the new product

¹⁰meaning the political, social and public factors which can affect the product

¹¹meaning the supportive internal activities in NPD

¹²structural elements and processes that increase the quantity and quality of ideas, knowledge and information an organization can access [177]

¹³structural elements and forces that integrate dispersed ideas, knowledge and information into collective action [177]

long-run development of the firm.

The different perspectives here expressed in brief, should also evoke what in the industrial world can be called short-, mid- and long-term planning. Going deeper into the firm and its frame, changing the point of view, is the way to understand how the decisions can appear differently from step to step, thus re-visiting in literature the puzzle of aggregations that should be used in the definition of the factors of influence, depending on the level at which we are looking at the framework.

2.3.3 Why Time-to-Market: the NPD revolution

MANY studies evidenced the importance of TTM in the industrial framework throughout the last two decades of the 19th century. The double role of TTM and the exploitation of newer technologies, with the aim of fastening the pace of new product development (NPD), is the source of its influence on the entire process. Literature proved the double-sided relation between TTM and the other main performance parameters, thus in some sense conferring to TTM an upper-level role in the battle to gain competitive advantage. In particular, we dwell on the relation occurring between:

- time and cost: this seems to be an opposite relation as when the firms strives to lower TTM, it should raise its investments in tools and skills. We will see in a few (Section 2.4) how modern literature proved that this relation could also reverse, as both time and cost could decrease in a good-for-good spiral;
- time and quality: TTM seems to reflect on the final quality of products, as the time spent in designing and testing them could strongly influence the results gained in the production process. At the same time, though, literature reflects on the evolution of technology as an innovation in methods and tools, thus giving birth to new streams of analysis counterbalancing the negative-effect proposition with a positive-effect one;
- time and customer: shorter TTM means the firm should exploit less time to react to market requirements, thus contributing to better economic results and an improvement in the corporate image on the market. At the same time, though, faster new product development could generate mistrust, thus needing further information release and higher marketing investments to convince customers.

In general, we state here that a reshaping of time to market could also reshape company's economic results. Moreover, it is interesting to observe that there are many factors able to influence, directly or indirectly, time performance, thus generating a front-back relation that *needs* to be further analyzed. Two streams of literature seemed to take place during years: on one side, the idea that TTM is the tail of the firm effort, as it is seen to generate, stand alone, better results

in all the main performance indicators; on the other, the idea that TTM has to be seen as an intermediate factor, influencing in some way (contrasting results in literature) the effects of operational performance on financial ones. In this second perspective, the idea to focus on TTM as a stand-alone performance is suggested to negatively influence the NPD process results. The profound changes TTM can unleash internally and externally a firm organization and decision making sustain the ten-yearly research programme on this subject.

We decided here to develop a sort of “paper-in-the-paper”, with the general structure of a stand-alone work: a theoretical introduction, aimed at giving birth to a soft description of the research framework, an in-depth analysis of the advantages and disadvantages of reducing time-to-market and a description of the most common approaches to TTM reduction. We help the reader listing some recent papers showing the last advancements in literature findings since 2001 till today. The aim of this second structured study reflects what we did in the first part of the paper: showing how past and recent literature faced the matter of analysis opens space both for some final considerations, and also for further works on the topic, both confirmative and explorative. We finally provide our position, and in particular we pose the existence of a third way with respect to the double development path we found in literature. We highlight the important effects both technical advancements, research improvements and organizational solutions could bear to the main performances in the NPD process. We further evidence the chance that the contrasting empirical demonstrations regarding the effects of shorter TTM on the main performances of the NPD process could be the effect of an inaccurate application of the main approaches aimed at TTM reduction. This perspective represents a tie connecting the borders of the entire set of theories on fastening NPD.

2.4 Time-to-Market and New Product Development: a long-lasting relation

THE emphasis on accelerating the product innovation is not new, with the presence of some contributions since the beginning of the 1960s. Since the end of the 1980s, though, it has acquired greater importance due to the increasing costs of slow product development [82]:

The rules of the game in new product development are changing. Many companies have discovered that it takes more than the accepted basis of high quality, low cost, and differentiation to excel in today’s competitive market. It also takes speed and flexibility.

Takeuchi and Nonaka, “The New New Product Development Game”,
Harvard Business Review (January/February) 1986.

Those who grasp the new calculus, who appreciate the unprecedented advantages of getting new products to market sooner and orders to customers faster, may well hold the principal tool for achieving competitive preeminence in coming years.

“How Managers Can Succeed Through Speed”, Fortune, February 13, 1989

In the future we might end up developing enabling technologies two years before the Japanese, only to fall behind in the market place because we did not implement this technology quickly enough.

Bobby Inman, Former President and CEO, MCC,
in an interview with World (March/April 1986)

Typically, managers regard time as a scarce resource and as a consequence attempt to analyze and optimize its use [106]. The demand for speed in the workplace is increasing, and this phenomenon forms the basis for recent efforts into speeding up innovation. Even if the issue of *doing things faster* is not new, only in the last two decades scholars have addressed themselves to the importance of time in innovation where costs and performance have typically been the chief metrics.

2.4.1 Theoretical Introduction

MANY are the contributions about the relationship occurring between TTM and NPD, and the reason is that during a long period of time TTM has been seen as one of the most influencing factors to gain product success and better financial performances. Moreover, in the last two decades, NPD speed became absolutely critical not only because product life cycles are shrinking, and obsolescence is occurring more quickly than in the past, while competition has also intensified [178] but also to deal with the continuous change in customer needs [3] and to rapidly incorporate new technologies into products [224]. Very briefly, it has become imperative for firms to move products to market faster to grow [47, 80]. The many different definitions of innovation speed during years left some space of discussion about the clear meaning of the word itself. A brief list of selected definitions and measures of innovation speed as far as the year 1995 is provided in Figure 2.7.

The interest about the theme has grown even faster since the beginning of the 90s, and many articles in the business press and academic literature maintained that one of the primary means for achieving competitive advantage through product development is by accelerating the development process:

There are significant economic rewards that stem from faster NPD. Earlier product introduction improves profitability by extending a product's sales life, creating an opportunity to charge a premium price, and allowing development and manufacturing cost advantages. Particularly in high-growth markets involving short product life cycles, the overall impact of NPD speed on profitability is compelling.

Karagozoglu, N. and Warren, B.B. (1993), *Time-Based Management of the new product development process*, Journal of Product Innovation Management Vol. 10

Many authors dealt with some interesting esteems on the profit losses caused by the late arrival of the products on the market. They seem to work as the proof

Author(s)	Definition and Measure of Innovation Speed
Gee (1978)	The time between the conception of an innovation (first invention or basic discovery) and its introduction into the commercial market.
Keller (1986, 1994)	The degree to which a project met an assigned schedule.
Mansfield (1988)	The length of time elapsed from the beginning of applied research (if there was any) by the innovator on a new product or process to the date of the new product's or process's first commercial introduction.
Clark (1989a); Clark & Fujimoto (1991)	The time elapsed between start of the development process and market introduction (i.e., lead time).
Schoonhoven, Eisenhardt, & Lyman (1990)	Waiting time to first produce shipment of new firms.
McDonough & Barczak (1991); McDonough (1993)	The degree to which a project was ahead, on, or behind schedule.
Birnbaum-More (1993)	The degree to which a new product was introduced to the market sooner or responded to another firm's competitive product introduction faster than others (i.e., racing behavior).
Tabrizi & Eisenhardt (1993)	The time from the first meeting to consider the development of a new product to its stabilization.
Cooper & Kleinschmidt (1994)	The degree to which a product stayed on schedule, and the degree to which the work was done relative to how fast it could have been done.
Ali, Krapfel, & Labahn (1995)	Total project time from the beginning of idea generation to the end of market launch in months and in person-years.
Nijssen, Arbouw, & Commandeur (1995)	The degree of acceleration, or ratio faster or slower than previous projects.

Figure 2.7: Selected definitions and Measures of Innovation Speed [105]

of the concrete relevance of TTM during the NPD process. Clark (1989) evaluated that for a \$10000 car, each day of delay in introducing a new model represents a \$1 million loss in profits. Moreover, as Cohen, Eliashberg and Ho report in their work (1996), a study by McKinsey evidences that, on average, companies lose 33% of after-taxes profits when they ship products six months late, as compared with losses of 3.5% when they overspend 50% on product development [39]. As a result of the evidence of an increasing temporal pressure, many companies¹⁴ have invested great resources into shortening their product development cycle time [100], adopting time-to-market as their principal product development metric [39]. The extensive research underlying this body of literature has often assumed that speed to market is the most crucial factor behind new product success, and consequently has empirically researched which factors drive an accelerate product development process. This literature has mainly examined the relationship between key development process drivers and time performance [57, 67, 68, 104, 106, 127, 136, 190], *et al.* Even though, only few studies explicitly and empirically investigated the relationship occurring between time performance and product success [23], and speed remains one of the least studied factors in the new product development literature, with only a (relatively) few systematic empirical tests of propositions [106]¹⁵. Moreover, the results of these studies often show that a clear relationship between time performance and product success does not emerge in empirical data. One implication is that there may be other factors interacting in the relationship [67, 104]. One of the main alternative school of thoughts emphasizes product performance: as shown in empirical studies [44, 235], new product success depends critically on its performance¹⁶ and its value for the customer. Clearly these observations provide space to improve existing products, even if such improvements often take more time to develop and can significantly delay the product launch [39, 81, 231]. As the research continues to grow, there is an increasing empirical evidence that a trade-off solution is necessary: significant improvements in product performance have the potential to capture a larger market share for competing (or substitute) products, but they take too long to accomplish and, consequently, the company will miss the window of opportunity. At the same time, less ambitious improvements in product performance can be achieved quickly, but they may not attract too many customers, so the rushing to the market can represent a failure for the firm. Performance is thus hypothesized to be a function of the interaction between cycle time, organizational practices [97], market knowledge competence [100], environmental features [65], product features [235] and process structure [54].

The work will proceed according to the following precise scheme: firstly (Section 2.4.2) we will widen the concept of fastening the NPD process through the report on the advantages-disadvantages debate. Then, we will proceed with some practical approaches (Section 2.4.3), with the intriguing conflicting results of the main confirmative studies. We will support our considerations with brief sugges-

¹⁴e.g. General Electric, Hewlett Packard, Motorola, Xerox et al. [39, 56]

¹⁵During the period between 1999 and 2008 many studies tried to fill the gap of knowledge about the topic, so we could assert that now literature is fairly less incomplete

¹⁶i.e. unique features, innovativeness, technology, appeal, all of them define a superior product [44]

tions about the main works on the topic, according to their ordering by citation index. The aim of the next sections will be mainly explorative: literature proved to be hardly understandable, and the main influences as regards TTM seemed to shade each other, such that their effectiveness fluctuates depending on the exogenous characteristics of the external environment; at the same time, though, we will prove that the advantages it showed in the industrial world grew (and are still growing) consistently along with the advancements in technology, and built up a literary framework strong enough to be analyzed. Moreover, we could state that time-to-market represents in the actual industrial world the most important performance/parameter to work on if firms want to compete and to be successful on the market. More effort should be exploited on the exploration of the external elements driving the final performance measure, as to deeper investigate firms' (intra- and inter-boundary) structure. We state, then, that also exogenous variables strongly influence endogenous solutions. Their power is still under investigation as literature proved to be contradictory while reporting on empirical case study analysis. A clear answer to the TTM dilemma is still under construction, and we will here report about the main hot topics to work on.

2.4.2 Advantages of faster NPD: A Prove and some Out-of-the-Chorus voices

PAST research focused on the advantages of faster New Product Development so as to understand the best way to exploit the new technologies and methodologies in an attempt of gaining better performance. Many qualitative works analyzed the reasons to put some more effort on fastening NPD. In an interesting study by Gupta and Wilemon (1990), the authors gave an introductory explanation of the main reasons to accelerate NPD; the findings of the work, as resumed in Figure 2.8, came from direct interviews to 38 key participants in the NPD process of 12 large technology-based firms.

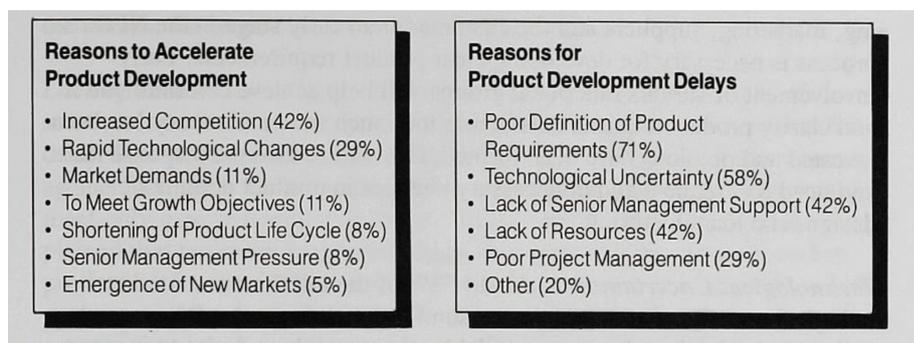


Figure 2.8: NPD Process Assessment (Gupta & Wilemon, 1990)

Other clustering methods seemed to improve the knowledge about cycle time reduction. Specifically, the main reasons to implement cycle time minimization

strategies according to a vast part of literature¹⁷ resemble:

1. *competitive advantage*, such as first-to-market benefits [21,24,106,113] *et al.*;
2. *cost reduction* through simplification, the elimination of delays and/or steps, and parallel processes;
3. *enhanced profitability* through higher initial prices, greater market share, and customer loyalty [120,135].

The belief that innovation speed can build competitive advantage stems from the notion that speed can facilitate either first-mover¹⁸ or second-mover strategies, depending on which is favored by industry conditions [106]. The first mover in an industry can: (1) build brand loyalty¹⁹ or as well increase buyer switching costs, such that late entrants must invest extra resources to attract customers away from the first-mover firm; (2) gain technological leadership, both with the exploitation of the experience curve, where costs fall with cumulative output, and with the success in patent or R&D races, so as to protect innovations for a number of years; and (3) preempt rivals in the acquisition of scarce assets, such as physical resources or other process inputs, both already existing or created by the firm through the development of a new technology, or eventually related to positioning in “space”, including geographic space, product space and so on.

In literature there exist many different ways to express the same concepts, we decided to cite here a couple of them as an example:

Introducing new products faster than the competition allows firms opportunities such as setting product standards, being a technical pioneer, being able to rapidly respond to customer feedback, and ultimately realizing higher profit margins.

Zirger, B.J. and Hartley, J.L. (1996), *The effect of acceleration techniques on Product development time*, IEEE Transactions on Engineering Management, Vol. 43

Companies with short cycle times can continually upgrade their products, incorporating state of the art technology when it becomes available. This enables them to better serve consumer needs, outrun their slower competitors and build brand loyalty. It also enables them to offer a wider range of new products to better serve niches.

Schilling, M.A. and Hill, C.W.L. (1998), *Managing the new product development process: Strategic Imperatives*, Academy of Management Executive, Vol. 12

¹⁷See Figure 2.9 for a deeper review of the main researches published between 2001 and 2008 about the topic, and the cited works below

¹⁸We define first mover advantages in terms of the ability of pioneering firms to earn positive economic profits [120]

¹⁹as noted in Schilling & Hill, 1998, brand loyalty may be important even in industries in which rapid technological change causes short product life cycles. In fact, when technological change is fast and the technology is complex, brand loyalty may reduce the uncertainty of customers who wish to stay on the technology frontier but who would be unable to adequately assess the quality of each successive technological generation.

As a demonstration of the reasonable assumption that “*first to market wins*” during the last two decades many researchers tried to quantify the enduring advantages in distribution, product-line breadth, product quality and market share [22, 96, 140, 191, 211] *et al*²⁰. Several studies of the PIMS (profit impact of market strategies) database show that mean market shares over a large cross section of businesses are around 30% for pioneers, 19% for early followers and just 13% for late entrants²¹. Moreover, more than 70% of the current (at the end of the 80s) market leaders are market pioneers. Pretty similar estimates were found using the ASSESSOR data²².

As most of the researchers came to believe in the strong advantages of market pioneering, some of them began to warn of potential problems of the empirical studies realized till that moment [103], and some other found sort of incoherence in their ideas as working on wider examinations [121]. First-mover disadvantages have been discussed since the end of the 1980s [120] firstly as sort of healthy disagreement between the authors of the same paper [121], and in a few years the debate enlarged to empirical demonstration with both established and emerging generalizations [101]. The mechanism that benefit the first-mover has been rapidly counterbalanced by various disadvantages, representing in some sense the advantages joined by late-movers [120]. These “disadvantages” seem to be stick to the same principles of the first mover advantages, in that the ability of late-entrants to respond fast to first movers is still to be considered as an un-equivocal advantage. At the same time, though, the recognition of some weaknesses in the first-mover theoretical definition lies on the concepts of free-riding on investments, resolving uncertainty matters, profiting by technological discontinuities, and exploiting improvements own to a better definition of the product and of user needs. Great enhancements in nowadays technology in some sense lightened the objective importance of these parameters, thus leaving some space for renewed considerations of the whole research structure. During the 1990s, finally, the debate on the influence between time and cost of the NPD process caught fire. Literature found itself split into two mainstreams, on one side the supporters of shorter TTM as an advantage, while on the other opponents proving it to be economically disadvantageous to faster the process, as it could increase firm’s expenditures. The latter, in fact, posed that the increased effort on the re-structuring of the entire organization could lead up to the possible generation of hidden costs [42, 47, 79, 154, 184] hailing from:

- Low profits, ought to the drive out of the breakthrough innovations²³: re-

²⁰An interesting and wide bibliography can be found in Lieberman and Montgomery [121]

²¹The main reference for the data is R.D. Buzzel and B.T. Gale, *The PIMS Principles: Linking Strategy to Performance* (New York: Free Press, 1987) but for the hints in this work we will use comments by Tellis & Golder, 1996. Other studies can be cited still using the PIMS dataset, and we claim that an interesting bibliography can be found in [195].

²²See the note above, here the main reference is G.L. Urban, T. Carter, S. Gaskin, and Z. Mucha, “Market Share Rewards to Pioneering Brands: An Empirical Analysis and Strategic Implications,” *Management Science* 32 (1986): 645-659

²³Gresham’s Law (*if a monetary system contains a mix of sound and unsound paper, the bad money will always tend to drive out the good*), applied to innovation, considering “bad” the incremental kind, and “good” the breakthrough one

sources devoted to incrementalism may be more highly protected in the short run, leaving breakthrough projects to lag, even if more profitable if considered on the long run;

- Increasing mistakes due to the lack of necessary information and skipping necessary steps²⁴;
- Process inefficiencies due to inaccurate organizational and process changes, or to under-pressure working conditions²⁵;
- Complex team structures fail to work together creating chaos, due to lack of communication and training²⁶

Resuming, a stream of literature, still aware of the effort (monetary, human-related, organizational) requested to faster the NPD process, followed the path of *shorter TTM today for economic rewards tomorrow*, while the other one focused on the hidden costs of accelerated product development, assuming these superior to the possible advantages for the firm²⁷. In an attempt to empirically prove the inadequacy of first-mover-advantages as an indicator of the firm success (thus an indicator of higher performances), Golder and Tellis (1996) re-worked on the PIMS data, in a research turning out to be a deep upset of the previous results: market pioneers were found to have a failure rate around 47%, with an average market share only around 10%, and a median period of market leadership not exceeding 5 years. By comparison, firms that were early market leaders, but not necessarily pioneers, had low failure rates (8%) and large average market shares (28%). The turnaround between analysis built on the same data-set may depend on the fact that PIMS and ASSESSORS only refer to surviving firms and may be biased by the interviews of current employee of the firm [195]. Moreover, the understanding of new product categories is roughly complete [121]. These considerations taken together suggest that the first mover advantages alone could not totally explain the success rate of the companies. In other words, believing that entry order automatically confer evident and immutable advantages is naive [103]. It is hard to know, then, if the results Golder and Tellis found in their empirical analysis are better supported with respect to previous studies. What remains from their work is the impression that first-mover advantage and its real effects on industries should be better analyzed. At the same time, though, an interesting insight of the

²⁴As research defined three main reasons for a project failure (no need for the item, needs not met by the object and no wisely marketing of the product), it is possible to overcome all of these with a deep market research during development. Thus, the lack of market information could deeply influence new product success

²⁵The need to widen the testing stage proved to be necessary, but the under-pressure conditions make it impossible to be well developed, so the system could crash as it really needs to work straightly

²⁶See the Toyota case in the USA, where the training centers failed to transfer the sufficient knowledge to workers, generating a worsening spiral into the firm [28]

²⁷An interesting work on the topic has been expressed in A. Camuffo and D.R. Weber (2009), *Il Toyota Way e la Crisi: Tornare alle origini del lean management per sopravvivere e prosperare, Economia e Management Vol.3*, a section of which regards the internal debate in Toyota on the relationship between the reduction of TTM and the quality problems of the vehicles

industrial world suggest that TTM has to be strongly taken into account, as it provides advantages (we would like to remember that first-mover is only a slight part of the whole) that needs to be exploited by firms, no more as a surplus, but as a necessary condition to survive.

To fulfill our analysis on the advantages of faster new product development, we suggest a list of papers that could be useful for deeper studies. We used *ISI Web of Knowledge* to catch papers citing Lieberman and Montgomery (1988), then we refined the sample such that it shows the list of the most influencing works (most-cited, we used the h-index method) published since the year 2000 in the top journals (according to the impact factor method [74]). The list in Figure 2.9 is ordered according to the number of citations, from the top (most cited) to the bottom (least cited).

Figure 2.9: Articles citing Lieberman & Montgomery (1988) since the year 2000
source ISI Thompson Web of Knowledge

Record 1 of 19

Author(s): Amit, R; Zott, C

Title: Value creation in e-business

Source: STRATEGIC MANAGEMENT JOURNAL, 22 (6-7): 493-520 JUN-JUL 2001

ISSN: 0143-2095

Record 2 of 19

Author(s): Rothaermel, FT

Title: Incumbent's advantage through exploiting complementary assets via interfirm cooperation

Source: STRATEGIC MANAGEMENT JOURNAL, 22 (6-7): 687-699 JUN-JUL 2001

ISSN: 0143-2095

Record 3 of 19

Author(s): Rindova, VP; Kotha, S

Title: Continuous "morphing": Competing through dynamic capabilities, form, and function

Source: ACADEMY OF MANAGEMENT JOURNAL, 44 (6): 1263-1280 DEC 2001

ISSN: 0001-4273

Record 4 of 19

Author(s): Simon, M; Houghton, SM; Aquino, K

Title: Cognitive, biases, risk perception and venture formation: How individuals decide to start companies

Source: JOURNAL OF BUSINESS VENTURING, 15 (2): 113-134 MAR 2000

ISSN: 0883-9026

Record 5 of 19

Author(s): Lumpkin, GT; Dess, GG

Title: Linking two dimensions of entrepreneurial orientation to firm performance: The moderating role of environment and industry life cycle

Source: JOURNAL OF BUSINESS VENTURING, 16 (5): 429-+ SEP 2001

ISSN: 0883-9026

Record 6 of 19

Author(s): Isobe, T; Makino, S; Montgomery, DB

Title: Resource commitment, entry timing, and market performance of foreign direct investments in emerging economies: The case of Japanese international joint ventures in China

Source: ACADEMY OF MANAGEMENT JOURNAL, 43 (3): 468-484 JUN 2000

ISSN: 0001-4273

Record 7 of 19

Author(s): Schilling, MA

Title: Technology success and failure in winner-take-all markets: The impact of learning orientation, timing, and network externalities

Source: ACADEMY OF MANAGEMENT JOURNAL, 45 (2): 387-398 APR 2002

ISSN: 0001-4273

Record 8 of 19

Author(s): Steensma, HK; Corley, KG

Title: On the performance of technology-sourcing partnerships: The interaction between partner interdependence and technology attributes

Source: ACADEMY OF MANAGEMENT JOURNAL, 43 (6): 1045-1067 DEC 2000

ISSN: 0001-4273

Record 9 of 19

Author(s): Denrell, J; Fang, C; Winter, SG

Title: The economics of strategic opportunity

Source: STRATEGIC MANAGEMENT JOURNAL, 24 (10): 977-990 OCT 2003

ISSN: 0143-2095

DOI: 10.1002/smj.341

Record 10 of 19

Author(s): Lee, H; Smith, KG; Grimm, CM; Schomburg, A

Title: Timing, order and durability of new product advantages with imitation

Source: STRATEGIC MANAGEMENT JOURNAL, 21 (1): 23-30 JAN 2000

ISSN: 0143-2095

Record 11 of 19

Author(s): Sorenson, O

Title: Letting the market work for you: An evolutionary perspective on product strategy

Source: STRATEGIC MANAGEMENT JOURNAL, 21 (5): 577-592 MAY 2000

ISSN: 0143-2095

Record 12 of 19

Author(s): Covin, JG; Slevin, DP; Heeley, MB

Title: Pioneers and followers: Competitive tactics, environment, and firm growth

Source: JOURNAL OF BUSINESS VENTURING, 15 (2): 175-210 MAR 2000

ISSN: 0883-9026

Record 13 of 19

Author(s): Song, M; Droge, C; Hanvanich, S; Calantone, R

Title: Marketing and technology resource complementarity: An analysis of their interaction effect in two environmental contexts

Source: STRATEGIC MANAGEMENT JOURNAL, 26 (3): 259-276 MAR 2005

ISSN: 0143-2095

Record 14 of 19

Author(s): Folta, TB; O'Brien, JP

Title: Entry in the presence of dueling options

Source: STRATEGIC MANAGEMENT JOURNAL, 25 (2): 121-138 FEB 2004

ISSN: 0143-2095

Record 15 of 19

Author(s): Kessler, EH; Bierly, PE

Title: Is faster really better? An empirical test of the implications of innovation speed

Source: IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT, 49 (1): 2-12 FEB 2002

ISSN: 0018-9391

Record 16 of 19

Author(s): Gavetti, G; Levinthal, DA; Rivkin, JW

Title: Strategy making in novel and complex worlds: The power of analogy

Source: STRATEGIC MANAGEMENT JOURNAL, 26 (8): 691-712 AUG 2005
ISSN: 0143-2095
DOI: 10.1002/smj.475

Record 17 of 19

Author(s): Alvarez, SA; Barney, JB
Title: Organizing rent generation and appropriation: toward a theory of the entrepreneurial firm
Source: JOURNAL OF BUSINESS VENTURING, 19 (5): 621-635 SEP 2004
ISSN: 0883-9026
DOI: 10.1016/j.jbusvent.2003.09.002

Record 18 of 19

Author(s): Agarwal, R; Sarkar, M; Echamebadi, R
Title: The conditioning effect of time on firm survival: An industry life cycle approach
Source: ACADEMY OF MANAGEMENT JOURNAL, 45 (5): 971-994 OCT 2002
ISSN: 0001-4273

Record 19 of 19

Author(s): Brush, TH; Bromiley, P; Hendrickx, M
Title: The free cash flow hypothesis for sales growth and firm performance
Source: STRATEGIC MANAGEMENT JOURNAL, 21 (4): 455-472 APR 2000
ISSN: 0143-2095

As we focused on the downstream part of the whole relational set of TTM, we will now search for the upstream approaches a firm can exploit to gain faster TTM advantages. Many works dealt with this topic, and we found it manageable to resume the approaching framework with the use of some fundamental pioneers, supplemented with other contributions aimed at providing empirical proofs and detailed explanations.

2.4.3 NPD acceleration approaches

A long-lasting stream of international literature focused on the main factors affecting time to market [27,39,53,54,155,232] *et al.* During years, many classifications have been done by different authors, first of all defining a 5-point scale of techniques [135] and then trying to integrate it with different approaches, covering the main shadows of the earlier works [56,113,114]. As the advantages of a faster NPD were gradually being demonstrated, even if with some out-of-the-chorus voices, the focus of researchers gradually centered on the methods to get the best results. The last decade, thus, has been characterized by a growing literature on the topic, since Millson, Ray and Wilemon (1992) shed light different approaches, clustering similar techniques, aimed at:

1. simplifying NPD operations;
2. eliminating unnecessary NPD activities;

3. paralleling NPD activities;
4. eliminating delays in the NPD process;
5. speeding up NPD operations.

In a few years, the lack of an empirical demonstration of the effectiveness in reducing development time and improving profitability, which was the main shadow-point of the analysis, was covered even if an intrinsic lack of definition relative to the individual approaches belonging to each technique still remained, and thus it is not evident which approach NPD teams can adopt to accelerate the process and to capitalize on first-mover advantage. In order to face and overcome the problem, since the end of the 90s, many studies proposed different lists of actions (or group of actions).

Droge, Jayaram and Vickery (2000) defined 14 individual techniques, clustered them into four groups (respectively, (1) human resource management, (2) synergistic integration, (3) supplier closeness and (4) design manufacturing interface) and empirically investigated their impact on NPD cycle time reduction both the single-variable effect and the group effect²⁸.

Kessler and Chakrabarti (1996) identified a conceptual model of innovation based on the distinction between strategic orientation and organizational capability, and then tested it empirically [106]. The categorization represents a clustering method of related factors discussed in literature and is consistent with the distinction between the strategic- and administrative-based dimensions of accelerated product development [47], and with other approaches [21, 139]. Inside each of the two broader categories, the authors found two subgroups: respectively, strategic orientation can be divided into *criteria-related factors* (i.e. the variables affecting speed of development through the priorities and objectives they set for projects) and *scope-related factors* (i.e. decisions regarding the amount of task undertaken by an innovator), while organizational capability can be split into *staffing related factors* (i.e. the assignment of key personnel within the development process) and *structuring-related factors* (i.e. the integration mechanisms within teams and units).

Langerak, Peelen and Nijsen (1999) suggested an approach based on more than 50 individual techniques that teams can adopt to achieve cycle time reduction; to render their empirical study more manageable, they used a clustering approach reducing the entire sample to nine NPD acceleration approaches, specifically: (1) supplier involvement; (2) lead user involvement; (3) speeding up activities and tasks; (4) reduction of parts and components in the new product; (5) training and rewarding employees; (6) implementing support systems and techniques; (7) stimulating cross-functional cooperation; (8) emphasizing value for customers; and (9) simplifying the organizational structure. An empirical test of the effectiveness of these techniques hasn't been realized yet, and this consideration leaves some

²⁸The analysis has been made on the automobile supplier industry. Many other factors can impact time minimization ability, the importance of timing itself may vary across industries, practices that accelerate timing in one industry may be more or less effective in another [56]

space for further investigations²⁹.

The interesting step forward in research is the empirical relation between NPD acceleration approaches and both speed and profitability of the firm [113]. The ideal results of this approach is to find the relation between speed and financial performance, and in such a case to identify the effect (positive, negative, combined) that the suggested approaches could gain as economic reward. The results of empirical studies proved to be slightly contrasting, thus requiring further analysis. This took researchers to focus their attention the structured timing of introducing innovations, as a newer method-identification approach. Approaches used at different time along the value chain proved to have different effects on the final results. Moreover, a thoughtful combination of approaches gives firms the chance to join the advantages they proved to exploit as used individually. Even if the emphasis between a random hierarchy and a MRW [135] hierarchy showed that the number of different acceleration methods accepted by the firm has a larger impact on cycle time than the order of implementation³⁰, the random approach has the highest impact on the degree of speed accomplished, the correlation analysis with regard to performance shows that this is done to the neglect of the costs and/or customer fit. Only MRW-HIERARCHY is positively and significantly correlated with most of the performance measures [143]. Even though, in their empirical test Droge, Jayaram and Vickery (2000) found that only three (i.e. computer aided design and engineering, group technology, and cross-functional teams) over fourteen techniques significantly reduced NPD cycle time, and only two over the four approaches (i.e. synergistic integration and supplier closeness) were significant related to development speed. Langerak and Hultink (2005) found that five out of nine NPD acceleration approaches [114] (i.e. supplier involvement, lead user involvement, speeding up of activities and tasks, training and rewarding of employees, and simplification of the organizational structure) increase development speed. Implementing support systems and techniques and stimulating inter-functional coordination decrease development speed. Finally, as they tested also the approaches connected to new product profitability, they found that only three of them (i.e. lead user involvement, training and rewarding of employees, and an emphasis on the customer) improve profitability, while other three (i.e. speeding up activities and tasks, reduction of parts and components, and implementation of support system and techniques) were found to decrease new product profitability [113].

Some conclusions could be taken by carefully observing data in our hand at the moment: first of all, that not all the NPD acceleration approaches suggested in literature to improve speed are effective even though it seems that the “ideal-hierarchy” has been found to be significantly correlated with NPD performances [143]. The obvious implication is that firms should carefully choose which practices to implement to get the best results. Moreover, as a first empirical connection between NPD acceleration approaches and profitability has been done, even if the relation between speed and profitability hasn’t been empirically tested yet, we could affirm that the findings of the earlier studies on the topic are consistent with

²⁹As explicitly noted in the “Limitations and Directions for Further Research” section of the paper [114]

³⁰As highlighted by the correlation coefficient of RANDOM EMPHASIS, that is evidently higher than that of MRW-HIERARCHY [143]

the theory that suggests a trade-off solution between time and financial performance [47]. This trade-off is depending upon which NPD acceleration approaches firms intend to adopt [113]. In brief, “*If you speed it up and make a mistake... it adds to time and it adds to cost*” [152].

2.5 Our position: an intermediate model in NPD practice

THE aim of our work is twofold. On the one hand, we decided to depict an introductory scene concerning New Product Development, as to supply readers of the principal information about the theme, enabling them to build up future researches. On the other, we tried to focus on what we considered to be the most important performance in NPD in the actual industrial world, Time-to-Market. In the course of our literature review, we found evidence of the strong effort posed on the use of Time-to-Market as a performance as progressing a NPD process. Our paper shows how, since the 1980s, this theme has been viewed as one of the main matters to be solved both to be competitive and to stay into the competition. In particular, we provided the readers of some proofs of the effects a shorter TTM generates along the value stream and of the main approaches commonly known to be successful in reducing TTM. We state that TTM should be considered the main performance while referring to the fast development in the industrial world since, as needs, technology, methods, tools are changing so fast, firms should adapt to these changes accordingly. At the same time, though, we highlighted some misunderstandings while talking about TTM. In fact, we found evidence of the existence of two contrasting theories, as literature seemed to split over two different evolutionary paths: on one side, authors proving that shorter TTM is by itself an advantage for the firm [21, 24, 106, 113], on the other, authors suggesting that saving time intended to be as the main purpose of the firm can show many shadows concerning the whole set of performances to be analyzed [42, 47, 154, 184]. In brief, we refer to these two streams of literature as: (1) *TTM itself generating advantages* and (2) *Savings without a clear purpose*. Both found empirical evidence. However, the space in between these two theoretical streams, seems to reduce during time. The main disadvantages of a shorter TTM, in fact, specifically ground on both (1) late entrants advantages, as counterbalancing the exploitation of first mover benefits, and (2) the use of time as a stand-alone performance, while quitting the reflection on the entire framework of analysis. In a word, then, we state that if firms are striving to achieve better TTM results, they could lose some internal competencies as sharing the production stream of the product with suppliers, without keeping in-house the main integration capabilities, or even quit some time-consuming activities; this will lead to the achievement of better TTM performance while involving misleading considerations on the state of the entire process, as it could lead to qualitative matters that should be solved after the market introduction of the new products, thus involving also image and cost damages impacting on future products [28], or even a detrimental future state, causing an

internal crisis hardly solvable. The mirror effect on the future directions of the firm cannot be seen if we refer simply to a myopic short-term perspective, but it is fundamental if we consider a long-term decision strategy.

With this work, we provided a strong literature review on this topic, but we would like here to express and partially answer a question we had in mind since the beginning: as empirical proofs seem to be inconsistent, as contrasting theories still arise, how can we decipher reality? How is it possible to depict it? Time-dependent or time-opponent?

Our position is in some sense a middle-way; we state, in fact, that:

- A shorter TTM is an advantage for the firm if it is willing to compete on fast-changing markets. In particular, firms should consider that the reaction to the evolutions in technology, to the changes in customer needs, and to competitors' innovations on the market, requires more and more effort on fastening the NPD approach, thus stronger attention should be posed on TTM as the main performance indicator of the entire NPD process;
- The space between the two counterbalancing literary paths is reducing due to:
 - Technological evolution: new technological solutions are available, providing faster tools and better qualitative results as firms strive to use them;
 - Organizational and Strategic solutions: lighter organizations, aimed at integrating spread over knowledge while quitting bureaucracy as intended to be one of the source for a slower NPD process, seem to be on hand as firms strive to maintain their integration capabilities with respect to direct production skills;

This can be seen as an advantage for short-term focused firms, even though it could hide their main problems, according to the principle that only when there are some troubles, then all the matters come to light;

- Firms should deal with both the advantages and disadvantages of shorter TTM solutions, as both proved to be effective. Thus, literature itself should work with a new concept as referring to the NPD process: the joint consideration of both goods and bads is the solution to achieve better performances for the entire process;
- TTM should not be the real focus of the firms' effort, as it represents a consequence more than a source of improvement.

We graphically resumed the concept in Figure 2.10.

Thus, we state that firms should strive to deal with shorter TTM solutions, while at the same time improving the entire NPD process: a better NPD process, in fact, allows the achievement of both shorter TTM, still keeping in evidence all the other performance indicators (costs, quality), determinant as concerns the

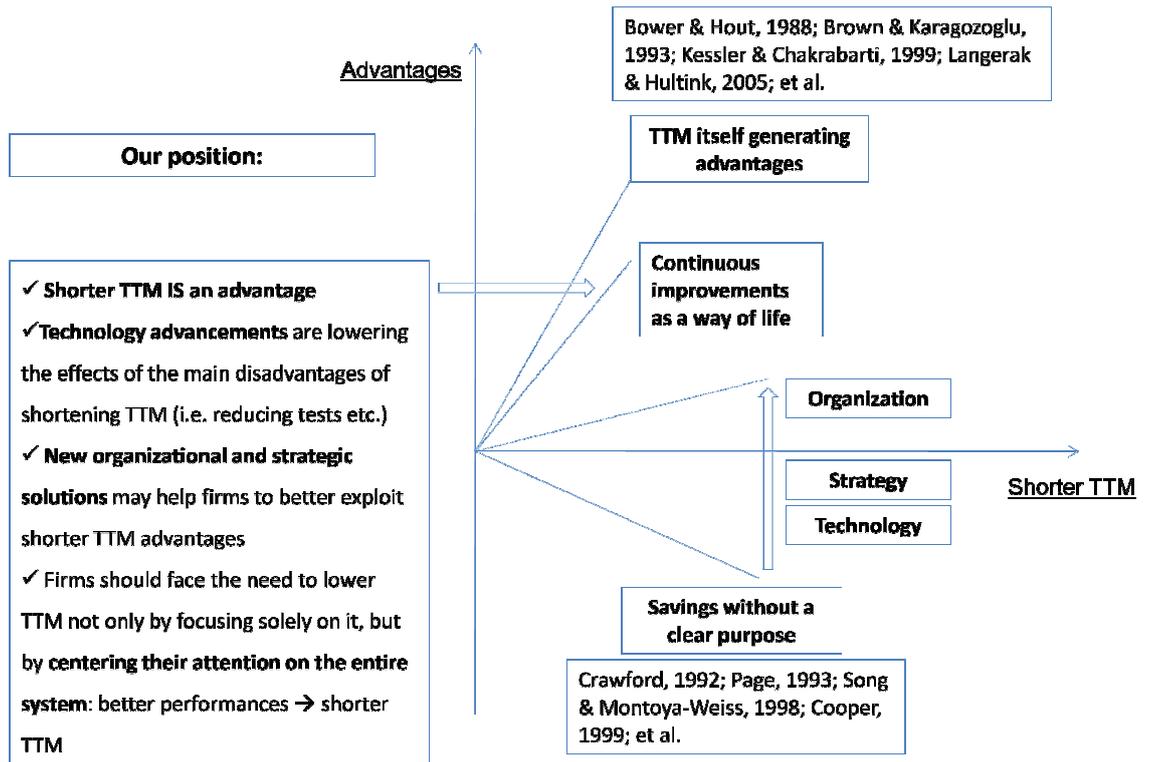


Figure 2.10: The resumming model: Our Position

long-term success of the firm. This approach can be explained by the counterintuitive mix between a drop in process costs due to the lack of over-production and accumulation of materials and information as work in process inventories, and an increase in quality due to the better performance of the whole NPD process, intended as necessary for the speeding up of the production cycle [21]. Then, we structured a model in which TTM is the final performance of the entire NPD process, along with the quality of the final product, as it could be a fundamental source in customer's decision process, while some indicators are to be held constant during the work, building up a framework to start the analysis (in particular, an interesting indicator is price, that is extremely different from the effective cost of production, as we focus on a marketing point of view). Finally, the acceleration approaches proving to be fundamental are not those directly acting on TTM, as they may be blind to the other performance indicators, while those influencing with a double, direct and indirect, effect the NPD process, in an attempt to render it better, thus enhancing also Time and Quality performance. In this sense, shorter time and higher quality taken together are the result of a better upstream process. Resumming, we state that a shorter TTM *is an advantage* for firms able to exploit the whole set of benefits it provides. At the same time, though, it should not be the *focus* of the entire firm effort, as it should be seen as a consequence of a better NPD process. Firms, thus, should work on the process itself, and shorter TTM will come out as a final consequence of its efforts in renovation (Figure 2.11).

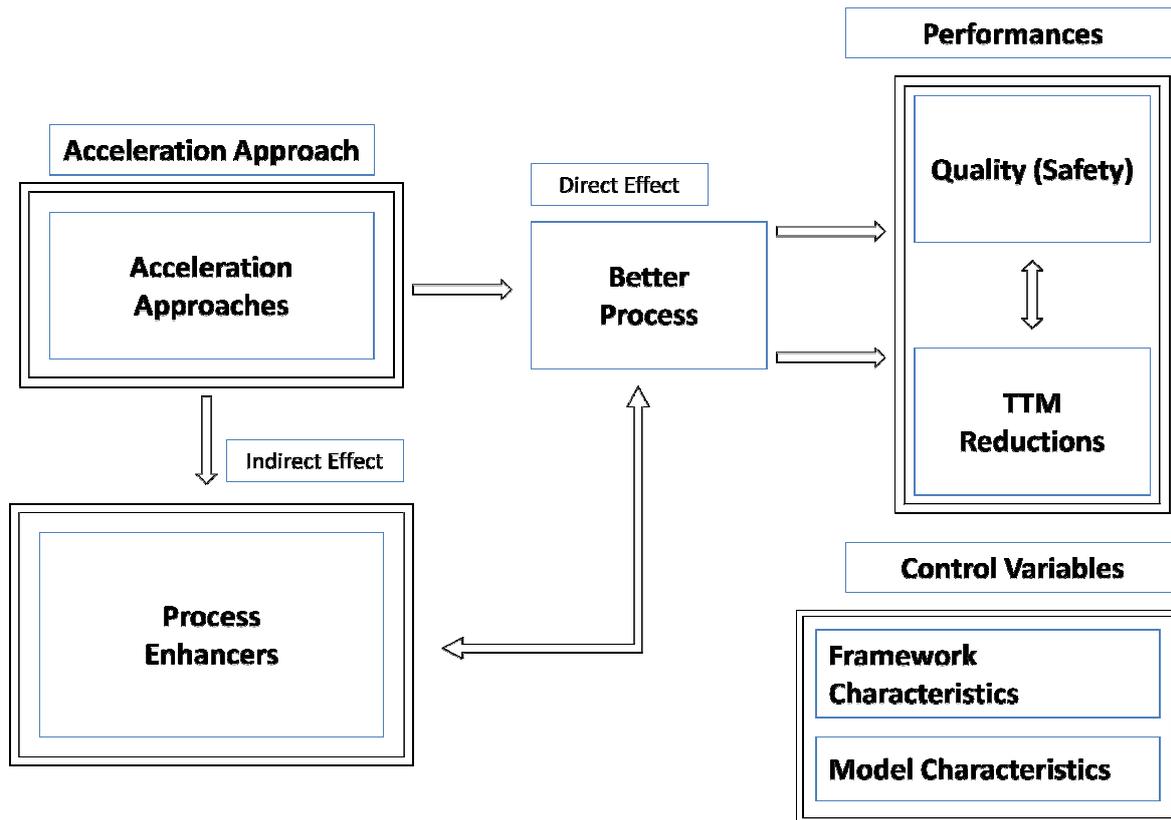


Figure 2.11: The resuming model: The Structure of Our Work

In this sense, we should take advantage of the Lean Management precepts, with the focus on a *continuous improvement as a way of life* [95, 122, 219, 227] strongly grounded in the learning experience in the automotive market. Their application evidenced its first effort in the early 1950s, even though it has been studied and analyzed during many years since 1980s, and it is still absolutely fashionable. We would say, as we further specify our position, that:

- saving time is saving money;
- saving time won't mean losing internal experience: it should be, otherwise, the opposite!
- saving time is learning faster, thus learning more: experiencing an enormous advantage with respect to your competitors;
- saving time is keeping old customers and, why not, building relational contacts with newer ones: customers will be satisfied to see their needs satisfied faster;
- saving time won't be saving quality, while structuring better processes to gain better products faster.

In a word, and that's where we wanted to settle, saving time may be the source of a renewed process, such that it pushes the firm to begin its good-for-good improving spiral, not to fall into a no-way-out process of savings without a purpose. We

are stating here that reality is absolutely time-dependent, *but* firms weren't able till now to best exploit time-advantages. In particular, the time competition took firms to understand the importance of reducing time to market, but sometimes (too often, we suggest) it didn't leave some space to breathe the existence of the upward spiral, thus forcing firms to reduce their timing while destroying their competence, impoverishing their quality on the market, chasing their customers away from the process and so on. The parallel evolution of contrasting theories in literature is then explained in this work as the result of the observation of the actual industrial world, where companies split into different operational mainstreams. In particular, we state that the distinction between successful and un-successful companies derives by the *way* they are able to implement affordable strategies, thus not only by the strategies implemented. We suggest, in fact, that the advantages of reducing time-to-market are common knowledge in the actual market framework. We state, thus, that even if firms are able to identify the main parameter of the present-time competition, they should not forget the "*all the rest being equal*" principle! There is not a one-way stream to solve problems, while in the whole solution framework it is possible to identify correct and un-correct solutions to achieve the same results. Leaving the *way-of-doing* matter out of the analysis is, with a high degree of probability, a synonymous of failure.

Obviously, our work is just a literature review, with its strengths and its weaknesses. Its lack of a case study proof is a shadow to be enlighten as soon as possible. Moreover, it comes as an obvious intuition that, even if we tried to cover as much as we could the entire literature framework, and we supposed to be as fair as we could, this work suffers for some subjectivity in the choice of the papers we cited and the bibliography we suggested, and some incompleteness as the literature on the topic is enormous. Our idea is, thus, to leave some space for further considerations, as we found out that during the last years literature became more and more specialized, in some sense niche-focused, thus generating an interesting framework to be resumed. The use of some literature reviews (since 1987 till 2001) in the course of our work is a useful way out to maintain the work manageable and to work with an extended plethora of concepts.

Finally, we underline again that we are strongly convinced that in the next years time competition will be the rule of thumb for all firms to stay into the market, and that the only firms able to get out of the economic crisis will be those better exploiting time to market principles. We leave it open space for analysis to empirically prove this concept.

Part III

The Determinants of Time to Market in Automotive New Product Development

Chapter 3

Mapping the Determinants of Time-to-Market in Automotive New Product Development: a Multiple Case Study Analysis

3.1 Abstract

As pressure to lower both time and costs of research and development (R&D) increased in recent years, firms strived to change their working habits accordingly. In the course of this analysis, we try to evidence the main parameters involved in this struggle to gain better results, specifically focusing on the Time performance. We devote our effort to identify the determinants of a shorter TTM, thus providing a guideline in the effort firms should pose as they will strive for competitive success. We use a qualitative analysis, based on the Multiple Case Study Research Method, between two European OEMs in the automotive market. We compare, thus, two performance indicators, respectively Time-to-Market and Quality, as milestone performances in the development of a new model, holding constant some characteristics of the vehicles (namely control variables), to reduce the variance in the analysis. We further highlight the influence exogenous parameters such as the previous experience of the firm in the market framework and its organizational structure could have on its willingness to innovate. The study shows that in the specific segment we analyzed –small family car– the main determinant as regards TTM advantages resulted to be supplier co-development management. In particular, the co-operation with a thin base of selected suppliers could come out not only in TTM advantages and equal qualitative results, but also in new methodological practices as realizing new product development. Moreover, we highlight that, counter-intuitively, firms in a worse competitive position are willing (and are able) to innovate more than successful ones, thus confirming the incumbent advantage theory. The question about which are the main parameters involved in the Time based competition, thus, finds here an answer both on internal organizational elements (long-lasting, relational knowledge and practices interchange with suppliers) and on external ones (past-experience). This study will thus provide the readers both a practical hint to solve the TTM pressure matter, and also a warning to quit the risk of slipping out of their successful position squeezed by their own inertia.

Index terms- New Product Development, Multiple Case Study Research, Time to Market, Supplier Integration, Customer Focus.

3.2 Introduction

PRODUCT development, a crucial activity for a firm competition and survival, is an area that benefits from collaborative relations with partners, including customers [123, 199, 216], research communities [87], competitors, and suppliers [16, 49, 162]. The final key players in the model are suppliers and customers. A long tradition of cross-disciplinary scholarship is concerned with the boundaries of the firm [38, 189, 204]. As determining the two-sided boundaries seems to be critical for market performance [23, 92, 123], literature centered its attention on the topic, so as to create a framework of in-depth analysis that could be useful for further investigations. Previous research has associated a faster and effective development process with early and extensive supplier involvement [5, 34, 83]; customer invol-

vement also has been shown to improve the effectiveness of the product concept [235]. Another focal point in literature is the relation between time-to-market and customer- and supplier-integration. Specifically, the involvement of users, and in particular *lead users* at the leading edge of the customer framework, accelerates the NPD process because it helps firms to acquire important need and solution information [114, 199]; the involvement of suppliers may significantly reduce costs and increment speed in the process, as their technical and design expertise is included in the early stages, through significant investments in new technologies both on the supplier side and on the communication techniques side [56, 85]. Empirically, involving suppliers in the development process proved to be a strategic advance for the OEM [35] and seems to strongly reduce development cycle time [234]. It's not a case that the leading edge firms widely practice partnering and alliance relationships [135]. Some studies seem to suggest a possible counter-intuitive point of view, such that if the firm strives not to improve its processes, while focusing merely on the final result to decrease development time, it could incur in some problems while omitting steps thought to be fundamental to the NPD process, i.e. the best possible recognition of information [47]. Even if literature refined during years, the matter remains, and is still under analysis. We will qualitative focus on a cross-firm comparison on a development process, so as to show a practical case study in an attempt to open some space for further debate on the actual practices of customer- and supplier-integration. We will then get deep into our comparison between two European OEM acting in the automotive market, structuring a "quasi experimental" research design approach [167] between two specific case studies (both referring to the year 2007) so as to verify literature assertions in the real world. We will, thus, structure a brief methodology section, and then we will show the results of our qualitative interviews. The research question we want to answer in this paper is: What are the main parameters involved in Time-to-Market reduction in New Product Development Process, and how are they acting in the automotive market framework? Despite the *coeteris paribus* conditions (used as control variables in the analysis) defined in the research design, we found significant differences concerning the supplier co-development management between the two OEMs and we pose here that these differences represent the base of the performance gap between the OEMs. Moreover, we highlight the importance of past experience and organizational characteristics of the firm in the choice of breakthrough innovative solutions. Finally, we evidence the importance suppliers could have in the methodological advancements in the NPD process, pointing out the idea that possibly method is more important than practice, as it reflects later on in the future evolving path of the firm, and in its future standards.

Our work will be structured as follows: firstly we will define a brief literature review, and we will split the entire topic in two different sections, as the matter is usually posed by researchers; the first subsection will be entirely dedicated to the supplier integration in the NPD process, the benefits it gives to the firm and the possible counterbalancing negative effects, and the second will focus on user involvement, intended to be in some sense an undiscovered way-of-doing in our research framework. A *method and data* section will briefly describe the methodology we used and the choice of the different models to use in the comparative case study approach, with an overview of the control variables we used to choose

them. The empirical findings of our research will be discussed in the course of the *Findings: Interviews and Results* section. Finally, in the last part of the paper we will pose some questions still unsolved, with possible future research directions. As an anticipation, we highlight that the aim of our paper is by no mean to find a unique-best solution, while it is to compare on the same topic two realities that, even if connected by the same marketplace -and thus the same needs- faced the specific problems of competition in a different way. Even if it is hard to define which is the best situation, as considerations should be driven by many different parameters and the model to analyze could be messy, we will provide our position with a high degree of detail, according to the results we obtained in the course of our study, and we will suggest some development paths in future research.

3.3 Theoretical Framework

3.3.1 Buyer-Supplier Integration: The Core of the Innovation Process

MANAGERS have continually struggled with the question of where to set the boundary between what works takes place inside vs outside a company, what kind of relation to build with suppliers and how to manage the division of labor with them [193]. Determining the boundaries of the firm appears to be critical on the final performance, especially in high-technology industries [15, 92]. While cutting-edge knowledge necessary for innovation tends to be widely dispersed across different firms, continual innovation in highly dynamic industries appears only possible if a firm reaches beyond its boundaries. This observation has prompted some to suggest that the locus of innovation might be found in a network of alliances rather than within individual firms [161, 169]. Access to knowledge external to the company, in addition to internal knowledge, enriches a firm absorptive capacity [40], and enables firms to avoid path dependence in the development of internal technological knowledge stocks [116]. In many industries, manufacturing companies give suppliers increasing responsibilities with regard to the design, development and engineering of components. During the past decades, also the research community increased its efforts on the definition of the main rules about the so-called “supplier involvement in product development” [16, 49, 131, 164]. The main result researchers found, becoming in a few the base of the whole stream of works connected with supplier integration, is that:

“(...) using the extra and specialised development potential embedded in the skills, competencies and knowledge of suppliers can make product development more efficient, by decreasing input (less development costs, less design changes, less engineering hours) or –but ultimately and– increasing the output (a better product, a more innovative product, a faster market introduction) (...)”

Wynstra, F. van Weele, A. and M. Weggmann, Managing supplier involvement in product development

European Management Journal, Vol.9, No. 2, 2001

Moreover, empirical demonstrations in the world auto industry suggest that, as outside suppliers are often involved in design and in manufacturing for more than 50% of the entire costs of the vehicle [34]:

“(...) it appears that supplier involvement (and strong supplier relationships) accounts for about one-third of the manhours advantage, and contributes four to five months of the lead time advantage (...)”

Clark, K.B. Project scope and project performance: the effect of parts strategy and supplier involvement on product development

Management Science, Vol.35, No. 10, October 1989

The main approach to buyer-supplier integration has been seen to be *outsourcing*. In this work, we won't define outsourcing as a mere production request, but as an integrated process where the OEM and the supplier interact with one another, both in defining and realizing the component. This kind of outsourcing, that could be considered as a sort of cooperation between the two firms, is the most common form of integration in many industries. Outsourcing some internal activities and building cooperative, interdependent, and long term relations with suppliers and alliance partners is considered to give the participating firms some benefits such as combining different competencies, sharing fixed costs, and gaining economies of scale [193]. The studies about interfirm technology cooperation comes from a couple of decades ago, when they widen the attention of researchers about the importance that this topic could cover in the entire competitive landscape. In figure 3.1, we showed in brief some forerunner works, as they were collected in an interesting reviewing study by Hagerdoorn [84].

The phenomenon of outsourcing deeply touched the automotive industry during the last decade [12], as the strong need for cost and time reduction influenced the recent decisions of firms. Moreover, outsourcing also guides on the possession of, and the access to, resources. Firms that are able to accumulate resources and capabilities that are valuable, non-substitutable, and difficult to imitate will in fact achieve an advantage over competitors [60,61]. As noted, though, by specializing further on specific capabilities, the firm could loose its all-rounded perspective, thus generating the need for alliances with other same-specialized firms. An alliance is defined as a collaborative relationship among firms to achieve a common goal that each firm could not easily accomplish alone [112]. These companies, thus, form an alliance because each required the others' complementary technology to create innovative products. Noordewier, John, and Nevin [149] argue that coordinated interaction patterns facilitate adaptation, and the authors develop data showing that closer (relational) ties improve purchasing performance when external uncertainty is high. The possible benefits of supplier involvement could be divided into short- and long-term. Explicitly, on the short-term they can be divided further into development efficiency¹ and effectiveness² [16,35,164,234];

¹supplier involvement may lead to the reduction of development costs and the reduction of development lead-time: this is achieved by realizing design changes earlier, developing activities in parallel, and destining tasks to the most competent company inside the co-operation

²supplier involvement may lead to the reduction of product cost and the increase of product value: this is achieved by mobilizing supplier expertise in product development.

Figure 3.1: An overview of motives for inter-firm technology cooperation and a sum up of the interesting works, Hagedoorn, 1993

-
- I Motives related to basic and applied research and some general characteristics of technological development:**
- Increased complexity and intersectoral nature of new technologies, cross-fertilization of scientific disciplines and fields of technology, monitoring of evolution of technologies, technological synergies, access to scientific knowledge or to complementary technology:
Mariti and Smiley (1983), Harrigan (1985), Ohmae (1985), OECD (1986a, b), Porter and Fuller (1986), Fusfeld (1986), Haklisch (1986), Mariotti and Ricotta (1986), Auster (1987), Hladik (1988), Klepper (1988), Mowery (1988a, b), Ouchi and Bolton (1988), Obleros and MacDonald (1988), Pisano, Russo and Teece (1988), Pisano, Shan and Teece (1988), Steinmueller (1988), Womack (1988), Hagedoorn and Schakenraad (1990a, b).
 - Reduction, minimizing and sharing of uncertainty in R&D:
Berg, Duncan and Friedman (1982), Ohmae (1985), Harrigan (1985, 1988), Mariotti and Ricotta (1986), Porter and Fuller (1986), Auster (1987), Mytelka and Delapierre (1987), Hladik (1988), Mowery (1988b), Obleros and MacDonald (1988).
 - Reduction and sharing of costs of R&D:
Ohmae (1985), Harrigan (1985, 1988), OECD (1986a), Mariotti and Ricotta (1986), Auster (1987), Mytelka and Delapierre (1987), Hladik (1988), Mowery (1988b), Obleros and MacDonald (1988), Steinmueller (1988), Link and Bauer (1989).
- II Motives related to concrete innovation processes:**
- Capturing of partner's tacit knowledge of technology, technology transfer, technological leapfrogging:
Mariti and Smiley (1983), Harrigan (1985), Hamel, Doz and Prahalad (1986), Lynn (1988), Pisano, Shan and Teece (1988), Hagedoorn and Schakenraad (1990a, b).
 - Shortening of product life cycle, reducing the period between invention and market introduction:
OECD (1986a), Mariotti and Ricotta (1986).
- III Motives related to market access and search for opportunities:**
- Monitoring of environmental changes and opportunities:
Mariotti and Ricotta (1986), Obleros and MacDonald (1988).
 - Internationalization, globalization and entry to foreign markets:
Ohmae (1985), OECD (1986a), Porter and Fuller (1986), Harrigan (1988), Lynn (1988), Mowery (1988b), Pisano, Russo and Teece (1988), Steinmueller (1988), Womack (1988), Vonortas (1989).
 - New products and markets, market entry, expansion of product range:
Hladik (1985, 1988), Harrigan (1985, 1988), OECD (1986a, b), Mariotti and Ricotta (1986), Porter and Fuller (1986), Klepper (1988), Mowery (1988a), Steinmueller (1988), Pisano, Shan and Teece (1988), Womack (1988), Hagedoorn and Schakenraad (1990a, b).
-

in the long-term, the common goal is creating a network of knowledge, connecting both buyer and supplier specialized knowledge. While, as we stated before, many studies on product development proved that participation of suppliers was important, the empirical literature was imprecise in testing the link between supplier involvement and performance, and was not clear exactly as to how and when suppliers should be involved in the development process. In fact, other empirical works found null [125] and even detrimental effects [209] of closer ties on performance: supplier involvement seemed not to lead to decreased costs or lead times, nor to higher quality of the final product [85,132], or even it could lead to higher costs and often longer development time [16]. An interesting perspective comes from an evolution of the Transaction Cost Theory (TCT), suggesting that if transactors make transaction-specific investments, then they must safeguard against the hazard of opportunism, as the contingent value of a specialized resource exposes its owner to a greater risk of opportunism than the owner of a generalized resource [61]. The obvious conclusion of this simple reasoning is that to protect buyer-supplier relation, the transaction costs should increase. Even though, some late 1990s studies found that Japanese transactors made greater asset-specific investments than their US counterparts and that these investments were correlated with superior performance, and this is not surprising, and also with lower transaction costs [59,60]. These findings appear to be inconsistent with TCT, and suggest that a firm can simultaneously achieve the twin benefits of high asset specificity and low transaction costs [62]. The explanation given in literature for these findings concerns the kind of protection taken into account to solve the safeguard matter: the existence of formal³ and informal⁴ safeguards leaves some space for further analysis on their specific effect on the costs of the relationship. Different safeguards are likely to have different set-up costs⁵ and result in different transaction costs over different time horizons [62]. According to Hill [91], then:

“The informal constraints of Japanese society have lowered the transaction costs of adopting economically efficient organizational arrangements”

Hill, C.W.L. National institutional structures, transaction cost economizing and competitive advantage: the case of Japan
Organization Science, 1995

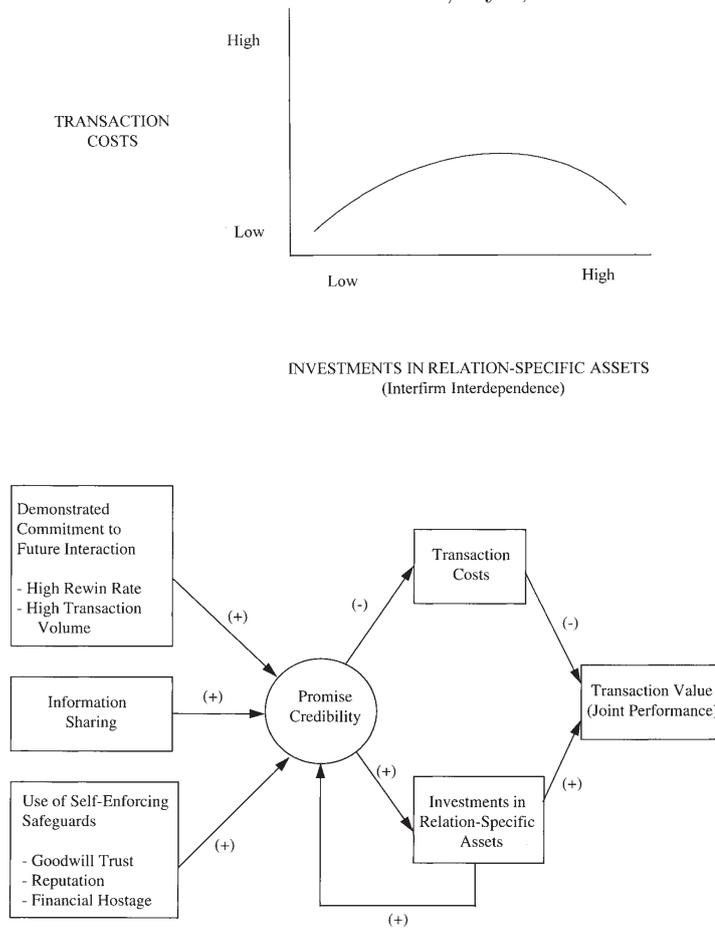
Interestingly this was not the only debate about the possible dis-advantages of a deeper interaction with suppliers. Another important aspect of the relational practices is the chance to integrate a wider knowledge in new products: a “wrong” behavior by the OEM could take it to loose its knowledge of the component itself, thus finally depending totally by the supplier for the design and production of the specific part. A fragmented knowledge without a leading head to integrate it has no value [12]. As the chief director of the Vehicle Concept & Integration told in an interview, as reported in Zirpoli [236],

³financial and investment hostages, as intended in the main contributions about TCE [225]

⁴relational or goodwill trust [173] and reputation [156]

⁵the costs incurred to create a safeguard which governs the ongoing relationship and typically include the costs associated with writing contracts, building personal trust, creating financial hostages, etc.

Figure 3.2: The relation between asset specificity and transaction costs, and a model of interfirm collaboration, Dyer, 1997



“It’s naive to think that it is possible to integrate a complex system without a deep and detailed knowledge of the single parts influencing performance of the entire vehicle⁶”

Zirpoli, F. Il ruolo dell’organizzazione nella gestione strategica dell’Innovazione
Economia e Management, 2008

Finally, it is possible to resume also other kind of managerial problems in buyer-supplier relationship, generated by the effective willingness and capacity of supplier and buyer themselves: if one of the two (or even both of them) is not willing to create a long-lasting relationship with the other, every effort in that direction by the other part is going to fail. The choice of the right supplier won’t be any more a matter of a few interactions, with the only aim of reducing costs in a single project, but it will be a brave choice for a relation destined to last a long period of time, with the aim of superior performance and quality of the products introduced into

⁶In Italian: *E’ ingenuo pensare che si possa integrare un sistema senza avere una profonda e dettagliata conoscenza dei componenti che andranno ad influenzare le performance dell’intero veicolo* (Direttore della Funzione Vehicle Concept & Integration, 2006)

the marketplace. There will be, thus, three important matters in the management of the entire relation:

1. Identifying specific processes and tasks that need to be carried out, thus defining core competence and knowledge inside and outside the firm;
2. Choosing the right suppliers, with adequate capabilities and future possibilities;
3. Staffing the organization with people that have the right commercial, technical and social skills, so as to recreate a framework for the best possible integration.

The fundamental role of suppliers has long been signaled in recent literature, and it will be our aim now to evidence with one comparative case study how two European automotive OEMs focused on the matter of choosing and integrating them into the NPD. We found differences resulting from the process of selection, while as regards the ideal level of co-development they both signaled that for adding-value-for-the-consumer components they decided to work on a co-development perspective, and for usual (common knowledge) parts they strive to generate competition. Even though, co-development is differently intended by the two firms, thus generating great variance as regards performance depending on the way it is optimized. Moreover, co-development proved not to imply a long-lasting relational practice between the firms (i.e. a replication of the relationship across similar projects), as competition was evoked also between projects grounding on the same technical base⁷. We suggest that the OEMs found themselves in a transitional phase, as the traditional adversarial method struggles with a co-operative style. We state that, at this stage, there is space for a better integration between the two solutions, instead of a rejection of one for the other. We finally underline the importance of the operating context, as the traditional concept could strongly vary depending on the culture and the life-style of the place where the firm strives to be involved.

3.3.2 Users Involvement: an Unused Advantage

NEW product development (NPD) can originate from new technology or new market opportunities [66]. But irrespective of where opportunities originate, when it comes to successful new products it is the consumer who is the ultimate judge [23]. The promise of customer as an external resource for NPD has been well recognized in theory and in practice [216]. To acquire the information from customers about their preferences, requirements and needs is routinely stressed as a pre-requisite for successful new product development (NPD) [102, 158]. As suggested by Thomke and von Hippel [199]

“Listen carefully to what your customers want and then respond with new products that meet or exceed needs”

⁷See the case Fiat Bravo (2007) - Lancia Delta (2008)

is the dominating mantra for many business. Consumer research can be carried out during each of the basic stages of the NPD process: (1) opportunity identification, (2) development, (3) testing, and (4) launch. It is most widely applied during the development, testing and launch stages [210]. The trouble is that fully understanding customers' needs, especially at these early steps of the product concept, is often a costly and inexact process: besides problems of conducting market research in a proper way, it has been shown that the transfer of need information from a customer to the manufacturer is even harder because this information tends to be *sticky*⁸. Thus, even if sometimes firms spend enormous amount of money for market research, new product success is often the exception rather than the rule [89]. At the same time research has consistently shown that new products and services must accurately respond to user needs if they are to succeed in the marketplace [215]. While customer was firstly considered as an evaluator, meaning someone whose role was simply to debate on the quality of the final (or intermediate) product, it soon became part of the development process, as he could not only express his needs, but also play an active role in the evolution of the product, being involved as a sort of co-creator. This new perspective fired the debate about the effectiveness of co-creator-users: while some researchers argued that customers need to play a pivotal role in the generation of new product ideas, others argued equally fervently that involving customers in new product design will simply lead to imitative, unimaginative products [142]. The most extreme theories [20, 31] suggested that manufacturers should not listen to their present customers as these may show a tendency of repeating old procedures rather than looking for radical innovation, in some way assigning the task of generating ideas for solutions leading to breakthrough⁹ products to manufacturers [66, 165], although the value of assigning idea generation to manufacturers is not supported in research. User innovation, however, has to be seen as a supplementary mean to support the NPD process, and not as a substitute for conventional internal practices. As many researchers noticed, not all the ideas and inputs coming from users can contribute to product success. Within the whole set of users, though, it is possible to identify some of them differentiating from the large majority of the entire framework, as they face needs before the others and can significantly benefit by innovative solutions to those needs [123, 126, 213]. If familiarity with existing products attributes seems to interfere with the ability to conceive of novel attributes and uses, it seems not so important for users that *live in the future* [123]. Thus firms may distinguish each other with respect to the main decisions they have to take according to the "customization" of the development process. Specifically, what kind of customers to refer to and what kind of analysis to carry out. The traditional research method is usually associated with the traditional customers, and new technologies and methods work better with lead users. The traditional method of obtaining

⁸The stickiness of a given unit of information in a given instance is defined as the incremental expenditure required to transfer that unit of information to a specified locus in a form usable by a given information seeker [150, 214]

⁹defined as new product ideas that form the basis for an entire new line of products or services

customer input is to gather data meticulously from representative customers in a chosen market sector and then to use this (need-related) information so as to create ideas for new products [165]. In order to reduce the risk of failure, need-related information from customers is integrated iteratively at many points in the new product development (NPD) process [50]. After many time-consuming iterations between the customer and the manufacturer, a new or adapted product is found, usually at high cost. The emergence of new information and communication technologies forced a rapid transformation of customer-producer relationship in many industries, with important implication for NPD performances [72,142], thus giving the chance to implement new methodologies of interrelationship between the main actors in the market search process. During ages, the advantages of technology evolution spread all over society, touching also user integration: the use of internet has enabled larger groups of users to access information that was formerly almost exclusive to the firms, to participate in exchange of ideas (e.g. on-line communities) and to share their own development with others, included the firm itself [144,193]. This meant that a larger slice of the entire market framework was able to join the development process, even if the debate remained focus whether or not they could really be “innovators”, as they were provided of more information about the product and the possible evolution. In a word, widening the framework of users involved in the concept of the new product, doesn't explicitly mean changing their traits, even if new technologies opens easily to new generations of users, with new-generation needs. Unfortunately, despite the large number of available methods and techniques¹⁰ to be used in the NPD process, the majority of them are not used by companies or mostly applied in an ad-hoc manner [144,145]. Even in those contexts where they are a promising resource, customers have played a largely passive role, with firms employing a range of structured inquiry mechanisms (market surveys, focus groups) to import customer knowledge. Customers rarely offer new product ideas without being prompted by firms; further, the use of structured inquiry mechanisms severely limits the richness and frequency of their contributions. Also, logistical and economic considerations force firms to involve only a minority of customers, often unrepresentative of the diverse market framework [142]. As observed by Eliashberg et al. [66], most of the products developed tended to be marginal contributors to the firm's portfolio, thus substantially intended to be profound failures. In their attempt to find the reasons of this sort of defeat, they focused on the customer-buyer integration process, and they pointed out the main matters of the traditional approach, suggesting that they were connected to:

- the limited-to-their-experience approach of traditional users, belonging to the center of the market, often concerned about their knowledge-base;
- the failure in the production of breakthrough innovations, greatly overwhelmed by step-by-step improvements of existing products.

As several reasons can be cited for the relatively weak utilization of this valuable resource in NPD, perhaps the most limiting factor still remains the poor

¹⁰for an useful, complete and accurate review of methods and techniques used in the earliest stages of NPD, see van Kleef, van Trijp and Pieternel Luning [210]

connectivity between customers and producers.

We will further evidence in our case-study how customer involvement is not yet well exploited by the two car-makers we will refer to. We will see how this could be principally a matter of the market niche we are analyzing, and we will try to focus also on the main exogenous parameters involved in the definition of the development process. It could be interesting to further investigate the market, focusing on one specific firm, to prove (as we suggest) the enormous changes in the process according to the features of the products and its meaning for the customer. We strongly support the hypothesis that, even in the same market-place, many differences could occur as different customer frameworks are involved, thus entailing different processing solutions by the firm.

Our work will evolve in a methodological section, concerning the multiple case study approach and the selection of the projects we decided to compare, followed up by the description and the discussion of the results we obtained through the initial survey and the direct interviews.

3.4 Method and Data

3.4.1 Methodology

IN our attempt to realize a case-study analysis between two OEMs in the automotive industry, we found it interesting to compare their performance referred to a specific new model they took to the market. The practices they used to develop it could show us some important differences. In order to do that, we opted, among the qualitative methods, for a *multiple case study* research design. A multiple case study approach is the adequate research strategy “when how and why questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context” [230]. To define the research question and the hypothesis to work with, we used both a deductive and an inductive approach, as “both (prior theory and theory emerging from the data) are always involved, often simultaneously”, and “it is impossible to go theory-free into any study” [166]. Prior theory, thus, had a pivotal function in the design of the case study and the analysis of the collected data-set [157]. Case studies typically combine data collection methods such as archives, interviews, questionnaires, and observations. The evidence could be qualitative (e.g. words), quantitative (e.g. numbers) or both [64]. In our research we used both a structured survey and direct interviews to deepen the results of the survey. We gained both qualitative and quantitative results on the matter of the analysis. The basic idea was to build a research setting in which some variables are held constant (control variables) and some others serve as performance indicators, thus varying according to the specific project. In our analysis we used common knowledge characteristics of the OEM and of the specific model as control variables. In particular, we split our control variables in *structural characteristics* (e.g. OEM framework, market segment and derivative vs template) and *model characteristics* (e.g. Price, Body, Dimensions, Engine, Environmental Approval). Then, as regards performance in-

dicators, we used Time-to-Market¹¹, according to the importance we proved it to have in the actual industrial world and a sort of Quality indicator. As concerns TTM, we used the standard milestone approach, in a first attempt in its latest version (Thomke, Fujimoto & Nobeoka, 2007) straightly with the questionnaire, and then we widened the space of the research with some direct interviews aimed at lightening some shadows in the NPD process still remaining. In the attempt to have a full overview of the evolution of the two projects, we decided to carry out interviews both to the technical and to the commercial function. We noticed many overlaps in the answers we obtained, while at the same time we emphasized the complementary effect between the two perspectives. The quality measure seemed to be in some sense less standardizable: as sales performance could be submitted not only to the quality of the model, but also to individual feelings about the external contents, the idea of the car-maker and so on, we state that it is not a signal of the effective quality of the vehicle, but it is just a mix of different parameters. We decided then to focus on safety, with the standard indicator EuroNCAP¹², intended to be a realistic and independent assessment of the safety performance, compulsory for all the European OEMs, as new models must meet the requirements as expressed in “Directive[s] of the European Parliament and Council”. To select the specific case studies to test, we referred both to specialized newspapers¹³ and to the internal classification by the OEMs.

Thus, our analysis began with the structure of a milestone survey, with the most important questions we wanted to ask during interviews, that should serve as a direction for the research¹⁴. Our idea was that in comparing the NPD methodologies between the two OEM we would be able to identify the major differences in standard practices. Since we haven't got the access to sensible data about NPD costs, we won't be able to provide a cost appendix to our analysis. Even though, we will use esteems on the main parameters we used, grounding on the hints we built up during the interviews.

¹¹See Chapter 1 for further details about the relation between NPD and Time-to-Market, as it could be a useful literature review to have an overview of the topic

¹²The *European New Car Assessment Programme* is a European car safety performance assessment programme founded in 1997 by the Transport Research Laboratory for the UK Department for Transport and now the standard throughout Europe. It publishes safety reports on new cars, and awards 'star ratings' based on the performance of the vehicles in a variety of crash tests, including front, side and pole impacts, and impacts with pedestrians. The top overall rating is five stars. The frontal tests are performed at 64 km/h (40 mph) into an offset deformable barrier of similar mass and structure as the car itself. The side impact tests are performed at 50 km/h (31 mph), but the side impact pole test is performed at 29 km/h (18 mph). The pedestrian safety tests are performed at 40 km/h (25 mph). Euro NCAP adopted the rear-impact (whiplash) test as part of its new crash-test regime from January 1 2009. For further information, see also the official web site: <http://www.euroncap.com/home.aspx>

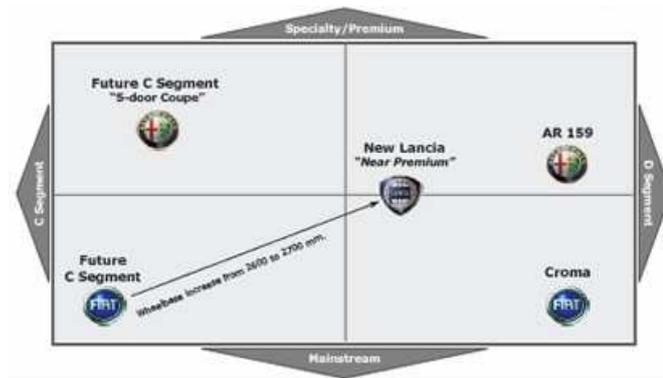
¹³See as an example the Italian “Quattroruote”, on its official website: <http://www.quattroruote.it/>

¹⁴See Appendix B to have a complete overview of the Standard Survey

3.4.2 Data selection

WE posed great interest on the growing newspaper articles relating the fast development of *Fiat Bravo* (2007), told to be realized in 18 months, with a reduction of development time of about 50% with respect to older Fiat models. We saw this case as an important innovation in the automotive market, as it posed a new standard for all the competitors, if they wanted to equally answer the market requests. We found it interesting to compare this NPD process with competitors' ones. The matter was to find a competitor acting in the same marketplace, with a product that could be reasonably comparable with Fiat Bravo, for technical and economical reasons. The first idea was to compare the entire NPD process with previous Fiat case studies. The change at the head of the Fiat Group in 2005 and the opened era of a renewal for the entire group, reflected at any level of the organization. As regards the C class of the market, representing the compact cars (US) or small family car (Europe)¹⁵ in 2006, an year before Fiat Bravo was presented, replacing Fiat Stilo (2001), the FGA framework was to be depicted like in Figure 3.3.

Figure 3.3: Fiat Group, C Segment, year 2006



On the low-left side, Fiat Stilo was the only solution for the group. As we decided to work with a comparative case study methodology, we should strive to reduce at a maximum the level of uncertainty in the comparison, holding all the control variables constant during the work. Then, we found out that the specific area we wanted to work on had been fulfilled since 2001 by only one solution, Fiat Stilo, no longer an improvement on the base of the previous models (a *derivative*), but a completely new work (a *template*¹⁶). As Fiat Bravo is based on the platform

¹⁵A compact car, or small family car, is a classification of cars which are larger than a supermini but smaller than or equal to a mid-size car. Current compact car size, for US and international models respectively, is approximately 4,100 mm and 4,450 mm long for hatchbacks, or 4,400 mm and 4,600 mm long for cabriolets, sedans or station wagons. Small European family cars include the Ford Focus, Opel Astra, Peugeot 308 (2007), Renault Mgane, Fiat Bravo (2007) and Volkswagen Golf. Japanese branded examples include Honda Civic and Toyota Corolla

¹⁶The template is defined as the initial model used to design and engineer all the other derivative products [10]. In this case, a template is the original platform, and the derivatives will be all

of Fiat Stilo, and exploits great advantages in terms of re-use, the comparison between the two models could not be effective, and doesn't respect one of the fundamental structural-characteristic control variables.

“I could state (the development of a template) lasts at least 30 months, more than doubling the development time of a derivative¹⁷”

Chief Technical Director Bravo Project, 2009

Moreover, comparing Fiat Bravo with other upper or lower class vehicles won't respect other control variables (e.g. dimensions, price, engine and so on). Going through the Fiat case alone could be considered, thus, a non-sense. Then, we had to widen the space of analysis, searching for similar models realized by different OEMs. Since a comparison with distinct OEM frameworks could lead us to provide misleading considerations on the encountered differences in the NPD process, due both to cultural and historical reasons, we focused our attention just on the European market. We found it interesting that the Peugeot Société Anonyme (PSA) group entered the market in the same period with a model that could be easily compared with Fiat Bravo, *Peugeot 308* (2007). Before stating anything about the two vehicles, though, we had to check if they were really comparable, and in particular we wanted to understand if (control variables, structural characteristics):

1. they both were derivative, as we already knew that Fiat Bravo was a derivative of Fiat Stilo, since it inherited the main “back-office” modules, including the base platform;
2. they both lie on the same market class¹⁸, both for performances and price reasoning;

The vehicles we considered were both produced as a substitution of previous models that have long been in commerce. As we found out that Fiat Bravo should substitute Fiat Stilo (2001), since January 2007, even if the SW model is still on sale in some countries and the 5-door model is still under production in Brazil, we had to check for Peugeot 308; launched on September, 22, 2007, it is the substitute for Peugeot 307 (mid-2001), taking from it a renewed (to raise the security level against car-accidents) flatcar and the same idea of a spacious passenger compartment (one of the successful innovations of Peugeot 307).

“(...) On a Marketing point of view, Peugeot 307 has been a sort of revolution. Peugeot 308 aims at capitalizing on the success of the same design¹⁹(...)”

the products coming next which use the same platform with a re-use modular method

¹⁷In Italian: *Potrei affermare che (lo sviluppo di un template) dura almeno 30 mesi, circa il doppio di un prodotto derivativo.* (Responsabile tecnico Progetto Fiat Bravo, 2009)

¹⁸The internal classification by the OEM was different as one of them referred to the market segmentation, while the other worked on an internal classification, ruled by technical instead of commercial practices

¹⁹In French: *Du point de vue marketing, la Peugeot 307 fut une petite révolution. La 308 avait pour objectif de capitalizer sur le succès de ce style extérieur* (Responsable de la conception model 308, 2008)

Finally, as a confirmation, both the models were lying on the same market class. We resumed these first remarks in Figure 3.4.

Figure 3.4: Control Variables: Structural Characteristics

Model			Bravo	308
Control Variables	Structural Characteristics	Derivative vs Template	Derivative	
		Market Segment	Segment C	
		Production Framework	Automotive, Europe	

Given the effectiveness of the structural characteristics similarity, we had the chance to look further to the technical comparison between the vehicles (model characteristics). This approach required us to get directly to some specialistic magazines concerning the automotive market, and to the news that appeared more and more on internet, visiting blogs, discussion sites and newspapers in order to find out the information required. A *visual* summary of the technical data is provided in Figure 3.5.

As we were able to establish a contact between the two models, we searched for the possible interviews to carry out to exploit the topic. We focused our attention both on the research contributions about the automotive world and NPD performance and we tried to spread over a larger basket of possible questions. Our idea was to develop firstly a couple of interviews at FGA, in order to understand the main changes in the organization that were able to provide such a benefit to the NPD process, so as to focus on them in the following interviews both at PSA and again at FGA. In this way we could broaden the analysis in two directions: primarily there was the chance to get into the development process of both firms, checking the main differences between the two, both on parameters and final performance, and consequentially we could test the main reasons for the changes happening to the two organizations, in order to identify their drivers. We carried out three 2-hours interviews at FGA and two 2-hours interviews at PSA. These worked in addition to the offhanded results we obtained as a compendium of the main answers to the structured survey²⁰. We mapped the final list (with the duration) of the interviews at Fiat and PSA during the project in Figure 3.6.

²⁰See Appendix B for the complete overview of the survey

Figure 3.5: Control Variables: Model Characteristics
FIAT BRAVO (1.4, 16_V) and PEUGEOT 308 (1.4, 16_V)

	 FIAT Bravo 1.4 16V	 PEUGEOT 308 1.4 16V 95CV VTi 3p. Comfort
Price	15.081 €	14.801 €
Body	Touring car, 3/5 doors	Touring car, 3/5 doors
Number of doors	5	5
Number of places	5	5
Engine	4 line cylinder	4 line cylinder
Capacity cm ³	1368	1397
Current (power)	Gasoline	Gasolina
Expenditure (Consumption) (litri/100km)	<ul style="list-style-type: none"> • urban 8,7 • extra-urban 5,6 • mixed 6,7 	<ul style="list-style-type: none"> • urban 9,0 • extra-urban 5,2 • mixed 6,5
Power max/regime	65 kW (90 CV) 5500 giri/min	65 kW (95 CV) 6000 giri/min
Environmental approval	Euro 4	Euro 4
Traction	front	Front
Max speed	179 km/h	182 km/h
Speedup 0/100 km/h	12,5 sec	12,4 sec
Dimensions (cm)	<ul style="list-style-type: none"> • Lenght 434 • Width 179 • Height 150 • Step 260 	<ul style="list-style-type: none"> • Lenght 428 • Width 182 • Height 150 • Step 261

Figure 3.6: List and Duration of Interviews at Fiat and PSA

FGA Fiat Group Automobile	Duration	No. of interviews
Bravo Project		
Technical Manager	4 h	2
Marketing Manager	2 h	1

PSA Peugeot Société Anonyme	Duration	No. of interviews
308 Project		
Technical Manager	2 h	1
Marketing Manager	2 h	1

3.5 Findings: Interviews and Results

THE analysis of the two performance indicators with respect to the case studies we highlight took us to identify the main parameter(s) involved. We used different approaches to gain data: respectively, as regards “quality”, we referred to EuroNCAP dataset, while the release of any detail concerning TTM has been made possible only with the joint use of the standard survey we proposed and the direct interviews we developed. In an attempt to clarify the results we are grounding our analysis on, we structured our work clearly defining them in “milestones”, followed up by comments and further investigations.

The use of the Euro-NCAP indicator as a source of qualitative evidence is quite common in the automotive industry.

“The Euro-NCAP results confirm that we have managed to produce a top-quality vehicle in terms of performance”

Dr. Eckhard Scholz, Skoda Auto BOD Member responsible for technological development,
AutomobilSport.com

We provide here an overview of the methodological testing approach in the European New Car Assessment Programm and of the detailed results achieved by Fiat Bravo and Peugeot 308, both considered in their basic version. The aggregate-level indicator turn out a 5-star rating, explicitly sub-divided as follows²¹ (Figure 3.7).

²¹See Appendix D for further details

Figure 3.7: EuroNCAP Safety Results

	General	Detail	Bravo	308
Safety (Euro 'N Cap)	Adult Occupant		33	35
		Front	12,8	14,3
		Side	16	16
		Seatbelt Reminder	2	3
		Pole	2	2
	Child Occupant		36	39
	Pedestrian		16	19
	Seatbelt Reminder		2	3

For cars tested before 2009, Euro NCAP released three ratings²²: adult protection, child occupant and pedestrian protection. The ratings for adult protection and child protection are achieved as a result of three impact tests: frontal, side and pole test. Euro NCAP carries out a separate range of pedestrian tests to reach the score of the Pedestrian Rating. The tests were chosen to cover the range of accidents responsible for the majority of serious and fatal injuries. In addition, Euro NCAP rewards cars for having an intelligent seat-belt reminder as part of the adult protection rating. Respectively, the three tests can be described as follows:

- *Adult occupant protection*: Points are awarded from the frontal, the side and pole impact tests. Modifiers are also given to extend the assessment to cover different sizes of people in a variety of seating positions, in particular for the knee contact area. The Adult Protection score is completed with the result of the Whiplash test that is carried out separately on the driver or passenger seat;
- *Child occupant protection*: As part of this assessment, Euro NCAP uses 18 month old and 3 year old sized dummies in the frontal and side impact tests. Moreover, the test verifies the clarity of instructions and seat installation in the vehicle to ensure that the child seat can be fitted safely and securely;

²²Since 2009, Euro NCAP only releases one overall star rating for each car tested with a maximum of five stars. This overall safety rating is composed of scores in four areas: adult protection, child protection, pedestrian protection and safety assist. The overall score is calculated by weighing the four scores with respect to each other, while making sure that not one area is underachieving. The underlying dynamic tests are identical to those before 2009, except for the addition of a test for Whiplash neck injury protection in rear impact. Also, Euro NCAP now rewards not only Seatbelt reminders, but also Speed Limiters and the standard fitment of Electronic Stability Control

- *Pedestrian protection*: results in this rating are achieved through leg form, upper leg form and child/adult head form testing.

EuroNCAP provides also some comments about the vehicle analyzed, in order to complete the scaling²³. The structure of the direct interviews gives us the chance to focus both on the commercial and on the technical side of the firm. Respectively, we refer to customers, suppliers and the whole organization, on the former, and technical matters such as testing quality, underbody, dimensional parameters on the latter. We found many overlaps in the answers given by our contacts inside the firms, in that as an example, suppliers were important both for the commercial and for the technical function, even if with different roles: on one side the focus was on the possible relation between them and the firm, on the other the selection and the effective conjoint development processes. The first analysis concerned the organizational structure, so as to understand the position of the specific working group inside the firm. Determining the “position” means also to define the main responsibilities between the members of the group itself, thus in some sense expressing its importance in the whole organization. We provide graphic evidence of both the organizational structures in Figure 3.8 and 3.9.

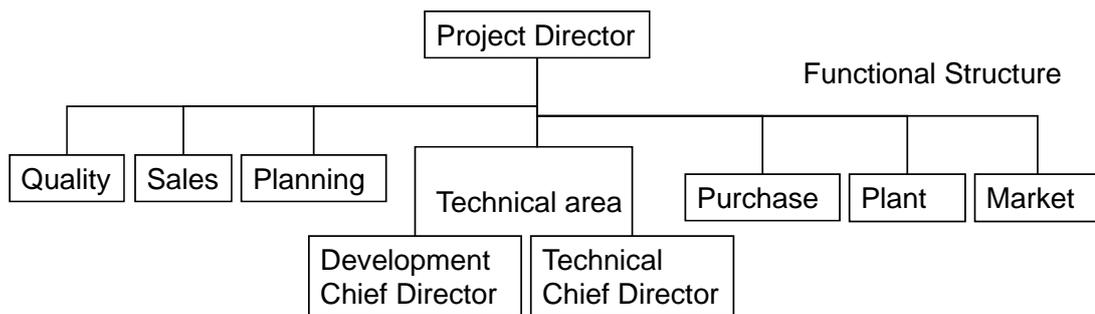


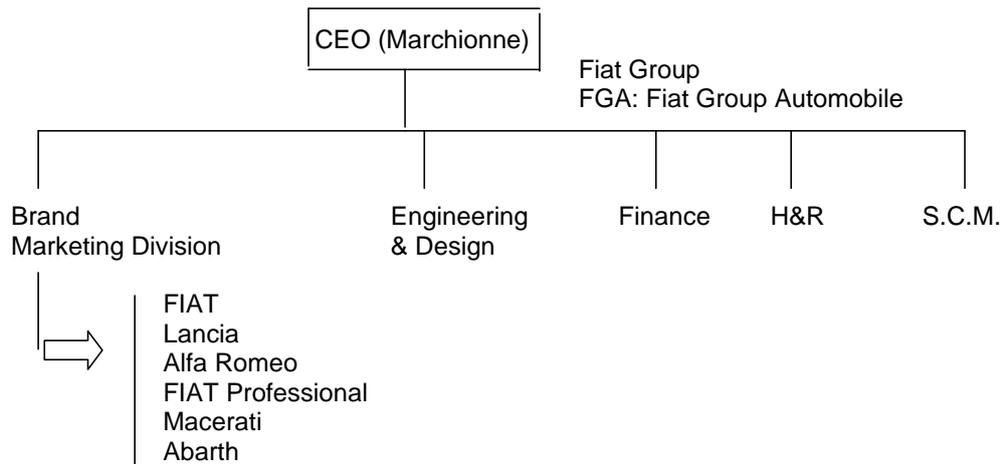
Figure 3.8: Functional Structure PSA, Chief Director Peugeot 308 Project, 2008

The internal structure of the two firms is different. On one side, Peugeot seems to refer to a classical functional structure, strongly bureaucratic and static in its reactions to innovations. The managing levels seem to recollect the shape of a long stair to the top, and the decisions should follow up these stairs, as the power of each stage is strongly subjected to the decisions of the upper steps. We have to point out that PSA strongly improved its functional structure²⁴ during Spring/Summer 2009. This extraordinary change could be the source for further investigations on the topic, according to two fundamental research questions: (1) How did the previous functional structure changed? (2) Why PSA decided to change its previous management model? On the other side, FGA refers to a matrix structure, where the intersection between the functional structure on one side and the brands on the other is the key for the differentiations between the huge number of new models. As an example, a Lancia model in the C segment will provide to

²³We provide the complete results and comments in Appendix D

²⁴See Appendix C for further information

1. Company Structure



2. BRAND FIAT Structure

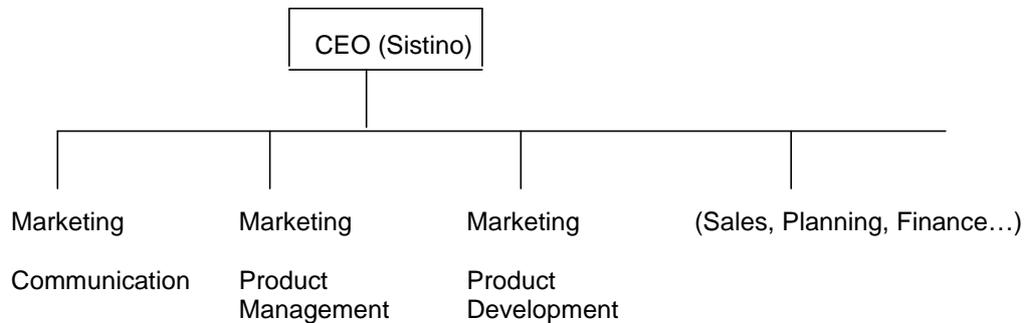


Figure 3.9: Organizational Structure, Marketing Chief Director Brand Fiat, 2008

the customer different performances in terms of speciality, price, dimensions, with respect to a Fiat model in the same class. This is only possible with the use of a functional structure that should control the entire system, while being further clustered into substructures depending on the specific brand. Each brand preserves its own distinctive characterization while being involved in a controlling superstructure. Finally, the brands themselves are further divided into working groups, according to the specific project to develop. These groups are project-oriented, and trace back the same structure of the entire organization. The relations inside these sub-groups are light, direct, with a great use of one-to-one talks or weekly meetings. This renewed structure gives FGA the chance to control over different brands (thus different specifications) and to get in deep into them, at the same time preserving different identities and controlling the entire system.

Our effort was then dedicated to provide evidence concerning time performance, according to its fundamental role in the entire system. The milestone approach we used in the course of the survey served to determine the elapsed time between a phase and another, so as to define the main differences occurring between the two development processes. This methodology has the main advantage to split the NPD process stages, thus increasing the depth of the analysis, even if it is hard

to refine since the order of the milestones could be different from firm to firm and it could also bring some mistakes when activities are developed in parallel. Even though, it could be an understandable base for further details. As we stressed in the preface that one of the first things that really impressed us was the timing of Fiat Bravo introduction into the market, we were interested in understanding what was the starting point of the project. We found out that the project didn't exist since CEO Marchionne decided to take to the market at the beginning of 2007 a new model for the C segment. The bad results of Fiat Stilo took the CEO to consider the fast introduction of a new model, with stronger appeal on customers, one of the “*must*” of his entire revolutionary campaign at FGA.

“(...) Anecdotically we could state that when Dr. Marchionne posed the new development goals (to take to the market the new model at the beginning of 2007) on April-May 2005, nothing was determined and no-one was able to do it²⁵(...)”

Chief Technical Director Fiat Bravo Project, 2008

Even if the staff didn't notice it in that moment, a new perspective and new standard process performances were driving through the firm, taking it out of its ten-yearly crisis, connecting to the other OEM tracks all over the world. At the beginning we supposed this sort of reaction could be only a forced goal for a specific model, in that Fiat *should* take out of the market a product that did never reach the foreseen objectives (Fiat Stilo). Let's say, we hypothesized that it was just a contingent situation. Soon it was clear, though, that it was not. In fact, this fast-and-accurate development became in a few a trademark of FGA in Italy and all over the world, forcing its return on the market as a leader. After Fiat 500, another 16-months-development product, presentation (July, 4, 2007) took place, the Economist titled “*Fiat is Back*”, acknowledging the rebirth of the Italian brand. On the other hand, we tried to get a useful comparison by PSA with its 308 project, and what we found was quite impressive. In fact, the 308 project started long time before the Bravo project, and grew up much slower. We present here a time-line of the evolution of the project, signaling the main events and differentiating between the various phases of the plan (Figure 3.10).

As it is easily noticeable, it began in the first months of 2003 (more than a couple of years before Fiat Bravo) and the vehicle was finally presented at the Frankfurt Motor Show in September 2007 (about eight months later that Fiat Bravo).

This means that the entire project, since its beginning with the commitment in 2003, took about four years and a half to get to the market. In our attempt to look for the main NPD process differences, we found out the great attention posed on supplier integration into the design process by both the technical and marketing chief director at FGA while real practices deny the existence of an effort on

²⁵In Italian: *Come aneddoto possiamo affermare che nel momento in cui il Dott. Marchionne pose gli obiettivi di sviluppo (all'inizio del 2007 il nuovo modello dovrà essere in commercio) tra Aprile e Maggio del 2005, non c'era nulla di pronto, e nessuno era in grado di svolgere il compito assegnatoci* (Responsabile tecnico modello Bravo, 2008)

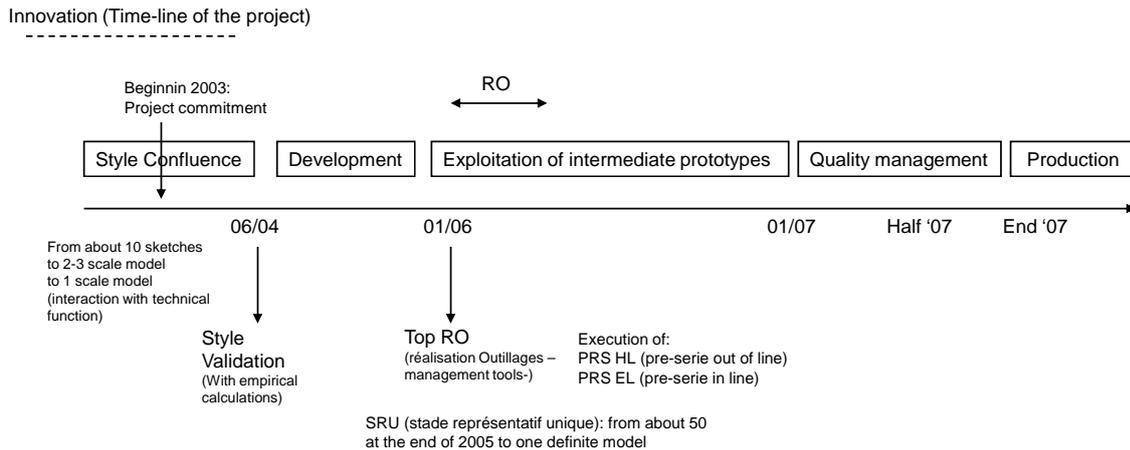


Figure 3.10: Time-Line Peugeot 308 Project, Chief Director Project 308, 2008

customer involvement, in contrast with theory:

“(...) in defining a new product we start from the existing product we want to replace, we identify the view-point of the actual customer, searching for the stream of development for the future customer, and the same happens for market conditions²⁶(...)”

Chief Director Marketing Function, Brand Fiat, 2008

“(...) we can state that as concerns Magna²⁷ the cooperation seemed to be fundamental²⁸(...)”

Chief Technical Director Fiat Bravo Project, 2008

It was not surprising, in fact, that this two-sided relation was important for the firm, as we already knew from previous studies that it could take important benefits to the whole process, hile it was almost interesting the stress both FGA Technical and Marketing Chief Directors posed on the new-born relationship with Magna Steyr, Fiat main supplier. The strongly repeated accent on this concept took us to consider it as the main advantage in the new NPD process at Fiat. We then asked for the reasons why this new solution was generated, the timing of the supplier choice, the methods of integration, and some emphasis was posed also on

²⁶In Italian: *quando si definisce un nuovo prodotto si comincia dal prodotto in esercizio, si identifica il punto di vista del cliente odierno, alla ricerca del punto di vista del cliente futuro, e lo stesso lavoro si svolge per quanto riguarda la situazione di mercato* (Direttore funzione Marketing Brand Fiat, 2008)

²⁷Magna Steyr, a leading global supplier of technologically-advanced automotive systems, components and complete modules

²⁸In Italian: *quindi possiamo dire che per la parte (di lavoro) consegnata a Magna, la collaborazione si é dimostrata fondamentale* (Responsabile tecnico modello Bravo, 2008)

customer integration. The same topics were then exploited in the course of the interviews at PSA. We were strongly interested in comparing the methodologies, so as to understand if they could be an influencing parameter on time performance. During the interviews at FGA, we found it interesting to share wider knowledge, even overtaking the generation project of the Bravo model, to understand the main innovations to the NPD process they took in place after that project ended. We found it interesting that customer integration practices were in place only in newer models, with respect to Bravo. We should underline here that customers in the automotive market are far from being considered as innovators themselves, as the whole technology and innovation involved exceed customer potential. At the same time, though, customer needs could be the source for innovations, as they can express ideas that will be later on posed in a technology shape by firm's experts. An important effort in customer integration has been done for Fiat 500 (the new model sold since July, 4, 2007), with the use of a blog in internet (500wantsyou.it) connecting people from all over the world to give suggestions and comments on the information made free by the car-maker. As regards Fiat Bravo, the same idea was used too late in the development process, as it was mainly intended to collect opinions on the advanced news.

“(...) development has been too fast, and the process was growing up rapidly, without the strong need for suggestions, considering also the different target with respect to Fiat 500. Even though, before the launch of Fiat Bravo (about 4-5 months before the launch) it was created a blog (www.quellichebravo.it) where the first advanced news were highlighted, to collect opinions from the customers²⁹(...)”

Chief Director Marketing Function Brand Fiat, 2008

We noticed that the importance of the incoming segment of the market leaves some space for a deeper analysis of the methodologies of customer integration, if necessary. As regards the C segment of the marketplace, it has been defined by both the car-makers as stable, somehow predictable. Its main drivers are style³⁰, price, quality, and the car-maker image on the market. The vehicle represents a family car, with customers aging between 30 and 60 years old, with similar needs. It represents more a thought-out purchase than an emotional one, thus involving a long-time-thinking expense. All these parameters can be intended as influential on the way customers could interact with the firm: they, in fact, represent a category that is in the center of the market dome, with needs related more to safety and price than to technological innovations. This left some space for opinions, but an effective co-development with the customer-locus generation of idea was hardly possible. Both the firms seemed to ask for customers' help late in the NPD process, while interacting with them in the earliest phases of design using

²⁹In Italian: *La gestazione é stata molto piú rapida, e il processo procedeva molto velocemente, senza necessitá di particolari suggerimenti, anche per il target molto diverso rispetto a Fiat 500. Ad ogni modo, anche prima del lancio di Bravo (circa 4-5 mesi prima) é stato creato un blog (www.quellichebravo.it) dove sono state depositate le prime anticipazioni, per avere un riscontro dal pubblico* (Responsabile Marketing Brand Fiat, 2008)

³⁰Style is always considered as a fundamental parameter, as it represents the dress used in every situation by the owner of the vehicle

well established methods, called clinic tests, such as direct interviews or surveys about the existing products and the related needs of actual customers. To resume, both the car-makers used internet technologies to open information to customers before the launch of the new model, receiving as a feedback comments and doubts. A final consideration about the use of internet technologies came out during the first interviews at FGA: even if they were not in contact with the firm, customers felt the need to talk about new projects, to express their opinions, to search for further information. This meant that they were already “talking” about Bravo project³¹, even without Fiat. This research for further information, comments, FAQ and so on is a symptom of a changing perspective in the market framework: the top-down perspective of the firm interacting with customers is being replaced by the bottom-up perspective, with the customer being more and more involved in the development process. This increased need to be part of the NPD process is partly changing the old-fashioned vision of the firm governing its relations with organizational and technological innovations, but at the same time is still strongly influenced by customization and innovation matters in the marketplace. We state, thus, that any consideration concerning customer involvement should depend on the characteristics of the marketplace, the choice parameters, the knowledge customers have of the product itself. No general purpose considerations could be made, while looking at customer integration.

The main strength as regards Fiat Bravo development project revealed to be, in the course of our interviews, *supplier integration*. While for common-knowledge components, both the firms referred to an adversarial competitive approach, made of more than one decision step, based principally on technical characteristics and the final price, as regards the value-enhancer components, the firms tend to behave differently. While PSA still refers to its competitive approach as regards the selection and then proved to be in some sense detached during the development of the project, Fiat relies more on a co-operational base approach, meaning that it was able to integrate a core of suppliers in its development stage, working with them co-developing the vehicle. As Fiat Bravo is a derivative project, the main innovation seems to be the structure of the body: platform, brakes, engine and more that 70% of the underbody structure derived entirely from Fiat Stilo, as it has been considered a fairly ambitious and strongly innovative project. The main contribution to the timely development of the entire model, thus, was given by Magna Steyr as supplier of the most critical part (the body itself). Going deep into the topic, with the aid of deepen analysis, we proved that both the car-makers found it easy to establish a strong boundary between different kind of suppliers. In particular, they both distinguished between an adversarial relationship and a co-design, mostly depending on the typology of the part to realize:

- **Co-design** specifically means that the car-maker structures a basket of specifications about the new product, and designs the part jointly with the supplier, using organizational structures as multi-functional joint working-groups, or co-location models;

³¹See as examples Quattroruote.it Autoblog.it Fiatfans.com

- **Adversarial** means that the car-maker exactly knows the structure of the part to build and explicitly supply the partners with all the details of it, expecting supplier to build it as recommended.

We found out that the major inputs to the innovative process were obviously given by co-developers, with the integration of their complementary knowledge into the car-maker standards. Both the car-makers clarified that the choice of a supplier was done on a concurrency-base, and that the suppliers may not be the same even in the case of carry-over. For instance, the choice of the ESP supplier for Fiat Bravo and Lancia Delta was different both for purchasing and technical reasons, even though the two models ground on the same platform and may be subjected to carry-over. As we found such commonalities between the two car-makers, we asked them the timing of the supplier selection, and we were quite surprised to see such different results! As regards the Bravo project, in fact, suppliers have been chosen at the beginning of the project, with a time-horizon of 4/5 months. As regards 308 project, they were finally chosen between 6 months and 1 year before the top RO definition, after about 1 year of selection. We should be aware that, as regards Fiat Bravo, the project was imposed to be short in time and high in quality, and many suppliers refused to join the development leaving Fiat in a challenging situation. A lonely ally, Magna Steyr, an automobile manufacturer and assembler based in Graz (Austria), accepted the burden to help in the generation of the new body. The selection time, thus, should be strongly constrained to the extremely reduced affordable supplier basket. Nevertheless, the supplier selection process time at PSA accounts for about two/three times the elapsed time at FGA. One of the main differences, thus, has to be searched in the selection process. Moreover, as we got deep into the matter of buyer-supplier relationship, we discovered that Magna Steyr was considered to have been absolutely fundamental for the success of the new vehicle, and the aim of our research was to understand explicitly where its influence was decisive in the joint development process. As an engineering supplier, Magna was involved in the project using the standard method of the responsibility matrix, that is a clustering method evidencing the task responsibility respectively of the OEM and the supplier, and then accomplishing the single tasks in co-location in Graz, near Magna Steyr development center. The reasons to transfer the entire design group in Graz were mainly (1) to develop a strict collaboration with daily meetings and joint development and (2) to quit the negative rumors about the possible failure of such an ambitious project. The value of Magna Steyr inside the project can be mostly ascribed to the methodological approach to the body development: on one side, it was focused on the German rigorous approach, on the other it used the most advanced technologies of virtual prototyping to realize and test all the parts it was accounted for in the project. The integration with Fiat knowledge proved to be successful when the project of the part was finally taken to the Fiat plant in Cassino (IT) to be produced. In this subtle difference resides the concept of engineering-supplier with respect to co-designer:

“(…) co-design means a supplier who develops a part jointly with our development team and manufacture it, thus meaning that it accounts for the entire project, while an engineering-supplier simply designs the part. Magna Steyr was our engineering

supplier for the body. Our internal technical group was responsible to manufacture the part on the base of the project³²(...)”

Chief Technical Director Fiat Bravo Project, 2008

Magna Steyr brought to Fiat a new procedure in realizing and testing parts, such that it gained great advantages with respect both to costs and time. The use of virtual prototyping as a new frontier in product development is one of the hot topics in the management literature [11, 153, 202, 203, 237], and should be further investigated to broaden the framework of analysis of the advantages of Fiat in NPD, as it has been told to be the major innovation in the development process³³:

“(...) the use of IT concerns simulations (virtual design and prototyping), and was used to totally delete physical prototyping. Every prototype costs about 1 million euros, and deleting physical prototyping means avoiding generation of about 50 prototypes. Calculus are fairly easy!³⁴(...)”

Chief Technical Director Fiat Bravo Project, 2008

Resuming in a few words, supplier integration proved to be the main parameter concerning the new product development process. Integrating suppliers with a co-development approach influences:

- Time-to-Market performance: it comes out a faster NPD process, still maintaining the same qualitative results;
- Methods and tools: integrating complementary knowledge in the process is the key for innovation in technology and for fundamental changes in methodologies.

The breakthrough innovation FGA brought into its process is, thus, the source of a completely new standard, as Fiat was able to adapt its organization to the renovation and to widen its knowledge during all the steps. It is not a case if the actual purpose of FGA for the next models is the improvement of the standard depicted by the Bravo experience. In a word: *not a contingency, but a standard*. The last point we were able to highlight in the course of the interviews is the past experience of both the firms concerning the C segment of the market. As we said that both the vehicles are derivatives of previous models, we state here that it

³²In Italian: *Co-design per noi significa un fornitore che sviluppa un componente insieme al nostro gruppo di sviluppo e lo produce, cioè segue tutto il processo, mentre un fornitore di engineering é quello che progetta e basta. Magna Steyr era il nostro fornitore di engineering per la lamiera. Il nostro gruppo tecnico interno é stato poi responsabile della realizzazione del pezzo sulla base del progetto* (Responsabile Tecnico Progetto Fiat Bravo, 2008)

³³See chapter 4 for further investigations on the topic

³⁴In Italian: *L'utilizzo delle tecnologie informatiche é relativo alle simulazioni (progettazione e prototipazione virtuale), e questo ha consentito di eliminare la fase di prototipazione fisica. Il costo di ogni prototipo é di circa 1 milione di euro, quindi eliminare la fase prototipale significa evitare la creazione di circa 50 prototipi. I calcoli sono piuttosto semplici!* (Responsabile Tecnico Progetto Fiat Bravo, 2008)

is important, in defining the degree of originality of the entire NPD process, to consider the previous results of the firm: in some sense, we suggest the presence of a never-ending challenge between continuous improvement versus breakthrough innovation. Evidence could be provided on the opposite development path concerning Fiat Stilo and Peugeot 307: the former, launched to be a revolution, in an attempt to “conquer” the market, came out to be a flop, while the latter gained impressive market share. We report on an intriguing situation: where Fiat was fighting to give birth to a new model jumping out of the previous downward spiral, PSA strived to capitalize on the success of its previous experience. The recent history of the two OEMs, thus, seems to strongly affect their behavior on the marketplace, and represents a revolutionary contribution in understanding the attitude of the firms with respect to risky innovations: PSA, in fact, seems to rely on its previous methods, as they proved to be successful, even if it has all the chances to jump into the future, while Fiat, fighting to survive, in some sense runs the risk, in an attempt to renew the whole organization. Interestingly, then, we are suggesting here the hypothesis that the real “innovators” are those firms that see innovation as their last chance, while success proved to build more static organizational structures.

We resume the results we obtained according to each parameter involved through Figure 3.11.

Parameters Involved	Technical Parameters	Customer Integration		Late involvement, Use of IT, Evaluator more than Co-Operator	
		Supplier Integration	Co-design	Co-location model, multifunctional working group, 100% on body structure	Concurrency base,
			Adversarial	Concurrency base	Concurrency base
			Methodological Advantage	Virtual Prototyping and Testing	Trade-off between Virtual Simulation and Rapid (Physical) Prototyping
	Framework Parameters	History of the Firm		Stilo lost more than 5% market share	307 gained more than 4% market share
		Market Framework		Stable, predictable, Reasoned Choice; Main drivers: Safe and Solid Technological Base, Affordable Price	
		Organizational Structure		Light, renewed	Strongly Bureaucratic, Static

Figure 3.11: Parameters Involved in the Analysis

3.6 Conclusions and further analysis

To conclude, then, we will have to build on a brief premise regarding the entire research framework: the analysis, in fact, suffered of some problems on the PSA side as regards the interviews, mainly caused by the effort in management renovation during the first part of the year 2009³⁵. This substantially hampered the possibility to elaborate on further data. We are still trying to widen the draw we made of the actual industrial concerns so as to increase the value of our conclusions. At the same time, though, the little box of interviews we have, shows an intriguing situation that leaves space for some considerations. We have to exploit our interest on two opposite directions: on one side of the chain, customer-integration, on the other, supplier integration.

As regards customer involvement in the course of the development process, we saw commonalities between the two OEM in the management of the relationship, as they both weren't able, in the course of the specific project, to exploit the advantages of new technologies in an appropriate manner. We state that the fundamental variable widening the importance of customer integration should thus be the characterization of the market place. A possible hint suggested during the interviews is that customer integration real advantages could be noticed depending on the type of product and the market. As regards Fiat Bravo and Peugeot 308, the main drivers are not technological innovation or extreme customization, while a safe and solid technological base and a price suitable for a large majority of medium class population. Literature about customer was sometimes critical with respect to a strong relationship between the OEM and its customers, in that it could take to strong efforts just in generating renovations of old models. In this case, that seems not to be so under-appreciated! As actually the automotive market seems to be strongly involved in the ecological-run, so that the future revolution will surely concern fuel, probably a step-by-step innovation waiting for a breakthrough to come could be the best organizational solution. Even though, it has been evidenced that further customer involvement in the development process has been achieved, at least at FGA, for newer models, as Fiat 500.

As regards **supplier integration**, both the firms showed a strong interest in the topic, and their efforts to involve suppliers have been rewarded by faster new product development and increased learning by doing. Even though, the car-makers showed some differences in the selection process, as FGA seemed to be much faster, even if there were commonalities in the concurrency method. As knowledge spreads more and more on the entire supplier framework, and specialization rules, the core capability for the OEM seemed to be the integration knowledge more than the concrete design and development of single parts, thus meaning not to loose internal capabilities in that they are fundamental in the coordination and control process. Both the OEMs clustered possible relations as co-develop and adversarial, using the concurrency adversarial method specifically for accessories, while innovations where found to be best threatened in a co-development organizational structure. At the same time, though, FGA proved to rely more on suppliers as co-developers, while PSA proved to threat them more as providers. In this sense,

³⁵See Appendix C for further information

PSA was forced to keep in-house all the design capabilities with respect to the final components of the product. Interestingly, we consider it noticeable that supplier knowledge regards not only the physical production of parts, but also (and sometimes this has been considered the most important ability to learn) the way parts were designed, tested and developed. In a word, more methodology than practice. We state, thus, that an interesting common “way of doing” has been identified during the ever-lasting process development. The aim of the firms, now, seems to understand how to better exploit the relationship with suppliers. This sort of change in perspective leaves some space for further considerations: the adversarial method, in many papers strongly contended as old-fashioned, still remains fundamental for not-at-the-edge-of-competition parts, while some components, supposed to increase the whole value of the final product, seemed to be developed on a one-by-one perspective. At the same time, though, an interesting observation on this suggestion is that as firms strive for a strong re-use of components, they may not be provided by the same supplier due to technical or economical reasons. This parallel run of the adversarial and the co-operational methods represents an evolution of both the black-or-white perspectives (adversarial vs co-development), as it sounds like a grey horizon to work with. The adaptation method is like to be recurrent in this reality, as there is not an ad-hoc solution for the whole system. Our research leaves some space for further considerations, to be empirically tested. First of all, the chance to extend our conclusions to the entire market framework is still under analysis, and must be accomplished with further interviews to other OEMs. Moreover, the history of the car-maker is a fundamental parameter to include in the analysis, in that successful car-makers could exploit their success to take more time to develop new products, as the older models can be still used in the market with a discrete success, while unsuccessful ones should faster their NPD process to substitute older vehicles as fast as they can. History determines also the idea customers have of the firm in a specific market sector. As highlighted during the interviews,

“(...) we have to consider that at the present time Fiat Group doesn’t enjoy of a good reputation on the C segment, and it is not considered a high-tech producer, though it really is, thus customers are not able to recognize the price of the new model as they can’t really recognize its real value³⁶(...)”

Chief Technical Director Fiat Bravo Project, 2008

Furthermore, an intriguing question regards different market frameworks: where literature mainly focused on the relation between performances and customer integration, without a real focus on market, an open space for further analysis could be that of testing customer integration according to the market niche, and the best organizational practices to develop in different cases. This could lead to the interesting result of huge firms with different integration levels and methodologies

³⁶In Italian: *Si deve considerare che Fiat ancora oggi sul segmento C non gode di ottima reputazione, non é considerata produttrice ad alta tecnologia pur essendolo, quindi non riconoscendo questa immagine, il cliente non é in grado di riconoscere nemmeno il prezzo della vettura* (Responsabile Tecnico Progetto Fiat Bravo, 2008)

according to the market and the potential customers. Finally, we argue that customers could not be the same depending not only upon their abilities, but also upon their culture, the way they faced product development and their specific regional characteristics. We suppose it is possible to find many different results depending on the region where the analysis is being taken. At the moment, without further analysis, we are not able to verify this hypothesis, and we leave this idea, as the others we suggested in this work, open for future investigations.

Part IV

Rapid vs Virtual Prototyping

Chapter 4

Time to Market as the Final Performance in the Rapid-Virtual Prototyping Challenge: A Case Study in the Automotive Industry

4.1 Abstract

As pressure to lower both time and costs of research and development (R&D) increased in recent years, firms embraced many novel technologies and approaches in an attempt to develop new capabilities that would give them an advantage over competitors. As information collected deeply influence product performances, intended both as technical requirements, market appeal and timing, strong improvements were brought to the testing phase, with the introduction of new methods and tools. This paper shows how IT instruments changed the way firms act with respect to testing new products, both on their technical and market side. We will refer to the timing of projects as our dependent variable, and we will show, with the aid of a comparative case study in the automotive market, the possible trade-offs between the extensive use of virtual prototyping (VP) and the old-fashioned method of physical ones, aided by great improvements in rapid prototyping (RP) techniques. We suggest a parallel advancement in research: on one side, we state that VP allows for the fastening of the entire NPD process, still maintaining the same performance as regards the quality of the final product, while on the other we refer to the importance of other variables in the decision of the firm whether to implement VP methods. Customer satisfaction, the image of the firm and historical matters should be a further base in the decision process. Along with these considerations, an important aspect actually dominating research framework is the challenge between rapid and virtual prototyping as opposite testing technologies. We will state, grounding on our results, that firms should focus explicitly on VP techniques, as they can both speed up the NPD process, reduce parallel-processing expenses and gain same-level qualitative results. In the conclusive section of the paper, we aware, though, that a “golden rule” is still under definition, as it is the results of a mixture of endogenous and exogenous factors, thus should be re-adapted every time market or firm conditions change. The result is, thus, a waving perspective on NPD tools, with the shape of the general conclusion and the features of the specific framework.

Index terms- Virtual Prototyping, Rapid Prototyping, New Product Development, Time to Market, Automotive industry

4.2 Introduction

A firm’s product development process can be a source of competitive advantage in many industries. Engineering organizations today are working to reduce product development time and to improve product quality [9, 23, 48, 69, 70, 86, 110, 177, 179]. The main industry connected with NPD is considered to be *experimentation*¹, as it can account for a significant part of the total innovation cost and time [202]. The

¹We will refer to this activity during the paper alternatively as experimentation or testing, with the same meaning

continuous process of trial and error related with it has been seen as one of the main activities for the firm since long ago, and it is still an on-going research topic [11,14,182,223]. Experimentation is seen to be fundamental to the learning process in areas such as technology integration and manufacturing [1, 2, 18, 90, 159, 203]. A key problem firms usually face in managing product development is to find the optimal timing and fidelity of testing activities. The execution of an experiment can be seen as involving a four-step iterative cycle² (Figure 4.1): (1) Design: One conceives of or designs an experiment. (2) Build: One builds the (physical or virtual) apparatus needed to conduct that experiment. (3) Run: One runs the experiment. (4) Analyze: One analyzes the result. If the results of a first iteration are satisfactory, one stops [202, 222].

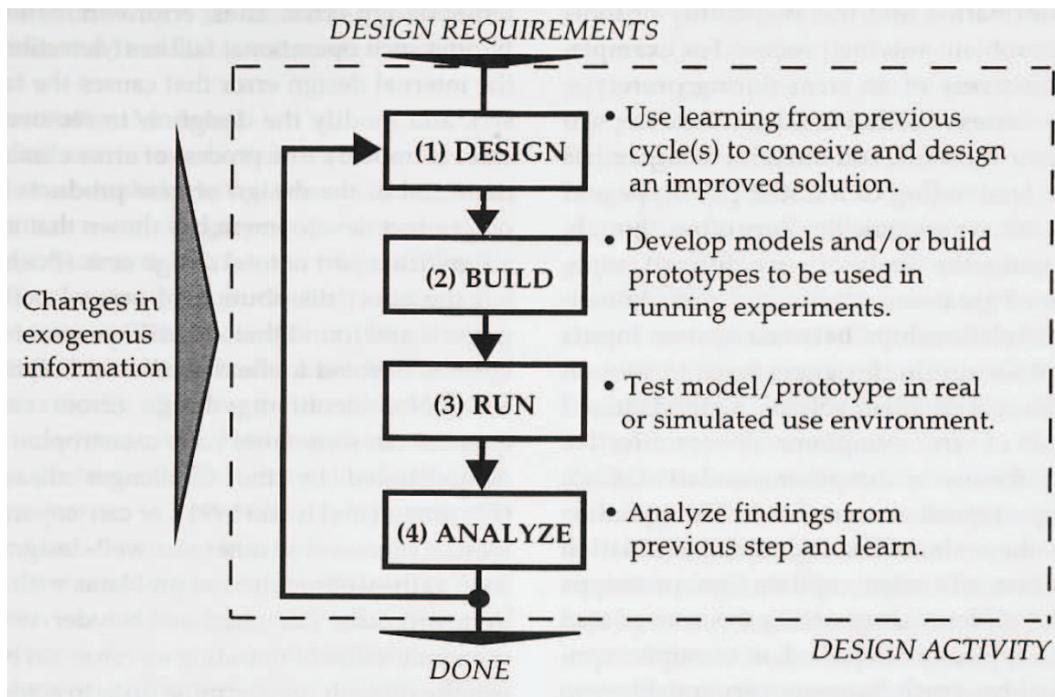


Figure 4.1: Design-Build-Test Cycle, Thomke, S.H. (1998)

Many examples can be made, as the cycle is common knowledge in most of the manufacturing firms acting on the marketplace, such as, for the automotive industry, the repeated cycle of designing a car (or parts of the vehicle), building a prototype, running the experiment and analyzing results. Models applied in testing come in many forms and can be used to reduce uncertainty about customer needs (by asking users to evaluate early prototypes, mainly in focus groups) and the feasibility of alternative technical solutions (by testing functional prototypes under laboratory conditions) [197]. Interestingly, the use of prototypes in the testing phase opens an unsolved problem as firms should determine good tradeoffs between development speed, product cost, product performance and the development programme expense [14]. Great improvements were made, though, in the

²Other researchers used related frameworks to study problem-solving in design. Simon (1969) used “generator-test” cycles and Wheelwright and Clark (1992) used “design-build-test” cycles.

field of prototyping, both on a technical and an economical side: as to generate faster and cheaper real prototypes, *rapid prototyping* centered on the chance to completely integrate production with 3-D computer planning [151], overnight instead of taking weeks or months, while at the same time a substitution technology was being developed, as *virtual prototyping* helped in the digital generation and simulation of events, overcoming the physical part of the testing stage [11]. After a brief presentation of both techniques, and in particular of the advantages and disadvantages of real versus virtual prototyping, in this study we will center on the automotive market, with the aid of a comparative case study analysis, as in that market (even if it is not the only one!) empirical studies have already shown dramatic impacts, in at least one very critical area –the design for crashworthiness–, though acting in other areas as well. In brief, research states that (1) by speeding up and simultaneously reducing the cost of design iterations, developers can increase the frequency of problem-solving cycles while reducing the total amount of time and money spent on the R&D process and that (2) the ability to conduct diverse experiments with novel technical possibilities more effectively than with alternative methods can lead to better output (in the sense of mixing its effects on performances) [203]. We suggest that firm’s attention should not be devoted entirely to the fastening of the NPD process, as it could loose its goal. Thus, the firm should raise its efforts to the comprehension of the external environment, as market requests could change dramatically as its priorities changes, and the development procedures should be revised accordingly. Furthermore, we state that in an attempt to “keep in touch” with present-time technologies, firms should jump into virtual reality technologies, as they proved to be better on some performance indicators, the others being equal. We suggest that rapid prototyping techniques could evolve less dramatically than virtual prototyping, thus the actual gap between the results evidenced by the two methods is forced to increase in the future. We finally found some space for further considerations, and we highlighted that an intriguing matter is the definition of the real effect of past history on actual decisions and customer reactions about the products. We pose as a future goal of research the definition of historical data influence on the actual performances of the firm.

We will structure our paper in a classical framework, with a theoretical introduction first, followed by the methodology we used in our comparative case study, data selection and the main results we were able to find. Finally, a brief section will close the paper, with some conclusions and suggestions for further analysis.

4.3 Theoretical Framework

LEARNING by experimentation is one of the fundamental steps of the NPD process, and can be viewed as an iterative trial and error process that is guided by knowledge of underlying relationships between cause and effect [2, 34, 182, 222]. This method is particularly valuable in complex and novel environments [221]. As many could be the different performances along which development process can be

measured, such as lead time, productivity, product quality [34], in our research we decided to focus specifically on lead time, intended as the measure of how quickly a firm can move a product from concept to market [198]. While literature on product development speed is vast, reporting on a number of different approaches to reduce development time, and is full of good reviews showing different view-point analysis about different stages and determinants [9, 23, 34, 45, 47, 67, 83, 222], we will focus mainly on the testing stage, as it has been one of the deeper-changing activities in the last decade. The main reason for this growing stream of literature concerns the improvements in technology that made it possible to choose between more than one alternatives: while in the past testing should be made with physical prototypes, sometimes hardly similar to real models, now the connection between computer technologies and prototyping made it possible to establish better strategies and different modes to develop the analysis. Furthermore, it brought to light two leit motif of the decision making process: if time was really one of the main performances to work on, regardless of the market characteristics, and which could be the best alternative to improve, while choosing it in the vast framework of new possibilities.

4.3.1 Why testing: Benefits and Costs

TESTING is considered to be fundamental as firms must sell products facing respectively safety rules and fashion standards. During the NPD process, thus, the development team should solve both the matter of achieving at least the necessary quality and of meeting customer needs. Testing can be represented as a sequential try-and-error activity that builds information about technical problems and/or customer needs [197]. Tests can generate information about the functionality and manufacturability of a product design and, if involving customers, about the extent to which it meets user needs. The decrease in uncertainty is not only a function of the number of times a test is being made, but also of the timing of the entire project: as the cost of engineering changes is growing over time, the earlier new information becomes available, the higher its value [109, 196]. Building and testing physical and virtual prototyping models is an integral part of product development, and many studies focused on the ways to improve quality and reduce costs at this stage [88, 222, 237]. As highlighted in previous studies, the value of prototypes was found to be the advancement in the effort and time required to realize same-quality products [197]. Not identifying design errors and their consequences may represent a sort of “disaster” for the entire project, as for example jeopardizing the commercial success of the product [208]. At the same time, though, the real value of testing comes out not on stable, known products, while where uncertainty is very high, and the research of answers seems to be fundamental for the firm:

“(...) prototyping is not necessary on familiar projects where there is little risk of getting the wrong user interface, requirements, or design (...)”

The advantage of reducing the economic cost of design changes and uncertainty is sometimes counterbalanced by some expenses, concerning both equipments, materials, facilities and time spent in the development of the testing phase. Testing is a time-expensive activity, and a job subjected to a high degree of uncertainty [14, 153]. Moreover, the realization of prototypes could represent for the firm one of the most expensive stages, even though it could be the opposite: costs could be as high as million euros, such as in the automotive industry for vehicle prototypes used in destructive crash testing, or substantially non influential on the entire budget, as for chemical compounds used in pharmaceutical drug development [200]. A trade-off solution in the NPD decision making proved to be fundamental: the definition of timing, frequency and fidelity of tests (and thus of prototypes) [197], in fact, strongly influence foreseen expenses related to prototyping and testing. As an example, one of the critical decisions as an attempt of cost and time reduction involves the degree of similarity with the real product and the technology used to realize prototypes [217]: manufacturing firms usually structure tests on incomplete models, where some real aspects considered to be irrelevant to the entire analysis are excluded³ such that the whole amount of the investment could be reduced. Moreover, literature focused on the trade-off between delaying prototype testing, in an attempt to reduce costs increasing the quality of the test and decreasing its frequency, with respect to the higher cost of a late-discovery of problems. In a few words, problems discovered too late could cause enormous delays on the entire project, if not its “killing”, while structuring tests too early could force un-needed expenses with no appreciable results. Whereas considerable progress to make development processes more flexible has been made in recent years [201], late engineering changes as a response to identified design problems still can be very costly and time consuming [33, 237]. But not only time and costs are part of the disadvantages of physical prototypes. New rapid prototyping methods⁴, in fact, partially decreased the influence of both the indicators by using different techniques and integrating computer design tools, while it is interesting to notice that, once made, physical prototypes are either difficult or impossible to modify [237], thus representing one-chance instruments. Moreover, as they are usually incomplete, they seem to suffer for residual uncertainty that cannot be resolved until the model being used in testing is replaced by a different (and more accurate) prototype, or by a real product in the real environment for the first time (i.e. pre-serie testing). Furthermore, as they could be used to test the proxy with customer needs, the tradeoff between accuracy and cost has to be considered when showing the prototypes directly to users. Finally (i.e. crash tests for the automotive market) it is hard to isolate all the interactions between different parameters

³classical examples of this practice are airplanes or car prototypes, used for the wind tunnel, where the inside face of the model is un-done

⁴Rapid Prototyping is a class of techniques, evolved during the last decade, able to realize fully functioning physical models with a high degree of complexity both in internal and external geometry, using CAD files as designing projects. This technology does not need expensive tooling. It has also been variously referred to as *layer manufacturing*, *material deposit manufacturing*, *material addition manufacturing*, *solid freeform manufacturing*, and *three-dimensional printing* [32, 118, 228, 229]

involved in the test, even with the use of greatly improved instruments, thus meaning that the prove should be repeated several times. The whole effects combined serve as a hint for the effort firms pose on delaying and even avoiding the use of prototypes as much as they can, even though being aware of their importance for the success of the entire project. To resume, we could simply state that the fundamental problem resides in identifying a “*not too bad*” solution (i.e. a trade-off between benefits and costs suggested above). The literature on prototyping and testing states that the actual framework is based on many firms testing too infrequently or too late. To solve this evident paradox (“*being aware of the importance of testing still trying to avoid it*”), a strong effort was posed on research, as new technologies were evolving so fast, particularly in the last decade. The availability and affordability of advanced computer technology has paved the way for a deeper use of digital short cuts in the generation of both physical and virtual prototypes. It is interesting to compare the advancements both methods realized in these years, to depict a stronger overview of the decision-making dilemma actually involving the whole market framework in some industries, such as automotive and aerospace.

4.3.2 Prototyping Techniques: the Hearth of Change

Rapid Prototyping: old style, new shape

As evidenced during the *Theoretical framework* section of this work, the need for faster, higher quality, greater efficiency and cost effectiveness product development process forced firms to develop new solutions in the testing phase, as it proved to be the most expensive during the whole procedure [108]. The evolution on the physical side of prototyping took firms to set in place new concepts and tools aimed at prototyping generation (Figure 4.2).

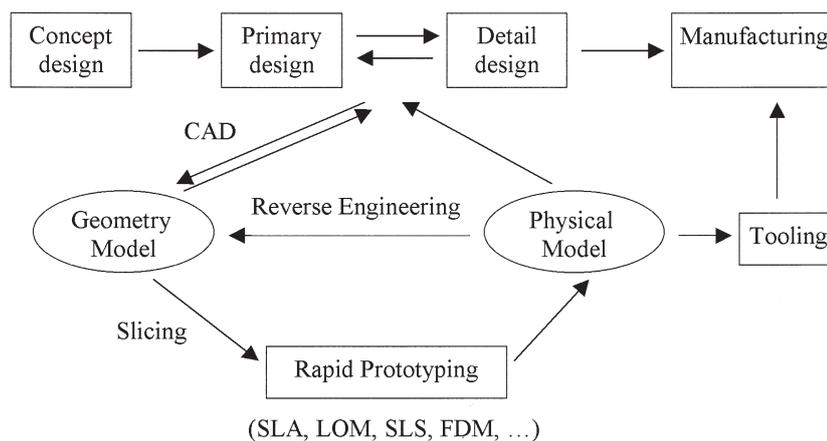


Figure 4.2: Product development system based on RP, Kochan, D., Chua, C. K. and Zhaohui, D. (1999)

Rapid Prototyping (RP) is a generic term for a number of technologies enabling

components to be made without the need of conventional tooling in the first instance or indeed without the need to engage the services of skilled model-makers. Usually RP techniques are additive processes. RP components are built-up gradually in layers until the final geometry is obtained. The way in which the layers are produced, however, and the materials by which parts can be built, vary significantly between the different RP processes [207]. Since it first appeared in 1988 (SLA, Stereolithography), the market has grown at an average rate of 58 per cent per year [107]: 2234 RP systems with about 20 kinds of processes were in use around the world at the end of 1996, 3289 at the end of 1997 [226].

Rapid Prototyping techniques found out to be a completely new method of shaping the external environment, as it is based on the same principles of the standard method of physical testing, while at the same time it forced the connection with new computer aided technologies, forging a constructive co-operation between the two. Briefly, we could state that RP is based on a two-stage process (Figure 4.3) [168]: first of all, the preparation of data on a virtual model, based on a CAD standard project; then, after data transferring on a different file format (usually an STL format), aimed at providing useful information about machineries and tools in the workstation, the physical object is generated using one of the many currently available RP systems.

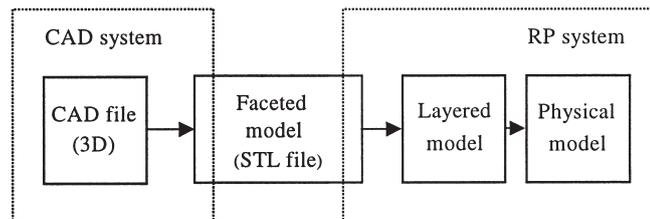


Figure 4.3: Data Transfer between the CAD and the RP system, Rosochowski, A. and Matuszak, A. (2000)

Rapid Prototyping technologies has proven successful in many ways as a process which can be easily and rapidly automated and with almost no geometry limitation in parts to be fabricated [108]. Its main applications cut across aerospace, automotive, component, tooling and medical applications. Generally, it showed benefits, with respect to traditional physical prototyping, in:

1. Reduced lead times (per component and product to market);
2. Reduced costs (direct manufacture savings and mistake avoidance);
3. Improved quality.

Evidence of deep advantages both in time and costs (even 'till 80%), is given in seminal works [151].

Limitations to this kind of technologies recur depending on the materials being used and on the physical properties of the objects produced: while researchers are

still working on lowering defects rate, such as surface roughness or dimensional accuracy, present-time prototypes could show properties that are quite different from parts that are made by conventional manufacturing processes with conventional materials (instead of the commonly used polymers, paper and ceramic). Over the latter years, one of the main changes in RP has been the ability to produce metal components directly, and a sort of continuous improvement in time and cost efficiency [207]. In some sense, since its first appearance at the 3D Systems of Valencia, California, USA, in 1986, RP research continually grew up and is still a burning issue. As Upcraft and Fletcher stated (2003):

“Many believe that the journey has only just begun!”

Upcraft, S. and Fletcher, R. The rapid prototyping technologies
Assembly Automation (2003), 318-330

Virtual Prototyping: the new frontier

WHILE the ability to design, test, and analyze technical and scientific concepts and solutions with the aid of digital tools has fascinated R&D professionals and scientists for decades, since 1970s [33], and has been successfully applied in some specialized fields [13,51,176], it has been only recently that the evolution of technologies and simulation methods reached a state where considerable and wide-spread performance enhancements are observed [137]. The rapid increase in both computing power and sophistication of computational methods and models of physical phenomena [237], together with the lowering of the prices of general purpose computers [198], made it economically affordable a technology which proved to be robust, accurate, realistic and cost effective [14], with the chance of great continuous improvements in the following period [90,153].

A virtual prototype may be represented as a series of graphical images or computer aided design (CAD) models, in animated or still format, created in the form of mathematical patterns and stored digitally in computer usable memory [237]. The main improvement with respect to rapid prototyping, though, refers to the chance to exploit virtual techniques also during the testing stage, without depending on the physical model to generate information about product reactions when submitted to different external conditions. Although the structure of this new frontier in the development framework is not yet exhaustive even in specialized literature, the advantages it seems to bring about are the source of the attention researchers devoted to its implementation (Figure 4.4). Computer simulation is, thus, being used as a substitute for or a supplement to physical experimentation in many fields [203], ranging from the design of drugs to the design of mechanical or electronic products.

Many are the critical parameters affected by virtual prototyping and simulation, both on the technical and on the market side [218], and many are its practical applications in the actual industrial framework [30, 51, 206, 233]. We will depict them in a brief list, as to collect the main contributions about the topic:

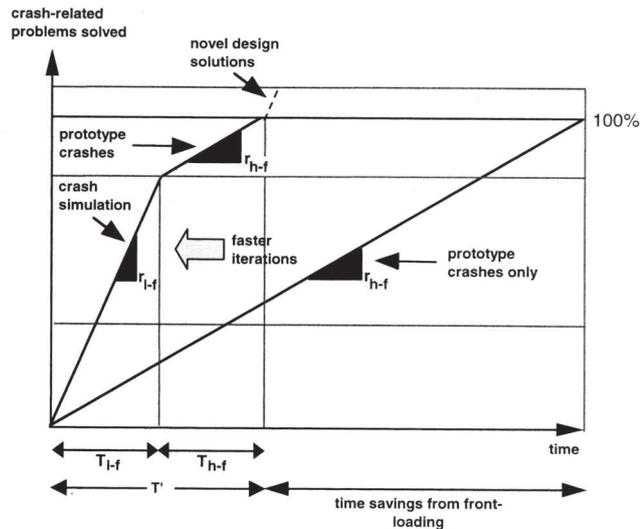


Figure 4.4: Combining prototype crashes with simulation can result in faster development *and* discoveries of novel design solutions, Thomke, S.H. and Fujimoto, T.(2000)

1. **less expensive in testing prototypes:** the main advantage here is that the need of the physical production of models vanishes; as we told before, sometimes prototypes could be extremely expensive, and the test could be of the destructive type (see as an example crashworthiness tests in the automotive industry);
2. **less time consuming:** time is a fundamental resource in the present market, thus reducing the cycle time gives firms the chance to fulfill the market with same-quality products before competitors, both achieving a larger market share and meeting customer needs;
3. **more informative** with respect to the single test: sometimes tests (see as an example a real explosion in a prototype cylinder of a gasoline-powered car engine) may take milliseconds, such that it is hard to understand the cause-effect relationship occurring on the product to be tested, even with the aid of advanced methods and tools, still subjected to a high degree of noise [18]. The same test might take minutes or hours on a powerful computer, thus being richer of information and details that could otherwise get lost;
4. **easier to change the prototype:** the chance to change some parameters of the prototype, as a result of previous test experiences, in an easy and mostly un-expensive way, offers the opportunity to identify better solutions that could otherwise be neglected;
5. **easier to change the environmental parameters:** all the rest being equal, it is possible to change single parameters to evaluate their influencing potential on the entire system;

6. **greater communication** between structures inside and outside the firm, through realistic graphical modelling based on full color, natural texture and appearance.

As evidenced by Becker et al. [11] in the case of the automotive industry, when virtual experimentation is not used only in the early stages of the process, while it is exploited much further, as the availability of good-quality physical prototypes is proven, the overall advantages of the use of digital tools represents 2-3 working months on an average of 12 per project, and even 25% cost savings on the overall cost generated from prototype building, or in general of about 10% of the project final budget, if the virtual prototyping is pushed to its extremes, totally eliminating the physical stage.

The main counterbalancing reason to quit virtual prototyping is the level of accuracy desired for the model. Many researchers since the end of the 90s [33,200,202] identified the reliability of tests as the focal point of discussion. In the automotive industry, as an example:

“(...) not all crash safety tests can be conducted via simulation because of the complex dynamics necessary to construct very accurate models that would identify all functional problems (...)”

Thomke, S. and T. Fujimoto, The effect of “Front-Loading” problem solving on product development performance, *Journal of Product Innovation Management*, 2000; 17:128-142

An intriguing matter, thus, is the percentage of simulation that can account for digital tools, as technology is improving so fast in recent years; it seems, in fact, that problems in the exact definition of the model and the external environment acting on it are vanishing with technology improvements [111,130,147], so as to allow firms to digitally structure the entire design and testing phase. In particular, it is interesting to notice that, as about a decade ago [202] the main matter seemed to be the identification of the optimal switching point between different modes, as experimentation efficiency⁵ decreases at different rates (Figure 4.5), now the decision-making process transfers to whether or not to digitally undertake the entire project.

The strong impact of the technology base on the development of new tools and methods is sometimes intended to be not as an advantage, but as a problem for the development project: some researchers argue that it becomes difficult to develop and adapt the simulation models quickly enough according to the changes in the technology base [203]. Hooking up to the evolution path of this technology actually seems to be expensive and sometimes frustrating as new solutions grow old in a few years, if not in months.

⁵The main idea is that, as a design progresses and experimental cycles are repeated within a given mode, efficiency, defined as “the economic value of information learned during an experimental cycle, divided by the cost of conducting the cycle”, decreases due to diminishing marginal returns from experimenting in that mode. For deeper evidence on the topic, see Thomke [202]

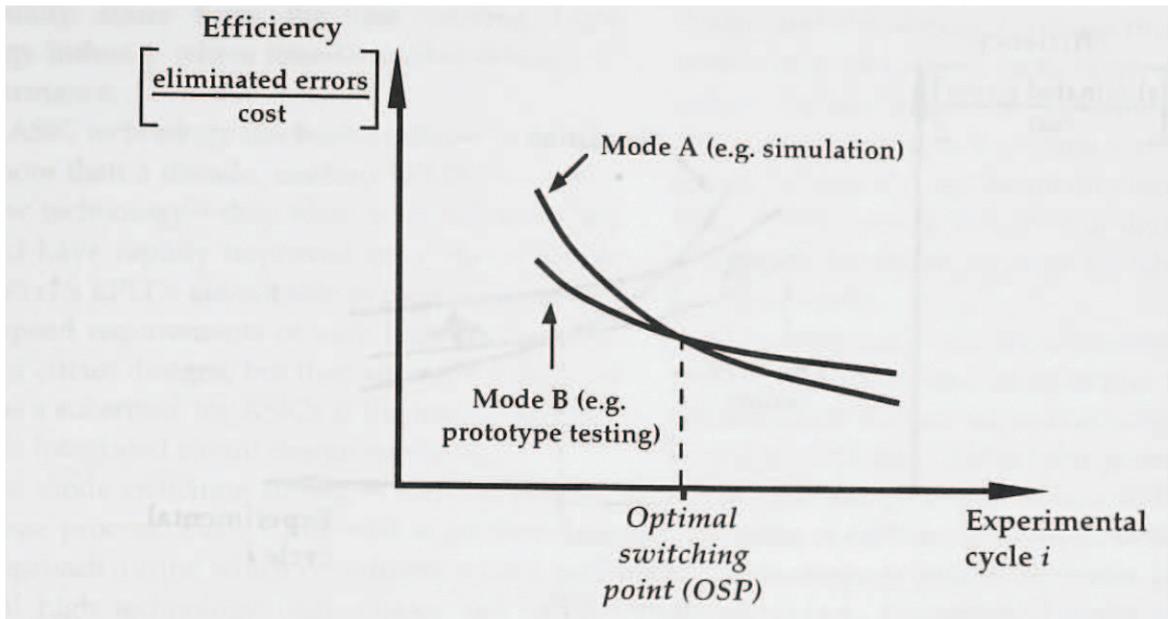


Figure 4.5: Switching between different modes as experimentation efficiency decrease at different rates, Thomke, (1998)

The Trade-off Dilemma: some hints

As both virtual and rapid prototyping methods advance rapidly, firms are struggling to find the optimal experimentation process, in an attempt to understand if it involves a dynamic balance between virtual simulation and physical prototype testing activities or it concerns only one solution. Balancing these two options could ask for great flexibility and significant investments. At present times, research split into two mainstreams: on one side improvements in virtual reality, on the other advancements in tools for rapid prototyping⁶ [14, 172, 203]. Comparisons between empirical results of the different solutions have rarely been made. The actual non-exhaustive conclusion could be resumed as follows; rapid prototyping seems to be preferred to virtual prototyping for kinematic simulation, assembly, fit and interference checking [32, 33, 76]. As a physical part, RP allows the user to gauge the size of the prototype. It is also used for ergonomic and tactile evaluations. Rapid prototyping parts are also used for manufacturing input, usually for a cross-functional team where representatives from all disciplines evaluate the prototype according to their knowledge and requirements. Most RP parts suffer from mechanical property drawbacks. In addition, very thin parts cannot be built by some RP systems. Virtual prototyping provides a quick iterative design process, where problems can be rectified immediately whenever indicated from analysis [13, 176]. Solving the problems in the VP domain helps reduce physical prototyping costs and time. The main drawbacks for virtual prototyping are the high initial investment costs in hardware and software and the demand for skilled and experienced operators to

⁶interesting reviews about methods and tools used can be found in Bernard [14] and Chua et al. [33]

extract the full benefit from the software.

As the proliferation of evolving simulation technologies and techniques rapidly increases, researchers will find it very interesting to gain a better and more detailed understanding of the underlying changes in learning processes that will result. Some questions seem to be still unsolved, and leave some space for further analysis. First of all, the continuous improvement of both physical and digital prototyping technologies opens some space for the definition of the optimal switching point between them, as the research is still indecisive. As firms continue to devote their strong effort in identifying the best way to speed up the development process, all the rest being equal, this stream of analysis, even though well explored since more than two decades, finds itself daily renewed. Moreover, a strong debate regards the chance that, independently of any kind of improvement in digital technology, there are some development activities that will be never undertaken via computer simulation. This will be better exploited in the next sections, as the matter was strongly posed both by engineers and designers working on the development project and by customers, worried about the new solutions adopted. The aim of the next stages will be to build and develop a comparative case study analysis in the automotive industry, thus working on the concept of Time-to-Market and on its relation with Prototyping and Testing techniques, and to finally elaborate on the relation occurring between Rapid and Virtual Prototyping, answering the question “Exploration or Exploitation?”. Identifying the best practice will be intended as a consequence of the specific framework of analysis, even though we will provide suggestions and comments on the evolution of the whole industrial world starting from our case study. In this sense, we are answering the question whether it is better to jump into an innovative solution, represented by virtual prototyping, or to get stick to previous practices (continuously improved), focusing on physical prototyping with the aid of high tech solutions (*rapid prototyping*), contextualized to the specific market framework we are analyzing. The final considerations and comments will refer to the exogenous variables able to influence the firm in its effort in the selection process.

4.4 Method and Data

4.4.1 Methodology

IN our attempt to realize a case study between two European OEM in the automotive industry, we found it interesting to compare their performance referred to a specific new model they took to the market. The practices they used to develop it, could show us some important differences. In order to do that, we opted, among the qualitative methods, for a *multiple case study* research design. A multiple case study approach is the adequate research strategy “when how and why questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context” [230]. To define the research question and the hypothesis to work with, we used both a deductive and an inductive approach, as “both (prior theory and theory emerging from the data) are always involved, often simultaneously”, and “it is impossible to

go theory-free into any study” [166]. Prior theory, thus, had a pivotal function in the design of the case study and analysis of its data [157]. Case studies typically combine data collection methods such as archives, interviews, questionnaires, and observations. The evidence could be qualitative (e.g. words), quantitative (e.g. numbers) or both [64]. In our research we used both a structured survey and direct interviews to deepen the results of the survey. We gained both qualitative and quantitative results on the matter of the analysis. The basic idea was to build a research setting in which some variables are held constant (control variables, Figure 4.6) and some others serve as performance indicators, thus varying according to the specific project. In our analysis we used common knowledge characteristics of the OEM and of the specific model as control variables. In particular, we split our control variables in *structural characteristics* (e.g. Derivative vs Template, Market segment and Production framework) and *model characteristics* (e.g. Price, Body, Dimensions, Engine, Environmental Approval).

Control Variables	Structural Characteristics	Derivative vs Template	
		Market Segment	
		Production Framework	
	Model Characteristics	Price	
		Body	
		Dimensions	Lenght
			Width
			Height
			Step
	Environmental Approval		

Figure 4.6: Control Variables in the Analysis

Then, as regards performance indicators (Figure 4.7), we used Time-to-Market⁷, according to the importance we proved it to have in the actual industrial framework, and a sort of Quality indicator. As concerns TTM, in a first attempt we used the standard milestone approach, in its latest version (Thomke, Fujimoto & Nobeoka, 2007) straightly with the questionnaire, and then we delved into the space of the research with some direct interviews aimed at lightening some shadows still remaining concerning the NPD process. In the attempt to have a full overview of the evolution of the two projects, we decided to structure interviews both with the technical and the commercial function. We noticed many overlaps in the answers we obtained, while at the same time we emphasized the complementary effect bet-

⁷See chapter 1 for further details about the relation between NPD and Time-to-Market, as it could be a useful literature review to have an overview of the topic

ween the two perspectives.

The quality measure seemed to be in some sense less standardizable: as sales performance could be submitted not only to the quality of the model, but also to individual feelings about the external contents, the idea of the car-maker and so on, we state that it is not a signal of the effective quality of the vehicle, but it is just a mix of different parameters; during the interviews we were provided of some confirmative hints regarding this intuition:

“(...) we have to consider that at the present time Fiat Group doesn’t enjoy of a good reputation on the C segment, and it is not considered a high-tech producer, though it really is, thus customers are not able to recognize the price of the new model as they can’t really recognize its real value⁸(...)”

Chief Technical Director Fiat Bravo Project, 2008

We decided then to focus on safety, with the standard indicator EuroNCAP⁹, intended to be a realistic and independent assessment of the safety performance, compulsory for all the European OEMs, as new models must meet the requirements as expressed in “Directive[s] of the European Parliament and Council”.

To select the specific case studies to test, we referred both to specialized newspapers¹⁰ and to the internal classification by the OEMs.

Thus, our analysis began with a structured milestone survey¹¹, grounded on an highlight of the main questions we wanted to treat during interviews, serving as a direction for the following exhaustive research. Our idea was that in comparing the NPD methodologies between the two OEM we would be able to identify the major differences in standard practices, thus . Since we haven’t got the access to sensible data about NPD costs, we won’t be able to refine our results to compare the processes referring to other specific performance. At the same time, though, in the course of the direct interviews, we were provided of some hints, thus we will be able to suggest some cost savings esteems due to the use of new technologies.

⁸In Italian: *Si deve considerare che Fiat ancora oggi sul segmento C non gode di ottima reputazione, non é considerata produttrice ad alta tecnologia pur essendolo, quindi non riconoscendo questa immagine, il cliente non é in grado di riconoscere nemmeno il prezzo della vettura* (Responsabile Tecnico Progetto Fiat Bravo, 2008)

⁹The *European New Car Assessment Programme* is a European car safety performance assessment programme founded in 1997 by the Transport Research Laboratory for the UK Department for Transport and now the standard throughout Europe. It publishes safety reports on new cars, and awards ‘star ratings’ based on the performance of the vehicles in a variety of crash tests, including front, side and pole impacts, and impacts with pedestrians. The top overall rating is five stars. The frontal tests are performed at 64 km/h (40 mph) into an offset deformable barrier of similar mass and structure as the car itself. The side impact tests are performed at 50 km/h (31 mph), but the side impact pole test is performed at 29 km/h (18 mph). The pedestrian safety tests are performed at 40 km/h (25 mph). Euro NCAP adopted the rear-impact (whiplash) test as part of its new crash-test regime from January 1 2009. For further information, see also the official web site: <http://www.euroncap.com/home.aspx>

¹⁰See as an example the Italian “Quattroruote”, on its official website: <http://www.quattroruote.it/>

¹¹see Appendix B for the details

Performance Indicators	Time to Market	Total
	Safety (Euro 'N Cap)	Adult Occupant
		Child Occupant
		Pedestrian
		Seatbelt Reminder

Figure 4.7: Performance Indicators in the Analysis

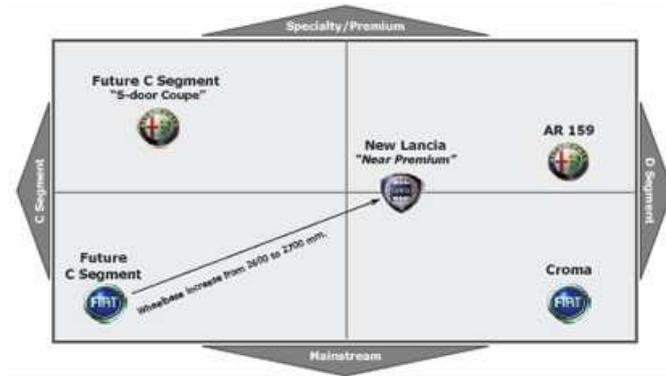
4.4.2 Data selection

WE posed great interest on the growing newspaper articles relating the fast development of *Fiat Bravo* (2007), told to be realized in 18 months, with a reduction of development time of about 50% with respect to older Fiat models. We saw this case as an important innovation in the automotive market, as it posed a new standard for all the competitors, if they wanted to answer the market requests as Fiat did with its new model. We found it interesting to compare this NPD process with competitors' ones. The matter was to find a competitor acting in the same marketplace, with a product that could be reasonably comparable with Fiat Bravo, for technical and economical reasons. The first idea was to compare the entire NPD process with previous Fiat case studies. At the same time, though, we found ourselves involved in an intriguing framework regarding the Fiat Group. Tracing back some hints regarding the recent history of the firm: in the year 2005, Dr. Marchionne became CEO of the Fiat Group, opening a new era for the brand, previously involved in a descendant parabola, grounded on the definition of new successful models, and an aggressive international politic of acquisitions (e.g. Chrysler) or attempt of (e.g. Opel, Saab). Intriguing observations concerning new models proposed by the group could be made, and we found it interesting to center our attention on the C segment of the market. In particular, as regards the C class of the market, representing the compact cars (US) or small family car (Europe)¹² in 2006, an year before Fiat Bravo was presented, replacing Fiat Stilo (2001), the

¹²A compact car, or small family car, is a classification of cars which are larger than a supermini but smaller than or equal to a mid-size car. Current compact car size, for US and international models respectively, is approximately 4,100 mm and 4,450 mm long for hatchbacks, or 4,400 mm and 4,600 mm long for cabriolets, sedans or station wagons. Small European family cars include the Ford Focus, Opel Astra, Peugeot 308 (2007), Renault Mgane, Fiat Bravo (2007) and Volkswagen Golf. Japanese branded examples include Honda Civic and Toyota Corolla

FGA framework was to be depicted as in Figure 4.8.

Figure 4.8: Fiat Group, C Segment, year 2006



On the low-left side, Fiat Stilo was the only solution for the group. As we decided to work with a comparative case study methodology, we should strive to reduce at a maximum the level of uncertainty in the comparison, holding all the control variables constant during the work. Then, we found out that the specific area we wanted to work on had been fulfilled since 2001 by only one solution, Fiat Stilo, no longer an improvement on the base of the previous models (a *derivative*), but a completely new work (a *template*¹³). As Fiat Bravo is based on the platform of Fiat Stilo, and exploits great advantages in terms of re-use, the comparison between the two models could not be effective, and doesn't respect one of the fundamental structural-characteristic control variables.

“(…) When we talk about 18 (17) months development, we are always talking about the body of the vehicle, never about the chassis or the engine. No-one can suppose to realize from a white board an engine, a spring or a steering in 18 months¹⁴ (…)”

Chief Technical Director Fiat Bravo Project, 2008

“I could state (the development of a template) lasts at least 30 months, more than doubling the development time of a derivative¹⁵”

Chief Technical Director Fiat Bravo Project, 2009

¹³The template is defined as the initial model used to design and engineer all the other derivative products [10]. In this case, a template is the original platform, and the derivatives will be all the products coming next which use the same platform with a re-use modular method

¹⁴In Italian: *Quando si parla di TTM di 18 (17) mesi, si tratta sempre del vestito della vettura, non delle componenti telaistiche o motoristiche. Nessuno può pensare da un foglio bianco di poter realizzare un motore, una sospensione, o uno sterzo in 18 mesi* (Responsabile tecnico Progetto Bravo, 2008)

¹⁵In Italian: *Potrei affermare che (lo sviluppo di un template) dura almeno 30 mesi, circa il doppio di un prodotto derivative* (Responsabile tecnico Progetto Bravo, 2009)

Moreover, comparing Fiat Bravo with other upper or lower class vehicles won't respect other control variables (e.g. dimensions, price, engine and so on). Going through the Fiat case alone could be considered, thus, a non-sense. Then, we had to widen the space of analysis, searching for similar models realized by different OEMs. Since a comparison with distinct OEM frameworks could lead us to provide misleading considerations on the encountered differences in the NPD process, due both to cultural and historical reasons, we focused our attention just on the European market. We found it interesting that the Peugeot Société Anonyme (PSA) group was taking to the market in the same period a model that could be easily compared with Fiat Bravo, *Peugeot 308* (2007). Before stating anything about the two vehicles, though, we had to check if they were really comparable, and in particular we wanted to understand if (control variables, structural characteristics):

1. they both were derivative, as we already knew that Fiat Bravo was a derivative of Fiat Stilo, since it inherited the main “back-office” modules, including the base platform;
2. they both lie on the same market class¹⁶, both for performances and price reasoning;

The vehicles we considered were both produced as a substitution of previous models that have long been in commerce. As we found out that Fiat Bravo should substitute Fiat Stilo (2001), since January 2007, even if the SW model is still on sale in some countries and the 5-door model is still under production in Brazil, we had to check for Peugeot 308; launched on September, 22, 2007, it is the substitute for Peugeot 307 (mid-2001), taking from it a renewed (to raise the security level against car-accidents) flatcar and the same idea of a spacious passenger compartment (one of the successful innovations of Peugeot 307).

“(...) On a Marketing point of view, Peugeot 307 has been a sort of revolution. Peugeot 308 aims at capitalizing on the success of the same design¹⁷(...)”

Chief Technical Director Peugeot 308 Project, 2008

Finally, as a confirmation, both the models were lying on the same market class. We resumed these first remarks in Figure 4.9.

Given the effectiveness of the structural characteristics similarity, we had the chance to look further to the technical comparison between the vehicles (model characteristics). This approach required us to get directly to some specialistic magazines concerning the automotive market, and to the news that appeared more and more on internet, visiting blogs, discussion sites and newspapers in order to

¹⁶The internal classification by the OEM was different because one of the considered the market segmentation, while the other has its internal segmentation, ruled by technical instead of commercial practices

¹⁷In French: *Du point de vue marketing, la Peugeot 307 fut une petite révolution. La 308 avait pour objectif de capitaliser sur le succès de ce style extérieur* (Responsable de la conception model 308, 2008)

Figure 4.9: Control Variables: Structural Characteristics

Model			Bravo	308
Control Variables	Structural Characteristics	Derivative vs Template	Derivative	
		Market Segment	Segment C	
		Production Framework	Automotive, Europe	

find out the information required. We found it interesting to summarize the technical data in Figure 4.10, in order to establish a simple *visual* comparison.

After establishing a contact between the two models, we searched for the possible interviews to carry out to exploit the topic. As we were focusing on the technical aspects of the testing stage, the main interviews should involve the technical function both at Fiat and at PSA. At the same time, though, we appreciated the contribution given by the commercial side, as it dealt with the reactions of customers, that still represent the main source of evaluation even when the firm strives to improve its internal activities. In particular, we will highlight a sort of waving shaped mistrust as the company uses newer and under-tested solutions, thus evidencing the importance of a strong and direct communication as information in the actual world runaway all over rapidly, no more under the control of the firm itself. A web based conception of the firm raise the communication problem of the firm, as internet is a source of both positive and detrimental information about any (even small!) change in firm's structure, organization, methods and tools. To work with both commercial and technical perspectives, we carried out three 2-hours interviews at FGA and two 2-hours interviews at PSA. Furthermore, we got back by both the technical and the marketing function the results of the survey we proposed. For the main results we suggest to refer to the next section, while a complete overview of the analysis concerning the EuroNCAP Indicator is provided in Appendix D, to make the next section slender. We mapped here (Figure 4.11) the final list (with the duration) of the interviews at Fiat and PSA during the evolution of the project.

Figure 4.10: Control Variables: Model Characteristics
FIAT BRAVO (1.4, 16_V) and PEUGEOT 308 (1.4, 16_V)

	 FIAT Bravo 1.4 16V	 PEUGEOT 308 1.4 16V 95CV VTi 3p. Comfort
Price	15.081 €	14.801 €
Body	Touring car, 3/5 doors	Touring car, 3/5 doors
Number of doors	5	5
Number of places	5	5
Engine	4 line cylinder	4 line cylinder
Capacity cm ³	1368	1397
Current (power)	Gasoline	Gasolina
Expenditure (Consumption) (litri/100km)	<ul style="list-style-type: none"> • urban 8,7 • extra-urban 5,6 • mixed 6,7 	<ul style="list-style-type: none"> • urban 9,0 • extra-urban 5,2 • mixed 6,5
Power max/regime	65 kW (90 CV) 5500 giri/min	65 kW (95 CV) 6000 giri/min
Environmental approval	Euro 4	Euro 4
Traction	front	Front
Max speed	179 km/h	182 km/h
Speedup 0/100 km/h	12,5 sec	12,4 sec
Dimensions (cm)	<ul style="list-style-type: none"> • Lenght 434 • Width 179 • Height 150 • Step 260 	<ul style="list-style-type: none"> • Lenght 428 • Width 182 • Height 150 • Step 261

Figure 4.11: List and Duration of Interviews at Fiat and PSA

FGA Fiat Group Automobile	Duration	No. of interviews
Bravo Project		
Technical Manager	4 h	2
Marketing Manager	2 h	1

PSA Peugeot Société Anonyme	Duration	No. of interviews
308 Project		
Technical Manager	2 h	1
Marketing Manager	2 h	1

4.5 The Testing Stage: Interviews and Results

DURING the testing stage one of the main activities is the building of prototypes to be tested on both a marketing and a technical view-point. The aim of prototypes is thus twofold: on one side, they are used as models to be displayed to a framework of selected customers, so as to understand the reaction of the market to the new product, on the other, they are used to test technical innovations and the final quality of product. In the automotive market testing accounts for about 40 (even 50)% of the entire development costs. During the 1980s, on average, the development of a new automobile took 2.5 million engineering hours and lasted 54.2 months [34]. Moreover, as this stage also accounts for general safety of the vehicles (and we evidenced this performance in the previous section), United States traffic safety statistics suggest that the impact of more effective automotive R&D can be dramatic from a public health perspective (Figure 4.12). In 2008, 37,261 people were killed in motor vehicle crashes alone and 2,346,000 people were injured. Aside from the tragic consequences for people that are directly or indirectly involved in a motor vehicle crash, accidents could be extremely expensive for the public economy.

Thus even minor improvements in automotive safety can have major consequences, with respect to public health and also on a business point of view. The continuous improvement of technology made it possible an advancement in quality of products, and seem to allow the use of digital tools in testing with similar (if not better) results.

As our aim was to determine the advantage IT methods brought about TTM performance in the development process, the first step concerned the identification of the time-line of the project. As in the survey precise questions were posed about

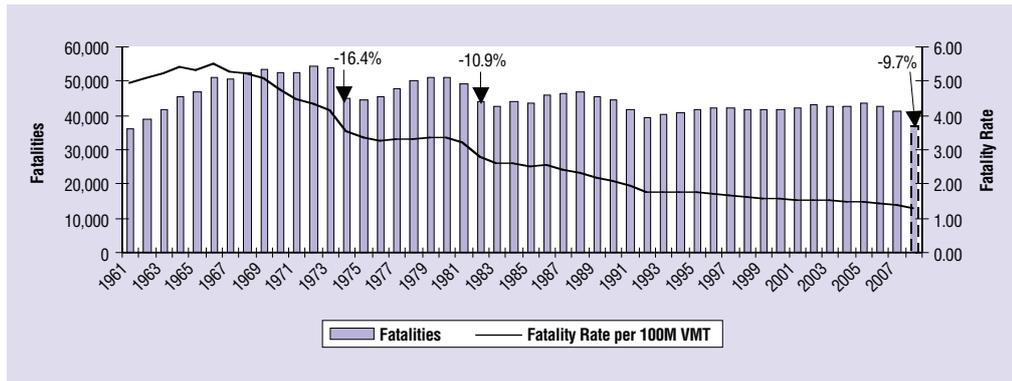


Figure 4.12: Fatalities and Fatality Rates per 100 Million VMT From 1961 – 2008; 1961–1974: National Center for Health Statistics, HEW, and State accident Summaries (Adjusted to 30-Day Traffic Deaths by NHTSA); FARS 1975–2007 (Final), 2008 Annual Report File (ARF); Vehicle Miles Traveled (VMT); Federal Highway Administration.

its the milestones, it was easy during interviews to resume the ideal starting point of the development stage, schematically said to be:

“(...) When Dr. Marchionne posed the new development goals (to take to the market the new model at the beginning of 2007) on April-May 2005, nothing was determined and no-one was able to do it¹⁸(...)”

Chief Technical Director Fiat Bravo Project, 2008

During the period between April 2005 and January-February 2007 the entire project was exploited and taken to an end. As regards Peugeot 308, the situation was different and hardly understandable, as during the interviews it appeared a long-lasting development process, starting in the first months of the year 2003 and finally ending during 2007, as the team was winded up mid 2007, about 3 months before the commercial launch of the product (Figure 4.13).

As we found so different results (a resume of which is here provided in Figure 4.14), our interviews evolved in two different directions: on one side, we were trying to understand the parameters responsible for such a great variance, on the other we wanted to show if other performances appreciably changed. In particular we focused our attention on costs, even though the treatment of sensible data is not allowed in these pages.

The framework we were facing was intriguing: we were forced to focus on different aspects of the IT introduction as the principal development methodology. In particular, internally the group was already sufficiently advanced, since

¹⁸In Italian: *Nel momento in cui il Dott. Marchionne pose gli obiettivi di sviluppo (all'inizio del 2007 il nuovo modello dovrà essere in commercio) tra Aprile e Maggio del 2005, non c'era nulla di pronto, e nessuno era in grado di svolgere il compito assegnatoci* (Responsabile tecnico modello Bravo, 2008)

Innovation (Time-line of the project)

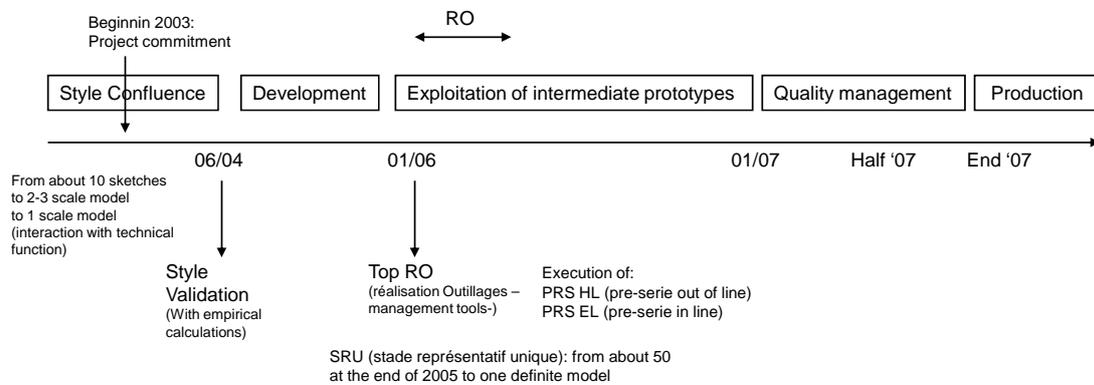


Figure 4.13: Time-Line Peugeot 308 Project, Chief Director Project 308, 2008

Models		Bravo	308	
Performance Indicators	Time to Market	Total	17 Months	48 Months
	Safety (Euro 'N Cap)	Adult Occupant	33	35
		Child Occupant	36	39
		Pedestrian	16	19
		Seatbelt Reminder	2	3

Figure 4.14: Resuming TTM and EuroNCAP Results

the information-exchange method FGA used came from the alliance with General Motors (GM) (March, 13th, 2000 - February, 13th, 2005), while in the design and development phase many steps have been taken:

“(...) Information exchange was already deeply advanced, with the use of a GM-inherited system, while on the development side great steps have been made during the last months/years: now all the project designers, even with scarce IT knowledge, can develop their work with a PC¹⁹(...)”

Chief Technical Director Fiat Bravo Project, 2008

Moreover, great advancements, aided by Magna Steyr²⁰ knowledge and capabilities, were realized in the testing and prototyping stage. As Magna Steyr has to be considered an engineering supplier, it accounted for the design of the entire part, while the production process took place at Fiat plants. This meant that its capability to develop and improve a useful virtual prototyping and testing method was fundamental not to change the locus of the development phase till the last-minute standing, with a few confirmative physical experiments. The aid of virtual simulation tools appears to be the real turning point in the success of the new project at Fiat:

“(...) Everything was made possible by the use of virtual prototyping (no other car-maker ever used it such evidently on large-series vehicles) with the consequent removal of physical prototyping. Thus, everything has been assessed virtually during the development phase, with the generation of the first physical models, used simply to confirm results already obtained, only during rump-up phase²¹(...)”

Chief Technical Director Fiat Bravo Project, 2008

As we wanted to understand the effective savings coming from the use of virtual prototyping techniques, we had to check the relevance they had at PSA. We

¹⁹In Italian: *Nello scambio di informazioni Fiat era già all'avanguardia, si utilizzava un sistema ereditato da GM, mentre a livello di sviluppo negli ultimi mesi/anni sono stati fatti passi notevoli: ora tutti gli addetti al progetto, anche con un livello di preparazione di base e discrete conoscenze informatiche possono svolgere i loro compiti al PC* (Responsabile tecnico modello Bravo, 2008)

²⁰The firm (properly Magna Steyr Fahrzeugtechnik AG & Co KG) is an automobile manufacturer based in Oberwaltersdorf, Austria, with its primary manufacturing location in Graz. It is a subsidiary of Canadian-based Magna International and was previously part of the Steyr-Daimler-Puch conglomerate. Magna Steyr engineers, develops and assembles automobiles for other companies on a contractual basis, and was the main first-tier supplier as regards the body structure of Bravo models. In the relation with FGA, it was intended to be an engineering supplier, meaning that its aim was to design the new part of the vehicle, that will be produced at Fiat plants later on

²¹In Italian: *Tutto è stato comunque reso possibile dall'uso spinto della prototipazione virtuale (che nessun produttore aveva mai utilizzato in modo così evidente su vetture di grande serie), con conseguente eliminazione della fase di prototipazione fisica. È stato quindi validato tutto in modo virtuale durante la fase di sviluppo, seguito poi dalla fase di rump-up, con la generazione dei primi modelli fisici sui quali i test eseguiti hanno confermato i risultati ottenuti in modo virtuale* (Responsabile tecnico modello Bravo, 2008)

found that PSA still works on a trade-off methodology, with the joint use of digital and physical techniques, during different development stages. Both physical and virtual prototypes are used respectively:

- at the beginning of planning stage, to show different solutions and finally determine the structure of the vehicle to be produced;
- during prototyping stage, before pre-serie project confluence.

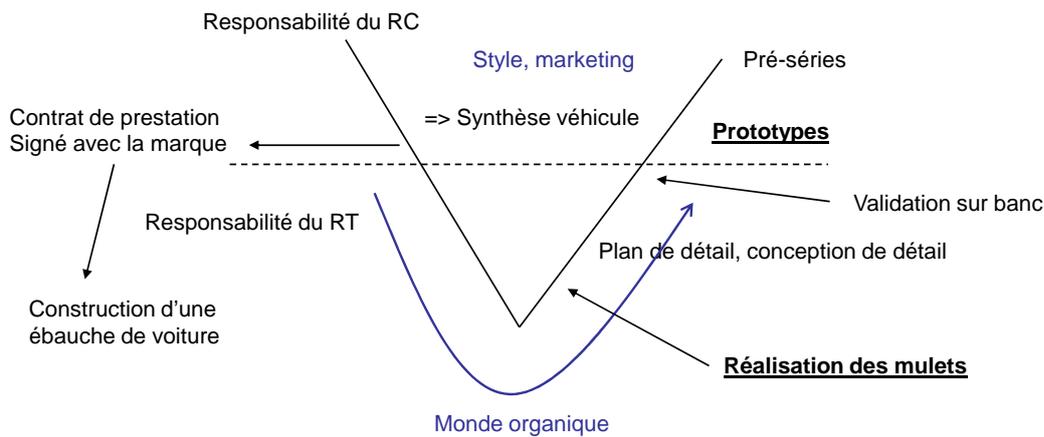


Figure 4.15: Development stages and responsibility, PSA Group

A “mulet” is a form of simple prototyping technique able to represent the chassis and the structure of the vehicle, such that it can be modified, re-designed, and finally accepted. The use of an enlarged team structure based not only on firm designers, but also on some suppliers’ representatives and, according to the possibilities, on lead users is strongly connected to this stage. The introduction of new technologies gave the firm the chance to open some information to a vast framework of different customers: e.g. the use of internet (blogs, specialized magazines, forums) widen the number of information disposal, and this customer-OEM forward-back relationship could begin even 2 years before the commercial launch of the product. “Emotions” about the vehicle are as much important as feasibility considerations. Even though, the firm found it hard to express real contents in a digital way, and the feelings about virtual technologies seem to be mistrustful:

“(…) It is becoming harder and harder to confirm customer point of view, if there is not the support of a physical model²²(…)”

Marketing Director Project 308, 2008

²²In French: *Ca va devenir de plus en plus dur de valider du point de vue du client des choses, dont on n'a pas une synthèse physique* (Responsable produit Peugeot 308 marque, 2008)

After the final acceptance of the chassis and internal structure of the vehicle, a process of trial-and-error prototype testing takes place. We found that at PSA strong effort is posed on new techniques to better perform the *building* phase, as virtual isn't still seen to solve some qualitative problems, thus substantially inadequate for in-depth analysis on the product. Virtual simulation tools are used on a two-level process:

- **Style:** virtual simulation is useful both to test ideas and to get a style convergence. In particular, the chance is not only to reduce the timing of decisions, but also to involve in the analysis many more engineering solutions, improving the quality of the choice as it considers a wider range of possible alternatives;
- **Calculus:** better results can be obtained with multi-variable equations, such as for acoustics, or air condition. Digital tools aid designers to easier and faster develop calculus on the effects changes in the design could have on the models.

The use of virtual simulation tools is being counterbalanced by considerations that still limit its complete introduction in the development stage at PSA. First of all, designers found that completely losing contact with reality, cause of the led use of digital technologies in the whole process, could take them to force solutions that exceed the intent of the firm as regards the product. A close contact with physical models, through prototypes, opens space for new solutions, but close the framework into "real" solutions. Moreover, the continuous improvement of physical technologies, such as wind tunnels for aerodynamic evaluations, led the firm to drive on the safe old-fashioned solution instead of jumping in the dark by working on revolutionary innovations in a consolidated framework. Time performance seems to be still under evaluation, as it was not considered fundamental. The great success of Peugeot 307 reduced the need of a fast replacing of the model on the market. The two models have been even produced jointly during the years 2008-2009.

At FGA, as great innovations modified TTM, an in-depth analysis focused on counterbalancing factors involving the other parameters. In particular, the other indicator under constant observation was the cost of the entire project. Resuming, it was found that:

"(...) To reduce time-to-market doesn't necessarily mean an increasing in costs, as it is possible to skip over some passive-cost stages (prototyping, testing) with the use of virtual prototyping techniques²³(...)"

Chief Director Marketing Function, Brand Fiat, 2008

²³In Italian: *L'aver ridotto il Time-to-Market non ha portato necessariamente all'aumento dei costi, poiché si possono saltare determinate fasi di costi passivi (prototipazione, test) tramite l'uso di tecnologie informatiche* (Direttore Funzione Marketing Brand Fiat,2008)

The chance to quit the physical prototyping stage gives the firm an economic advantage that can be approximately estimated in 50 million euros, since at least 50 physical prototypes should be built during the design and development stage, each at a price of 1 million euro²⁴. The cost to build a prototype regards mould tools, extremely expensive as usually their price is damped on many products, while during development they could be used only for one product, while the direct cost of the material for a prototype could be extremely low, thus substantially non influent on the entire budget. The chance to still consider a physical testing moves from the development to the production stage. The advantage is the extreme reduction of costs, as a production model could cost even 100 times less than a prototype, but meant to be absolutely trustful on virtual simulation, as late design changes could be hardly economically sustainable.

The main concern regarding Fiat Bravo has been expressed directly by customers, as information spread all over internet through official and un-official blogs (i.e. www.quellichebravo.it; www.quattroruote.it; www.autoblog.it; www.fiatbravo.it; www.fiatfans.com): the closeness between virtual and real testing results has been strongly discussed, before EuroNCAP results were published. The idea that the “real” product could resemble to the “virtual” one, even if not being equal, seemed to scare potential customers. When we interviewed both the technical and marketing Chief directors for the Bravo project, they both confirmed the robustness of the results obtained with virtual simulation. They also provided us of some hints on the technical results, such as:

“(...) As regards rigidity we calibrated the entire system to 115 kg, while in the physical testing we found it was 140 kg, thus to quit minimum risks we’ve been conservative in measures. This means that, if physical testing evidenced better results than the virtual, we are “giving” something to the customer²⁵(...)”

Chief Technical Director Fiat Bravo Project, 2008

Moreover, the chance to control variables individually made it possible to widen considerations on the effects they have on the product, while, with the use of real prototyping techniques, parameters were all mixed in the same system, thus they changed from time to time, leaving some space for uncertainty and worsening the final results. We schematically resumed influential parameters results in Figure 4.16.

A fundamental question was posed regarding the reliance of virtual prototyping results as time-to-market decreases: we found it interesting [28] that the first-class car maker in the world, Toyota, decided to slower time-to-market and to reduce the product percentage built under virtual prototyping conditions as quality problems were identified, supposing its development phase could be too rushed; as

²⁴These data have to be considered as more or less precise esteems in that their treatment is subjected to privacy

²⁵In Italian: *Per quanto riguarda la rigidità personale, avevamo tarato il sistema a 115 kg, mentre alla fine nei test sul fisico abbiamo misurato un valore di 140 kg, quindi per evitare anche minimi rischi siamo rimasti conservativi nei calcoli. Ovviamente se il fisico è andato meglio del virtuale, questo significa che stiamo “regalando” qualcosa al cliente (Responsabile tecnico modello Bravo, 2008)*

Parameters Involved	Technical Parameters	Virtual vs Rapid Prototyping	Use of Virtual Prototyping Technique all along the Design and Testing Stage. Test of Physical Models during Pre-Serie	Tradeoff between Virtual Simulation and Rapid Prototyping: Virtual Simulation used in the Design Stage (style) and during development (Calculus). Rapid Prototyping at the beginning of the planning stage and before pre-serie project confluence.	
	Framework Parameters	History of the Firm	Stilo lost more than 5% market share	307 gained more than 4% market share (till the introduction of Astra and Focus, 2004)	
		Market Framework	Stable, predictable, Reasoned Choice; Main drivers: Safe and Solid Technological Base, Affordable Price		
		Organizational Structure	Light, renewed	Strongly Bureaucratic, Static	

Figure 4.16: Resuming Table Parameters Involved and Differences Across Models

we suggested the hypothesis that some quality problems could come out as Fiat forced the speed of its process and increased (till the maximum) the product percentage built under virtual prototyping and testing conditions, and that stronger attention has to be posed so as to quit the lowering-quality spiral, we found that strong effort has already been devoted to make digital techniques as reliable as possible, and that they assure better technical results: as physical prototypes do not allow any distinction between parameters, are usually under-defined to lower production costs, and suffer for visualization problems as many tests could be too fast or complex even for highly improved vision tools, virtual prototypes seem to solve all these problems at once. We perceived no doubt regarding the effectiveness and precision of the new method, and this trust was justified also by the qualitative results obtained in the physical pre-serie tests.

“(…) I hardly feel an agreement with the idea that a virtual prototyping and testing technique could lead to worse results than a physical one, as virtual development enables designers to evidence 3-dimensionally and in advance all the details eventually clear on the physical prototype (usually “badly” made as built with the aid of provisional tools, thus different with respect to the final model). Since it is possible, it seems much better to directly observe (even if with a rough simulation) calculation results than to refer to a complete prototyping generation and testing (designs, production tools, prototype generation, testing –with all the possible defects masked during the production process–, reporting, modifying, proceeding)²⁶.”

²⁶In Italian: *Sono decisamente in disaccordo con l'idea che la prototipazione virtuale possa portare a risultati peggiori di quella fisica, poiché lo sviluppo virtuale consente di vedere in 3D*

Far from being discussed, the adoption of virtual prototyping techniques seems to be one of the main reasons for the TTM shortening. Qualitative results being the same with respect to competitors, reducing development time allows the firm to build products better and quicker satisfying user needs, as market research and commercial introduction are not so far away each other. The vastness of the effects of these advantages seemed to overcome even the initial troubles and perplexities.

4.6 Virtual Prototyping vs Rapid Prototyping: Exploration or Exploitation?

OUR research brought to light the parallel existence of two mainstreams in the automotive market framework we analyzed. On one side, the innovative use of virtual prototyping, on the other, the improved exploitation of rapid prototyping. Our work compared these two techniques on a two-performance scale. We proved no difference exists as regards the objective quality measure (safety), while consistent differences could be found when comparing development time. However, the hypothesized distance between virtual and real prototyping slightly reduced in the real case, suggesting the occurrence of consistent improvements in real prototyping methods and tools aimed at reducing development time and costs. As we were able to highlight the actual market framework dependence on firms' time performance, our instinctive deduction would be to devote all the efforts at continuous improvements of virtual prototyping, as it proved to be faster, all the rest being equal. This poor-rationalized solution still leaves unsolved some questions; in particular, we resumed as fundamental these two matters of analysis:

1. cost esteems must be realized in an attempt to solve an investment dilemma. We are actually discussing, in fact, about the difference occurring between a breakthrough innovation cost (VP) and a continuous improvement process cost (RP). We should highlight, in the meanwhile, that consistent investments on tools and labor force should come along with a firm's adopting a new methodological system. These investments could be namely devoted to the present-time working process. The proof of an approach between the results of the two methods should open some space for further investigation concerning their evolution path;
2. as we highlighted some mistrust on virtual prototyping techniques results, especially concerning customer analysis and (at PSA) quality matters, the

e in anticipo quello che si potrebbe osservare sul prototipo fisico (normalmente eseguito "male" poich ottenuto da attrezzature provvisorie quindi differente dal pezzo definitivo). Dal momento che é possibile, é molto meglio osservare direttamente (anche se con una simulazione approssimativa) l'esito dei calcoli piuttosto che sviluppare tutto il processo di generazione del prototipo e testing dello stesso (design, definire le attrezzature per la produzione, costruire il prototipo, testarlo - considerando che lo stesso può avere dei difetti non evidenti di fabbricazione- riportare il test sul progetto, modificarlo e procedere).

main question we would solve is the nature of virtual and rapid prototyping: may they be complementary or substitutes in their use? The answer to this question may be the driver for future research direction, as if one technology is explicitly better than the other and they resemble to be substitutes, then research should center on one specific solution, while slowly neglecting the other's evolution, and firms should focus on making steps in the direction of a change or a confirmation of that technology.

We will now structure some reasoning around these topics, while suggesting our idea, still aware of the need for further analysis on empirical data. As we focus in the development proves of the two vehicles, we can state: First of all, virtual prototyping proved to be better on time to market, even though the advantages it was able to generate were not as consistent as we initially supposed them to be (more than 50% time reduction). As our analysis shows some references to substitutes (respectively Fiat Stilo and Peugeot 307), we were tempted to build a cross-industry time reduction analysis. Unfortunately, these two models are the result of a template building process, while Bravo and 308 are based on a derivative platform. The timing of the development process, thus, is not comparable. Moreover, interesting esteems could be performed on process expenses, as for example virtual prototyping helped reducing the cost of wasted physical prototypes used in crashworthiness tests, even if these savings do not reflect on the model price on the market. In addition, virtual prototyping seemed to generate a breeze of mistrust around its deployment, and Fiat was forced to highlight Euro 'N Cap results on its marketing campaign to dissolve it. We proved, however, that qualitative results seemed to be equal for both vehicles. Furthermore, RP literature showed strong concern about materials used and production processes, in some sense evidencing that between the two technologies the most imprecise one should be rapid prototyping. Finally, we found evidence that giving birth to a completely new prototyping system is a costly activity, meaning not only expensive in terms of investments, but also of workers' capabilities, training, experiencing, problem-solving. We argue here that the parallel implementation of two technologies aimed at obtaining the same results provide no advantage and is a source of higher costs for the firm. Even if we found evidence that VP and RP are rooted in the same digital devices during the first phase, they split into opposite directions when jumping into the testing stage, thus generating the need for different investments and skills to be managed. Our conclusion is, thus, that firms should step forward into virtual reality as soon as possible as this represents the technology of the future, and its still un-discovered advancements and possibilities are much wider than those of rapid prototyping technology. We state here that probably in the technology evolution curve, rapid prototyping is on the descent path, while virtual prototyping is on the ascendant one.

4.7 Conclusions and suggestions for further analysis

THE great improvements in prototyping techniques and tools allowed firms to change their strategies as regards the entire development stage. Research followed two mainstreams: on one side, strong effort was posed to lower costs and faster the physical generation of prototypes, with the use of rapid prototyping techniques such as reverse engineering and layered manufacturing²⁷, while on the other the research effort regarded the final exclusion of physical prototyping, with the use of digital methods, such as virtual prototyping or the advanced virtual reality [153]. In the automotive industry, the use of new methods seem to be extremely important as the development phase accounts for about 50% of the entire costs of a new model, and the testing stage could influence the whole development costs for more than 70%. Moreover, the strong need for an increase in safety forces firms to carry out many expensive destructive tests on prototypes, with the result of increasing both time and cost of development. We found it interesting to compare two realities that seemed to be similar on the resulting project performances, but strongly different in the methodology adopted. This comparative case study is not able to evidence the overall best instruments, or methods, to use in any case, while it is a source of interesting discussion matters and personal suggestions. In particular, as during the last decade the main concern regarding virtual techniques regarded the accuracy of these methodologies, we were able to demonstrate that, with the strong improvements they suffered for, digital techniques are providing firms the chance to reach the same qualitative results, possibly with lower costs and faster time-to-market. The entire competitive framework will be, thus, completely changing: as many literature contributions ascertain the importance of “doing good products as fast as possible”, firms that are now able to do so in this uncertain market conditions, will surely gain advantages over competitors, as they can react faster to unexpected changes in customer needs and at the same time lower production costs. As the automotive market is now crossing a deep crisis, only the best firms on the market will be able to compete in the environment that is going to come out of this situation, thus a continuous improvement method should lead to better results. We finally evidenced the existence of a management decision problem, as firms should force themselves to jump ahead to the use of digital testing, while staying stick to their previous physical-prototyping technique. We state that a trade-off solution is inadequate to solve the testing-dilemma, and that better results could be achieved with step-by-step improvements of virtual prototyping methods. Even though, our research leaves many shadows, that should be covered with deeper studies. In particular, we would like to underline:

1. the relationship between different variables in the model: in such a complex environment, analyzing a single variable won't explain the entire advantage a firm can gain; the cross-relationships between variables such as customer-

²⁷for an in-depth recent analysis of these techniques, see also Bernard [14]

supplier integration, organizational framework, prototyping and testing technologies, innovations and so on, can be exploited neither in a paper nor in a hundred! The space for investigations is extremely vast and intriguing;

2. the continuous improvements in technology: as methods and tools continually improve, with an impressive innovation rate, considerations about advantages and disadvantages in the use of new technologies seem to age year by year, thus re-configuring the competitive framework. Tools now in charge as innovative could resemble to be old-fashion in a few years, thus in some sense vanishing firms' investment and effort;
3. the history of firms plays a fundamental role: even if this is not a variable to be changed with actual actions, it should be considered cause it could represent the reason of firms' choices at present times, and (fundamental!) of customers' choices! The economic success of a new product is, in fact, not only determined by its technical capabilities, while it could be mainly due to the name of the car-maker and its reputation; we suggest that past history of the firm could be even the main driver for deep changes in a firm's methods and tools, thus a source of present time success. Our guess is that in a framework where the decision making process should focus on a continuous improvement of actual technologies or a jump into innovative solutions, a firm facing an historical period characterized by failures and troubles will be more successful as its willingness to change will force it to develop new solutions before than competitors, thus gaining an advantage over the future generations of products;
4. the ever-cited possibility of a great innovation in the market: present times seem to be characterized by the phantom of this revolutionary innovation in fuel technology. As the entire competitive framework is devolving its effort in the search for a "clean" engine technology, its revelation to the market could completely change the structure of the whole environment and its equilibria could be upset.

Finally we would like to underline that our analysis focused on a European environment, in the attempt to lower any exogenous differentiating parameter. An interesting elaboration on our considerations should be made using different frameworks, so as to include in the analysis cultural aspects that could be fundamental in a world-oriented environment (with world-oriented OEMs) as the automotive market.

Further analysis will be structured, but our final consideration is that the virtual-physical debate will be prolonged for a long time, as it could really be the main source of competitive advance for any mechanical environment, obviously included the automotive industry.

Appendices

Appendix A

Integrative Bibliographic Index

WE will present here a brief index of the main bibliographic contributions connected to the last three reviews we cited in Paper 1. We decided to use the same methodology we employed in the generation of the citation vector of papers, refining the entire data-set according to the subject areas (i.e. Management, Business and Organization) and the document type (i.e. Paper and Reviews). Finally, we structured the list citing only papers published since the year 2000. We used the h-index to cut the entire sample (to get the sample more manageable we focused just on the papers which exceeded 50 citations for [23]).

A.1 Articles Citing Brown & Eisenhardt (1995)

Author	Title	Year	Source
Krishnan, V; Ulrich, KT	Product development decisions: A review of the literature	2001	MANAGEMENT SCIENCE
Carlile, PR	A pragmatic view of knowledge and boundaries: Boundary objects in new product development	2002	ORGANIZATION SCIENCE
Sambamurthy, V; Bharadwaj, A; Grover, V	Shaping agility through digital options: Reconceptualizing the role of information technology in contemporary firms	2003	MIS QUARTERLY
Rothaermel, FT	Incumbent's advantage through exploiting complementary assets via interfirm cooperation	2001	STRATEGIC MANAGEMENT JOURNAL

Carlile, PR	Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries	2004	ORGANIZATION SCIENCE
Sethi, R; Smith, DC; Park, CW	Cross-functional product development teams, creativity, and the innovativeness of new consumer products	2001	JOURNAL OF MARKETING RESEARCH
Calantone, RJ; Cavusgil, ST; Zhao, YS	Learning orientation, firm innovation capability, and firm performance	2002	INDUSTRIAL MARKETING MANAGEMENT
Miner, AS; Bassoff, P; Moorman, C	Organizational improvisation and learning: A field study	2001	ADMINISTRATIVE SCIENCE QUARTERLY
Takeishi, A	Bridging inter- and intra-firm boundaries: Management of supplier involvement in automobile product development	2001	STRATEGIC MANAGEMENT JOURNAL
Li, HY; Atuahene-Gima, K	Product innovation strategy and the performance of new technology ventures in China	2001	ACADEMY OF MANAGEMENT JOURNAL
Calantone, RJ; Cavusgil, ST; Zhao, YS	Learning orientation, firm innovation capability, and firm performance	2002	INDUSTRIAL MARKETING MANAGEMENT
Miner, AS; Bassoff, P; Moorman, C	Organizational improvisation and learning: A field study	2001	ADMINISTRATIVE SCIENCE QUARTERLY
Takeishi, A	Bridging inter- and intra-firm boundaries: Management of supplier involvement in automobile product development	2001	STRATEGIC MANAGEMENT JOURNAL
Li, HY; Atuahene-Gima, K	Product innovation strategy and the performance of new technology ventures in China	2001	ACADEMY OF MANAGEMENT JOURNAL
Franke, N; Shah, S	How communities support innovative activities: an exploration of assistance and sharing among end-users	2003	RESEARCH POLICY

Lee, H; Choi, B	Knowledge management enablers, processes, and organizational performance: An integrative view and empirical examination	2003	JOURNAL OF MANAGEMENT INFORMATION SYSTEMS
Tatikonda, MV; Montoya-Weiss, MM	Integrating operations and marketing perspectives of product innovation: The influence of organizational process factors and capabilities on development performance	2001	MANAGEMENT SCIENCE
McDonough, EF	Investigation of factors contributing to the success of cross-functional teams	2000	JOURNAL OF PRODUCT INNOVATION MANAGEMENT
Cummings, JL; Teng, BS	Transferring R&D knowledge: the key factors affecting knowledge transfer success	2003	JOURNAL OF ENGINEERING AND TECHNOLOGY MANAGEMENT
Keller, RT	Cross-functional project groups in research and new product development: Diversity, communications, job stress, and outcomes	2001	ACADEMY OF MANAGEMENT JOURNAL
Tatikonda, MV; Rosenthal, SR	Technology novelty, project complexity, and product development project execution success: A deeper look at task uncertainty in product innovation	2000	IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT
Menor, LJ; Tatikonda, MV; Sampson, SE	New service development: areas for exploitation and exploration	2002	JOURNAL OF OPERATIONS MANAGEMENT
Sheremata, WA	Centrifugal and centripetal forces in radical new product development under time pressure	2000	ACADEMY OF MANAGEMENT REVIEW
Nambisan, S	Designing virtual customer environments for new product development: Toward a theory	2002	ACADEMY OF MANAGEMENT REVIEW

A.2 Articles Citing Balachandra & Friar (1997)

Author	Title	Year	Source
Krishnan, V; Ulrich, KT	Product development decisions: A review of the literature	2001	MANAGEMENT SCIENCE
Shenhar, AJ	One size does not fit all projects: Exploring classical contingency domains	2001	MANAGEMENT SCIENCE
Ernst, H	Success factors of new product development: a review of the empirical literature	2002	INTERNATIONAL JOURNAL OF MANAGEMENT REVIEWS
Reid, SE; de Brentani, U	The fuzzy front end of new product development for discontinuous innovations: A theoretical model	2004	JOURNAL OF PRODUCT INNOVATION MANAGEMENT
Meyer, MH; Datal, D	Managing platform architectures and manufacturing processes for non-assembled products	2002	JOURNAL OF PRODUCT INNOVATION MANAGEMENT
Nellore, R; Balachandra, R	Factors influencing success in integrated product development (IPD) projects	2001	IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT
Cooper, LP	A research agenda to reduce risk in new product development through knowledge management: a practitioner perspective	2003	JOURNAL OF ENGINEERING AND TECHNOLOGY MANAGEMENT
Scott, GM	Critical technology management issues of new product development in high-tech companies	2000	JOURNAL OF PRODUCT INNOVATION MANAGEMENT
Shenhar, AJ; Tishler, A; Dvir, D; Lipovetsky, S; Lechler, T	Refining the search for project success factors: a multivariate, typological approach	2002	R & D MANAGEMENT
Fricke, SE; Shenhar, AJ	Managing multiple engineering projects in a manufacturing support environment	2000	IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT

Adams, R; Besant, J; Phelps, R	Innovation management measurement: A review	2006	INTERNATIONAL JOURNAL OF MANAGEMENT REVIEWS
Dvir, D; Lechler, T	Plans are nothing, changing plans is everything: the impact of changes on project success	2004	RESEARCH POLICY

A.3 Articles Citing Krishnan & Ulrich (2001)

Author	Title	Year	Source
Menor, LJ; Tatikonda, MV; Sampson, SE	New service development: areas for exploitation and exploration	2002	JOURNAL OF OPERATIONS MANAGEMENT
Terwiesch, C; Loch, CH; De Meyer, A	Exchanging preliminary information in concurrent engineering: Alternative coordination strategies	2002	ORGANIZATION SCIENCE
Gerwin, D; Barrowman, NJ	An evaluation of research on Integrated Product Development	2002	MANAGEMENT SCIENCE
Michalek, JJ; Feinberg, FM; Papalambros, PY	Linking marketing and engineering product design decisions via analytical target cascading	2005	JOURNAL OF PRODUCT INNOVATION MANAGEMENT
Sosa, ME; Eppinger, SD; Rowles, CM	The misalignment of product architecture and organizational structure in complex product development	2004	MANAGEMENT SCIENCE
Ramdas, K	Managing product variety: An integrative review and research directions	2003	PRODUCTION AND OPERATIONS MANAGEMENT

Koufteros, X; Vonderembse, M; Jayaram, J	Internal and external integration for product development: The contingency effect of uncertainty, equivocality, and platform strategy	2005	DECISION SCIENCES
Fixson, SK	Product architecture assessment: a tool to link product, process, and supply chain design decisions	2005	JOURNAL OF OPERATIONS MANAGEMENT
Huang, GQ; Zhang, XY; Liang, L	Towards integrated optimal configuration of platform products, manufacturing processes, and supply chains	2005	JOURNAL OF OPERATIONS MANAGEMENT
Joglekar, NR; Yassine, AA; Eppinger, SD; Whitney, DE	Performance of coupled product development activities with a deadline	2001	MANAGEMENT SCIENCE
Nambisan, S	Information systems as a reference discipline for new product development	2003	MIS QUARTERLY
Hausman, WH; Montgomery, DB; Roth, AV	Why should marketing and manufacturing work together? Some exploratory empirical results	2002	JOURNAL OF OPERATIONS MANAGEMENT
Krishnan, V; Bhattacharya, S	Technology selection and commitment in new product development: The role of uncertainty and design flexibility	2002	MANAGEMENT SCIENCE
Jiao, JX; Zhang, YY	Product portfolio planning with customer-engineering interaction	2005	IIE TRANSACTIONS
Blau, GE; Pekny, JF; Varma, VA; Bunch, PR	Managing a portfolio of interdependent new product candidates in the pharmaceutical industry	2004	JOURNAL OF PRODUCT INNOVATION MANAGEMENT

Note: As the readers can see we left some repetitions between the three samples, aimed to understand the works citing more than one of the reviews chosen as pioneers, that possibly make a connection between them.

Appendix B

Standard survey

Fiat Bravo – Peugeot 308

A model comparison

Index :

- Part 1.
 1. Description of the market
 2. Purposes of the firm

- Part 2.
 1. Car model: a brief description

- Part 3.
 1. Milestones
 2. Time to market
 3. Decision Process
 4. Resources dedicated to the project
 5. Computer aided development

Part 1.**Description of the market**

This part is related to an initial description of the market (considered first in general and then the specific segment). We would like to check the growing level of the market to better understand the new policies of the firm concerning its New Product Development Practices.

The questions below are intended to be only a "guide" to the initial discussion.

1. Can you describe the automotive market as it has been in the last 5 years?
2. Can you describe the B-segment market as it is for your company?
3. Is your company hardly involved in this segment or is it only a niche?
4. How many car models did your company provide to this market segment in the last 5 years?
5. Are you planning to expand in the B-segment in the next years? If yes, how are you planning to do so (e.g. new models, new distribution centres, new alliances...)?

Purposes of the firm

This part is related to the purposes of the firm regarding the general aims of new product development (ex. Business model made by the firm), the specific market and the specific model.

1. Which are the main purposes of the firm as regards the New Product Development Process? (e.g. We would like to know any change the firm planned to develop for the next years' production)
2. Which are the most important competitive variables that characterize the industry of the selected product (e.g. price, innovativeness, reliability, etc.)? Which is their weight using a 1-5 scale? (Responses on 5-point scale with 1= low and 5= high)

Competitive variables	Weight
Innovativeness	
Quality	
Price	
...	
...	

3. Which are the most important competitive variables for your firm? Which are the main characteristics your firm usually uses to differentiate herself by the competitors in the market?
4. Which is the importance of Time-to-Market to compete in the segment considered?
5. Are there any purposes concerning TTM in New Product Development? Can you please describe them in deep?
6. What kind of market (B-segment) share would you like to reach with this new model?
7. How many products per year did you plan to sell? Have these predictions been confirmed in the last year?
8. Are there any differences in the purposes you planned between this model and the previous (last 5 years) models you produced for the same segment?

Part 2.**Car Model: a Brief Description**

This section is strictly connected to the description of the models we want to analyze: their features, their evaluation on the market, the different body variations the firm is going to produce.

We will then struggle to get a better understanding of the idea the firm has of its model, and by the way (using specialized magazines) also of the idea the market got by the new model.

We want to consider now a specific car model from your production:

1. The model is completely new or it can be referred to a previous “experience” on the same market segment? Can you please define a previous model of the same car, or a model that has been substituted by the new one? (ex: can we consider 307 an old model of 308? Or Stilo an old model of Bravo?)
2. Which are the most valuable variables in your new product? What are the factors on which you are trying to differentiate your products on the B-segment with respect to your competitors?

Competitive variables	Weight
Innovativeness	
Quality	
Price	
Safety	
Design	
...	
...	

3. These variables are the same your company usually uses to differentiate or did you try to find a new “concept” for your model? (eventually) Did you present this new concept using any particular marketing devices?

4. Your choice of the characteristics of the new model was in any way influenced by the results of the previous models in the same market segment? If yes, how?
5. Do you consider the new model satisfying (as a first impression or as the results already given)? Do you think that all the formal purposes had been reached?
6. How many variations of body type (e.g., sedan, coupe, station wagon, etc.) does this project have?
7. How did you plan TTM for this project? Did you decide it in advance with respect to the main activities planned for the project, considering previous experience?
8. Do you think that a change in TTM could also change the results (ex. Better performances with higher TTM)?

Part 3.**Milestones**

This section is entirely dedicated to the definition of the milestones of the project and of the critical path. The idea is to find the real development time for the firm, in order to better compare the firms in the development of the new products.

The importance of milestones is well proven, and we will cite here one of the many studies on the topic: (Block, Z. and MacMillan, I.C.) *This approach to milestone planning has three advantages for enterprises: 1. it helps avoid mistiming errors, 2. It gives logical and practical milestones for learning and for re-evaluating the entire venture, 3. It offers a methodology for "re-planning" based on a growing body of ever harder information.*

We will use the complete approach (Thomke S. , Fujimoto T. , Nobeoka K. , 2007) to define the main milestones.

Please answer to the survey, and if there are any other milestone you consider important to signal don't hesitate to do it.

Milestone	(Year/Month)
Stage 1	
a. Kick-off meeting for concept initiation	
b. Project manager formally assigned to project	
c. Completion of first design sketches that approximated the approved styling of vehicle exterior	
d. Start of vehicle layout/packaging plan	
e. Start of rough drawings (planning or structural drawings)	
f. Completion of first full-scale clay model	
g. Approval of engine selection	
h. Selection/approval of basic concept for vehicle	
Stage 2	
i. Approval of exterior styling	
j. Approval of vehicle hardpoints	

k. Approval of layout/package design	
l. Budget approved to build Engineering prototypes (including	
m. Budget approved to purchase tooling/dies	
n. Start of detailed engineering drawings (prototype quality)	
Stage 3	
o. Completion of the first engineering prototype	
p. Final approval of detailed engineering drawings	
q. Start of detailed drawings for body panel dies	
r. Start of detailed assembly line/assembly tooling design	
s. Start of stamping press try-out (answer for side panel) OR PANELS?	
t. End of stamping press try-out (answer for side panel)	
u. Start of body-welding line try-out	
v. End of body-welding line try-out	
w. Start of final assembly line try-out	
x. End of final assembly line try-out	
Stage 4	
y. Start of first pilot run at plant	
z. Job 1 (production start-up)	
aa. First retail sales to customers (exclude rental fleets)	
bb. First plant that did high volume production for this vehicle achieves full production rate for new model	
cc. Plant achieves quality level (defect rate) of previous model (or comparable model)	

NB: This chart is related to the timing of the NPD project. It is in fact important to check the real development time to better compare the products, not to fall down in the mistake to compare different times for different stages of the project.

Other few questions on the topic are presented below.

9. Which are the main points on the critical path of NPD process? Are you able to find the critical path in the development process for the new model?
10. Did you analyze the bottlenecks using your previous experience in production? Where were they located? How did you try to solve them?
11. Did you change your development methods in the last years? Did you introduce any new development tools? (Please weight them in a 1 to 5 scale)

Development tools	Weight
Information Technology	
Software Prototyping	
CAD Engineering	
...	
...	

12. When did you plan the different models of the same car? Are you developing them in parallel or sequentially?
13. How did you choose your suppliers? (meaning: is it a long-time relation or are there any "elections"?)
14. What are the main characteristics you search for in a supplier? (Please weight them in a 1 to 5 scale)

Main Characteristics	Weight
Quality	
Price	
Information technology experience	
Time to Market	
...	

15. When did you organize relations with your suppliers? Did you plan any form of outsourcing?

(If yes - otherwise skip the following 3 questions)

16. Please define the level of suppliers participation in the project (using the percentage of the product made in outsourcing)

Level of Supplier Participation	(Supposed) Percentage of New Parts
a. <i>Supplier proprietary parts</i> : parts developed entirely by supplier - auto manufacturer simply ordered them	%
b. <i>Black-box parts</i> : suppliers did detailed design work given loose specifications from manufacturer	%
c. <i>Detail-control parts</i> : auto manufacturer did all or most of the detailed design work and gave the design to a supplier upon parts bidding/ordering	%
d. <i>In-house parts</i> : auto manufacturer designed and manufactured the parts in-house	%
TOTAL	100%

17. How is the outsourcing organized? (this meaning: are there working groups of the partner inside the OEM, or is it completely made by the supplier, which is the connection between the OEM and the supplier, and so on...?)

18. What kind of contract did you sign with your supplier? (performance-based, forfait, ...)

Time to Market

'You win by being first' (Ries & Ries, 2000).

This section is entirely dedicated to Time to Market. We would like to know the decisions explicitly connected to the reduction of time to market, and the possible implications of these choices.

19. Can you please "value" TTM for your firm?

The first-mover advantage concept is self-explanatory in that it posits that the first mover into the marketplace may acquire certain advantages over subsequent entrants, resulting in a sustainable competitive advantage for the first-mover in the form of abnormal profit returns and higher market share (Miller, 1989; Kerin et al., 1992).

20. How did you use Information Technology to gain a better TTM?
21. How did you use Outsourcing to gain a better TTM?
22. What fraction of the parts was *newly designed* for this vehicle (e.g. parts not carried over from a previous or existing model)?
23. Can you please suggest how re-use influenced time to market?

Re-used parts, Influence of Re-use	(Supposed) Percentage of New Parts
1. Platform and Wheels	%
2. External Design (doors, windows...)	%
3. Internal Parts (e.g. seats, instrumental panel)	%
4. Engine and Electronics	%
TOTAL	100%

Decision Process

This section is dedicated to the freezing of the decisions: when a decision is taken (frozen) then the firm will get along that "road" to define the product concept. We have to consider, though, that an early freezing allows the firms to grow on a precise direction quickly, but at the same time impose a decision that couldn't be verified.

The solution to this problem could also be re-use: with a great re-use many informations are already inside the common knowledge of the firm, and it is possible to use them, avoiding the informative gap common in all the "new projects".

24. Did you plan any market study before getting through the first phase of design?

25. Can you temporally define the two main steps of the decision process (beginning and end)

Main Steps of the Decision Process	Date (Month/Year)
a. <i>First</i> kick-off meeting for concept initiation	
b. <i>Last</i> meeting, concept definition and design freezing	

26. Did you involve suppliers and customers in the design definition? How was your front-loading activity? What means did you adopt to get the principal results (e.g. survey, direct interviews...)?
27. Did you use any Computer-Aided method to develop the project? Which one?
28. Did you plan to use these methods along with your suppliers or did you impose them a particular instrument?
29. Did you find any particular advantage using the IT?

Resources dedicated to the project

This section will be used in combination with the "milestone"-one, to check whether TTM depends on a better use of technologies and aid to the production, on an improvement of the entire process, on a specific use of more and more resources on the specific project or all these components together.

We would like to notice that the main differences that could occur between TTM of different firms could also be determined by the different effort the firm put on the specific project (depending on the importance of the project, of the market itself and so on...).

30. What is the importance of the B-segment of the automotive market in your firm's business project? Can you provide a comparison on a 1-to-5 scale with all the other segments?

Market Segment	Weight (level of importance 1-5)
Segment A: Superminis (it includes city cars)	1 2 3 4 5
Segment B: Small family cars (also for stand-alone saloon superminis)	1 2 3 4 5
Segment C: Sports cars (3-5 doors)	1 2 3 4 5
Segment D: Large family cars (includes compact executive cars)	1 2 3 4 5
Segment H1: Trucks	1 2 3 4 5
Segment H2: Executive cars (for expensive cars over 4.80m long)	1 2 3 4 5
Mono-space	1 2 3 4 5
Off-roaders (small and large):	1 2 3 4 5

31. What is the importance of the model we are considering for your firm in that specific segment of the market?
32. Are there any other products of your firm already in the market in that specific segment?
(if yes)
33. Can you define their life-cycle condition? Will they be substitute by the new model or will they compete with it in the same market?

34. Have you got any other projects for the same market already working at the moment?

35. How many resources did you devoted to the project considered during its development phase? Can you please distinguish each sub-phase of development and consider how many resources did you devoted to it?

Please consider as resources both human (workforce) and technical resources. We would like to understand how many people were working at the design and testing of the new model. We would like moreover to analyze here the connections with the suppliers, and how they influenced the growing of the project itself. We know (it is already expected) that the precision of this answer couldn't be so high (we should in fact consider also the resourced devoted by the supplier) but it is just to have an initial idea for further analyses. Please define the resources used in a 1 to 5 scale, comparing them to all the possible resources the firm could devote to the process.

Development Process	Resources Devoted to the Project
Preliminary Design	1 2 3 4 5
Prototyping	1 2 3 4 5
Testing designs (e.g. crash tests, wind-tunnel...)	1 2 3 4 5
...	1 2 3 4 5
...	1 2 3 4 5

Computer-Aided Development

This final section is dedicated to a brief discussion to the use of computer aided design tools in new product development. We want here to analyze the effort these new techniques give to the development, both in money and time saving.

1. Can you please define the level of importance of the IT in the main new development processes?

New Development Process	IT Weight
Preliminary Design	
Prototyping	
Testing designs (e.g. crash tests, wind-tunnel...)	
...	
...	

2. Can you please distinguish the specific effort of IT in two specific application fields: information exchanging (internally and with suppliers) and prototyping?
3. Can you please define the advantages in terms of costs your firm gain from the use of IT in the development phase? (e.g. reduction of the physical prototyping costs, reduction of the cost of crashing test...)
4. In comparison with other older models produced by the firm, can you define the effort IT gave to reduce the TTM during the New Development Process?

Development Process	Time to Develop	
	Precedent Model	Actual Model
Preliminary Design		
Prototyping		
Testing designs (e.g. crash tests, wind-tunnel...)		
...		

5. Did the use of IT change your relations with suppliers? If yes, how? Did you use IT to improve relations and to strengthen them?
6. Did the use of IT change your relations with customers? If yes, how? Where you able to let customer get deeper into the project?

Appendix C

PSA Organizational Changes, year 2009

JEAN-MARC Gales, in the role of General Manager since June, 18, 2009, made it official the new organizational plan of PSA, according to the three-fold goal of the firm: globalizing the firm, being a step ahead as regards customers products and services, increasing efficiency. In an attempt to better achieve these purposes, Peugeot equipped with an “*attack*” organization aimed at expanding its presence on promising markets, thus including selling to corporations and commercializing bargain vehicles. Marketing and Communication are now grouped together in a single entity, responsible for managing the image of the firm, repositioning products, launching them on the market, advertising, and Brand communication. The chief directors of this new function, straightly connected with the General Manager, are:

- France: Mr. Christophe Bergerand;
- Germany: Mr. Olivier Dardart;
- Marketing and Communication: Mr. Xavier Peugeot;
- Corporation Markets and Administrations: Mr. Marcel de Rycker;
- Bargain Vehicles Commerce: Mr. Olivier Quilichini;
- Assistant Manager of Peugeot Brand: Mr. Nicolas Wertans.

We depict below a brief characterization of these new members of the broad of directors at PSA Group.

Mr. Nicolas Wertans, 41, is in charge for Spain, Italy, United Kingdom and other European markets, as well as for Russia, Iran, Turkey, a huge part of the Latin America area, Middle East, some sections of Asian continent, and he is the responsible for the development of the Net. Graduated at Suplec (cole Suprieur d’ Electricit) and INSEAD (Institut Europeen d’ Administration DES affaires), entered as a part of the PSA Peugeot Citron Group in March 2009. Previously involved in the automotive market at other car-makers (BMW), where he was designed for

other charges. He hold the Vice-Director Peugeot Brand charge since June, 18.

Mr. Christophe Bergerand, 46, graduated at HEC (cole DES hautes tudes commerciales) and Sciences Po (Institut of tudes politiques de Paris), held several positions in Peugeot France between 1988 and 2001. Director of Peugeot Portugal (between 2001 and 2003) and Peugeot Italy (between 2003 and 2007), in February 2008 has been appointed as Director of Peugeot France.

Olivier Dardart, 50, graduated at ESSEC (cole Suprieur des Sciences Economiques et Commerciales), entered in the Group in 1983. Since 1983 he was assigned to France Trading Function. Between 2001 and 2004 he held the role of France Net Director, while between 2004 and 2005, has assumed the direction of the Net Development Function. Assigned as an Area Director (Benelux, Austria, Switzerland and Portugal), he is Director of Peugeot Germany since June 2006.

Xavier Peugeot, 45, bachelor in Sciences de Gestion at Sorbona University, with a specialization DESS (Diplme of tudes Suprieures Specialises) in International Transactions at Paris Dauphine University, got into the PSA Peugeot Citron Group in 1994. He covered different assignments in Peugeot Trading Department before assuming the Direction of Peugeot Netherlands in 2005. He is in charge of A and B segment within the Production Department since 2007.

Marcel De Rycke, 47, bachelor ESDE of Paris and MBA Hartford University, covered several functions of marketing and trades at other car-makers (the last one at Mercedes). He got into the Brand in July, 2009, as Corporation Markets Director.

Olivier Quilichini, 39, aeronautical engineer (ISAE Tolosa), entered PSA Group in 1994. Between 1994 and 2002 he covered various functions in Sales Department in France. International Fleet Responsible between 2003 and 2005, he became European Reciprocations and Attendance Responsible since 2006. Named Bargain Vehicle Responsible in 2009.

Appendix D

EuroNCAP results and comments

THE main results we found in the EuroNCAP official site seem to show a substantial accordance between the two models. Some safety differences could be obviously due to the shape of the vehicles, and to the intrinsic characteristics of the projects. We present here results and comments.

For cars tested before 2009, Euro NCAP has released three ratings¹: adult protection, child occupant and pedestrian protection. The ratings for adult protection and child protection are achieved as a result of three impact tests: frontal, side and pole test. Euro NCAP carries out a separate range of pedestrian tests to reach the score of the Pedestrian Rating. The tests were chosen to cover the range of accidents responsible for the majority of serious and fatal injuries. In addition, Euro NCAP rewards cars for having an intelligent seatbelt reminder as part of the adult protection rating. Respectively, the three tests can be described as follows:

- *Adult occupant protection*: Points are awarded from the frontal, the side and pole impact tests. Modifiers are also given to extend the assessment to cover different sizes of people in a variety of seating positions, in particular for the knee contact area. The Adult Protection score is completed with the result of the Whiplash test that is carried out separately on the driver or passenger seat;
- *Child occupant protection*: As part of this assessment, Euro NCAP uses 18 month old and 3 year old sized dummies in the frontal and side impact tests. Moreover, the test verifies the clarity of instructions and seat installation in the vehicle to ensure that the child seat can be fitted safely and securely;
- *Pedestrian protection*: results in this rating are achieved through leg form, upper leg form and child/adult head form testing.

EuroNCAP provides also some comments about the vehicle analyzed, in order to complete the scaling. Respectively, for Peugeot 308 and Fiat Bravo, the comments provided are:

¹Since 2009, Euro NCAP only releases one overall star rating for each car tested with a maximum of five stars. This overall safety rating is composed of scores in four areas: adult protection, child protection, pedestrian protection and safety assist

Peugeot308

	RATING	SCORE	Front: 14.3	Seatbelt reminder: 3
	ADULT OCCUPANT	35	Side: 16	Pole: 2
	CHILD OCCUPANT	39		
	PEDESTRIAN	19		

Adult occupant protection



Child restraints

18 month old Child Britax Römer Baby-Safe, rearward facing

3 year old Child Britax Römer Duo Universal, forward facing

Pedestrian protection



Safety equipment

Front seatbelt pretensioners	<input checked="" type="checkbox"/>
Front seatbelt load limiters	<input checked="" type="checkbox"/>
Driver frontal airbag	<input checked="" type="checkbox"/>
Front passenger frontal airbag	<input checked="" type="checkbox"/>
Side body airbags	<input checked="" type="checkbox"/>
Side head airbags	<input checked="" type="checkbox"/>
Driver knee airbag	<input checked="" type="checkbox"/>

Car details

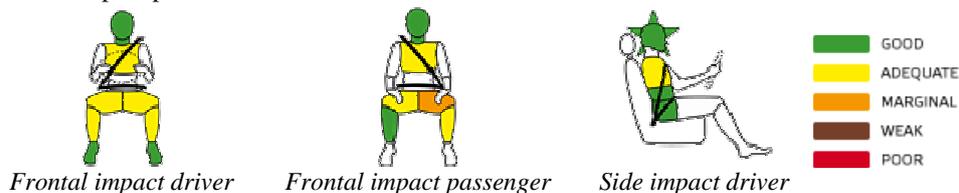
Tested model	Peugeot 308 1.6 diesel 'Premium', LHD
Body type	5 door hatchback
Year of publication	2007
Kerb weight	1322kg
VIN from which rating applies	Applies to all 308s

Figure D.1: EuroNCAP results, Source: <http://www.euroncap.com/home.aspx>

FiatBravo

RATING	SCORE	Front	Side	Seatbelt reminder	Pole
 ADULT OCCUPANT ★★★★★	33	12.8	16	2	2
 CHILD OCCUPANT ★★★★★	36				
 PEDESTRIAN ★★★☆☆	16				

Adult occupant protection



Child restraints

18 month old Child Britax-Römer Duo Plus ISOFIX, forward facing

3 year old Child Britax-Römer Duo Plus ISOFIX, forward facing

Pedestrian protection



Safety equipment

Front seatbelt pretensioners	<input checked="" type="checkbox"/>
Front seatbelt load limiters	<input checked="" type="checkbox"/>
Driver frontal airbag	<input checked="" type="checkbox"/>
Front passenger frontal airbag	<input checked="" type="checkbox"/>
Side body airbags	<input checked="" type="checkbox"/>
Side head airbags	<input checked="" type="checkbox"/>
Driver knee airbag	<input type="checkbox"/>
ISOfix front	<input type="checkbox"/>
ISOfix rear	<input checked="" type="checkbox"/>

Car details

Body type	5 door hatchback
Year of publication	2007
Kerb weight	1300kg
VIN from which rating applies	All Bravos

Figure D.2: EuroNCAP results, Source: <http://www.euroncap.com/home.aspx>

- **Peugeot 308**

- **Front impact:** the passenger compartment remained stable during the impact. The driver's knees were well protected by an airbag mounted in the lower dashboard. Peugeot showed that the airbag would also protect occupants who were larger or smaller than the dummy used in the test, and those sat in different seating positions. The passenger was well restrained and his knees did not get close to the dashboard
- **Side impact:** the 308 scored maximum points in the side impact and pole tests
- **Child occupant:** the passenger airbag can be disabled to allow a rearward facing child restraint to be used in that seating position. However, information provided to the driver regarding the status of the airbag is not clear. The presence of ISOFIX² anchorages in the front passenger seat and the rear outboard seats was not clearly marked
- **Pedestrian:** the bumper scored maximum points for its protection of pedestrians legs. Also, the protection offered by the bonnet to the head of a struck child was predominantly fair. However, protection of adults' heads was mostly poor

- **Fiat Bravo**

- **Front impact:** Fiat have done much to remove hazards from the dashboard area but the steering column and ignition barrel still posed some risk of injury to the driver's femurs;
- **Side impact:** the chest was the only body region not to score maximum points in the side impact test. The car scored maximum points in the pole test;
- **Child occupant:** the presence of ISOFIX anchorages in the rear outboard seats was not clearly marked. The front passenger airbag can be disabled to allow a rear-facing child restraint to be used in that seating position. However, information provided to the driver regarding the status of the airbag was not sufficiently clear.

²ISOFIX is International Organisation for Standardisation standard ISO 13216, which specifies the anchoring system for Group 1 child safety seats. It defines standard attachment points to be manufactured into cars, enabling compliant child safety seats to be quickly and safely secured. ISOFIX is an alternative to securing the seat with seat belts. Seats are secured with a single attachment at the top (top tether) and two attachments at the base of each side of the seat

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