Dynamics of internal R&D stakeholders in the Fuzzy Front-End of breakthrough engineering projects

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DYNAMICS OF INTERNAL R&D STAKEHOLDERS IN THE FUZZY FRONT-END OF BREAKTHROUGH ENGINEERING PROJECTS

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ABSTRACT

In competitive industries, intensive innovation is a recognized necessity (Wheelwright and Clark, 1992; Le Masson et al., 2010). One success factor of breakthrough R&D projects lies in the knowledge articulation between innovation definition phases, composed of fuzzy front-end (FFE) and innovative new product development (NPD) stages (Koen et al, 2002; Cooper et al, 2001), and industrial development processes. Then, central issue for innovation projects managers becomes internal R&D stakeholders' management (Elias et al., 2002) and sustainable learning dynamics across the two parts of the organization (O'Connor, 2008). Our paper fits into this research gap for local breakthrough R&D in the dominant design. We discuss the role of technical expertise level of NDP stakeholders involved in early stages of innovative projects. The research mobilized two longitudinal studies (Yin, 1989) carried out with a global car manufacturer through collaborative management research (Radaelli et al., 2012) since 2005, one focusing on the FFE management, while the other was devoted to learning dynamics of engineering development departments. A cartography of the internal network of breakthrough R&D (Mitchell et al, 1997) underlined a stable organizational network across projects. Nevertheless, a quantitative analysis of accounting data on 8 projects highlights important dynamics of involvement or dis-engagement within the network. The analysis showed that the accounting reporting at the portfolio level used to hide to top-managers the heterogeneity and depth of resources dynamics at the project level. The impacts of local breakthrough R&D on the engineering development organization was similar to waves: some stakeholders, who played roles of experts, spokespersons or innovation design strategists, were able to involve quickly the individuals to maintain the project progress, sometime generating an over-commitment on innovation projects. At the opposite, a lack of trust of the design partners generated withdrawal of resources that needed a strong stakeholder management to be prevented.

Keywords: Breakthrough R&D; Stakeholders; Commitment

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Abstract

In competitive industries, intensive innovation is a recognized necessity (Wheelwright and Clark, 1992; Le Masson et al., 2010). One success factor of breakthrough R&D projects lies in the knowledge articulation between innovation definition phases, composed of fuzzy front-end (FFE) and innovative new product development (NPD) stages (Koen et al, 2002; Cooper et al, 2001), and industrial development processes. Then, central issue for innovation projects managers becomes internal R&D stakeholders' management (Elias et al., 2002) and sustainable learning dynamics across the two parts of the organization (O'Connor, 2008). Our paper fits into this research gap for local breakthrough R&D in the dominant design. We discuss the role of technical expertise level of NDP stakeholders involved in early stages of innovative projects. The research mobilized two longitudinal studies (Yin, 1989) carried out with a global car manufacturer through collaborative management research (Radaelli et al., 2012) since 2005, one focusing on the FFE management, while the other was devoted to learning dynamics of engineering development departments. A cartography of the internal network of breakthrough R&D (Mitchell et al, 1997) underlined a stable organizational network across projects. Nevertheless, a quantitative analysis of accounting data on 8 projects highlights important dynamics of involvement or dis-engagement within the network. The analysis showed that the accounting reporting at the portfolio level used to hide to top-managers the heterogeneity and depth of resources dynamics at the project level. The impacts of local breakthrough R&D on the engineering development organization was similar to waves: some stakeholders, who played roles of experts, spokespersons or innovation design strategists, were able to involve quickly the individuals to maintain the project progress, sometime generating an over-commitment on innovation projects. At the opposite, a lack of trust of the design partners generated withdrawal of resources that needed a strong stakeholder management to be prevented.

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Introduction

Industrial expectations of management research on breakthrough R&D project processes have two main dimensions, as follows: first, measurement and performance management of activities and, second, models of financing innovation projects that disrupt established organizations and business models. Referring to these issues, many studies have described the components of the management process that designs, deploys and maintains a cross-functional management of innovation projects from the early stages of design to the commercial phase of new product development (NPD) (Weelwright and Clark, 1992). Breakthrough R&D projects could be distinguished from others optimization R&D projects as they include a Fuzzy Front-End (FFE) stage of ideation (Koen et al., 2002) before the other stages of New Product Development. Due to opposite logics of uncertainties management, these projects were dissociated as exploratory projects (Lenfle, 2008) or creative projects (Gillier, Hooge and Piat, 2015) from the R&D projects that follow traditional funnel portfolio approaches (Weelwright and Clark, 1992). Thus**,** compared to conventional forms of management of NPD, a breakthrough innovation project in a dominant design is characterized by the existence of an FFE phase; uncertainties surrounding each managerial component of a project during all the steps of the R&D project (goals, constraints, management and organizational structures); dynamic planning progress and its associated managerial decisions (recurrent validation, redirection or stop); and a more complex network of stakeholders within the company who influence the advancement of the project and its guidelines (Lenfle, 2008; Le Masson et al, 2010). Connections between the two managerial logics have been largely studied. Processes are intended to describe the maturity levels and content of decision milestones to ensure the robustness of projects at each stage of NPD, including the FFE stage (Cooper et al, 2001), to help achieve an internal consensus between FFE and NPD actors in terms of the value of the project and its potential deliverables (Hooge and Hatchuel, 2008), to secure and stabilize the allocation of resources (Hall, 2000), and to introduce flexibility in projects' funding in accordance with decisions that were made at milestones (Akroyd et al, 2006).

To establish a unified monitoring process of R&D projects in the FFE and NPD stages, it is therefore necessary to identify actors and decision makers of these projects and their expectations of the management process. This dimension of project management concentrates on the building and the gradual strengthening of internal R&D stakeholders' commitment (Mitchell et al, 1997) to the company's breakthrough innovation projects. If one considers that the funding of breakthrough innovation is a consequence of the involvement of internal stakeholders, then the identification of internal stakeholders and these internal stakeholders' commitment to breakthrough innovation projects are leading issues of the R&D management process. The current paper fills this research gap by studying the conditions of the identification of internal R&D stakeholders of breakthrough innovation projects. Furthermore, we study the impact of the engineering expertise of this player network to support the innovative activity in companies with a strong dominant design (Utterback, 1994; Henderson and Clark, 1990). The research relies on a long-term collaborative partnership (Adler et al., 2004; Shani et al., 2008) with a global car manufacturer that focused on the managerial process to improve the management of stakeholders in highly innovative R&D projects. The authors conducted two longitudinal studies (Yin, 1989) with the car manufacturer since 2005. One study focused on the FFE management process and organization, and the other focused on NPD management, and especially learning dynamics within the engineering development department. As these studies represent collaborative management research, data analyses were enhanced through in-depth interviews with project managers, technical experts and decision makers.

Theoretical framework on internal R&D stakeholders: purpose and issues

Internal Stakeholders of R&D projects

Since the creation of the word "stakeholder" by Ansoff and Stewart in 1963, and particularly since the work of Freeman in 1984, Stakeholder Theory has progressively been deployed through several books and numerous scholarly papers that have described and improved various approaches to the strategic management of stakeholders (Elias, Cavana and Jackson, 2002; Savage et al., 2011). Beyond the scope of analyzing the firm through its industrial and economics trades, Stakeholder Theory integrates social and political exchanges between actors (Post et al., 2002; Wilson, Bunn and Savage, 2010). The abundance of research in this field has led to the coexistence of many definitions of the stakeholder concept and divergent approaches, as follows: descriptive, instrumental or normative approaches (Donaldson and Preston, 1995), strategic or ethical approaches (Jones and Wicks, 1999), etc. This divergence has led to confusion or ambiguity about the content of Stakeholder Theory, and central definitions remain debated for a decade (see, e.g., Elias and Cavana, 2000; Freeman et al., 2012). Nevertheless, the various streams agree on the significance of the systematic identification of stakeholders to enhance a firm's performance. Specifically, they agree that the understanding of expectations and stakes of the various actors involved in an activity determines the potential success of the collaboration in regards to achieving targets. As highlighted by Andrioff and Waddock (2002), the identification exercise is a component of organizational control; without the commitment of stakeholders on a project, the entire organization may no longer support the activity.

Freeman's definition of stakeholders, i.e., "*any individual or group who can affect the achievement of an organization's objectives or who is affected by the achievement of an organization's objectives*" (Freeman, 1984 - 91), is the most popular definition in the literature. In the context of R&D projects, scholars have used the more accurate definition of internal stakeholders proposed by Post, Preston and Sachs (2002 -13): *" The stakeholders in a firm are individuals and constituencies that contribute, either voluntarily or involuntarily, to its wealth-creating capacity and activities, and who are therefore its potential beneficiaries and/or risk bearers".* This specific definition focuses on the management of internal networks of a firm, including external stakeholders' stakes and expectations based on interactions with their representatives inside the firm.

From an operative point of view that extends Freeman's work, many authors have stressed the importance of an effective definition of stakeholders to achieve an R&D project (Mitchell, Agle and Wood, 97; Coombs et al., 1998). Since the end of the 90's, a lot of studies have investigated this specific issue of R&D stakeholder and project management (Olander and Landin 2005, Achterkamp and Vos 2008, Jepsen and Eskerod 2009, Aaltonen 2011). Nevertheless, the approach of Mitchell, Agle and Wood (1997) remains a theoretical reference as their research proposes an analytical framework to shed light onto the potential dissymmetry between stakeholders through preliminary interactions. These authors described the actors impacted by a project according to their cumulative ownership of the following three managerial attributes:

- Power: the stakeholder has coercive, utilitarian or normative ability to impose its will in the relationship;
- Legitimacy: judgments and acts of the stakeholder are commonly perceived or assumed as desirable, proper and appropriate;
- Urgency: others consider the stakeholder's claims to be critical or highly important.

Players with more of these attributes should be considered as more essential in steering the project, and their aims and expectations must be integrated into the FFE and NPD processes of a breakthrough innovation. The attributes of power and legitimacy were presented in the work of Freeman, but Mitchell, Agle and Wood included the concept of urgency, feeding the views of a dynamic management of stakeholders. Indeed, these authors emphasized the influence of time on stakeholders' attributes (Mitchell, Agle and Wood, 1997 - 879): "*Static maps of a firm's stakeholder environment are heuristically useful if the intent is to raise consciousness about « Who or What Really Counts »*[1] *to managers or to specify the stakeholder configuration at a particular time point. But even though most theorists might try for static clarity, managers should never forget that stakeholders change in salience, requiring different degrees and types of attention depending on their attributed possession of power, legitimacy, and/or urgency, and that levels of these attributes (and thereby salience) can vary from issue to issue and from time to time.*"

In later research on R&D stakeholders' management, Elias, Cavana and Jackson (2002) proposed a combination of Freeman's and Mitchell, Agle and Wood's recommendations to establish an 8-step process for the systematic identification of stakeholders, their interests in an R&D project and actors' attributes mapping. With this process, R&D project leaders plan to systematize the association of the

[1] Authors refer to the principle of the same name previously developed by Freeman: " *On such principle, which I will call ''The Principle of Who and What Really Count'', says that the primary function of the corporation is to enhance the economic well-being, or serve as a vehicle for the free choices of, the owners of the corporation*" (Freeman, 1994).

identification of a new actor with the description of its expectations and its bargaining power with other actors.

Although the definition of R&D project stakeholder has been clarified and the purpose of their dynamic identification has been demonstrated, scholars have underlined that the tools to operationalize dynamic identification and the process to manage stakeholders once they have been identified remain under-investigated issues, especially in the FFE stage of an R&D project (Bessant et al., 2010). Indeed, identification does not provide evidence on the efficiency of stakeholders' involvement in breakthrough R&D projects.

The research gap between the identification of internal R&D stakeholders and the commitment of relevant stakeholders for the progress and achievement of breakthrough R&D projects

Breakthrough innovation projects differ from other design activities of new product development due to their ability to introduce new design rules into the NPD process or to change corporate standards (Utterback, 1994; Le Masson, Hatchuel and Weil, 2010). Thus, NPD projects in large industrial firms are the result of multidisciplinary interactions of an abundant, dynamic and complex network of actors. According to L. Meade and A. Presley (2002), internal stakeholders of an innovation project fall into the following four groups of skills and roles in a R&D project: management, marketing, manufacturing and technologists. Understandably, these four types of actors convey specific needs and expectations for radical innovation projects, and their needs and expectations are often contradictory. This diversity raises a central issue in the management of internal stakeholders, as follows: if the size of the network could place the progress of the project at risk, who are the relevant actors to involve in a breakthrough R&D project?

A first approach to this issue is proposed in actor network theory (ANT), where the sociologist M. Callon and his colleagues highlighted the specific role of mediator played by some actors that are able to interest and enroll other stakeholders in an activity (Callon, 1986; Akrich et al., 2002a; Akrich et al., 2002b). According to the indefinite state of a project's innovative outputs in the first stages, it is not uncommon for debates on innovation potentials to feed exacerbated reactions of supporters and opponents' players inside a stakeholder's network (Akrich et al., 2002a). These authors claimed that an innovation project cannot be achieved without a sufficient number of allies that will support the progress of the activity (ibid), but they also highlighted that such efficient alignment could be overcome by *spokespersons* that know how to convince people to support the activity (Akrich et al., 2002b). Spokespersons are not devoted to integrating and reconciling the wishes of all stakeholders; rather, they feed the interactions between them to facilitate the progress of the project.

A second approach to relevant stakeholders is proposed by the application of knowledge creation theory to radical innovation processes (Nonaka, 1991; Nonaka & Takeuchi, 1995; Nonaka and Peltokorpi, 2006). According to Nonaka and Peltokorpi (2006 - 90), radical innovation processes succeed because "*through their small-world networks, people locate external collaborators with the right knowledge to speed up the product-development process*". As much of the necessary knowledge is tacit, the involvement of experts and knowers who have the pertinent skills and knowledge at the right time is compulsory to successfully achieve the project (Nonaka and Takeuchi, 1995). Moreover, in the case of breakthrough innovation projects, all relevant experts and knowers are rarely identified in NPD stages, particularly in the FFE stage. Building the network of appropriate and competent individuals in the innovation takes place over time and is associated with the identification of business opportunities and definition of competitive technical deliverables.

A third approach to internal R&D stakeholders is specified by innovation capability theory (Hatchuel, Weil and Le Masson, 2003). Beyond the social process and the learning process, a strategic process occurs that supports the innovative design orientation. Acting as innovative design strategists, some managers are able to generate *design metaphors* of expected concepts of innovation, which are forms of framing or guiding patterns that drive the collective action.

Based on the design metaphor provided by the innovation strategist, FFE & innovative NPD engineering designers could use existing knowledge or products for original applications. These designers generate and combine lineages of products and lineages of knowledge to design a new product, process or service. Disseminating the design metaphors in FFE and NPD projects, innovative design strategists appear as key actors to coordinate both structural dynamics and knowledge creation. In later work, the authors described this activity of innovative design strategy as the ability to build a specific orientation to create new design rules and to assess the generativeness and robustness of these new rules within the firm's design context (Hatchuel et al, 2011).

In the framework of Mitchell et al. (1997), spokespersons, experts and design strategists must at least have the legitimacy attribute to be effectively convincing. Nevertheless, these key actors are not necessarily committed to leading the project; rather, they could emerge from many areas of the stakeholders' network of the project. Consequently, relevant NPD stakeholders are often overextended in large firms and face a scarcity of time for debating the different points of view. Yet, spokespersons, experts and innovative designers could defend different rationales of the opportunities of a project in the FFE or NPD stages, even if their visions could efficiently be confronted. In response to this predicament, reasons to consider decisions as illegitimate within the framework are proliferating. To avoid this locking situation, project leaders involve the key stakeholders in a process that is independent of decision committees that "*consist of myriad actions, negotiations, and micro-decisions in the effort to create strong networks, leaving few decisions for the official gate and portfolio meetings"* (Christiansen and Varnes, 2007 - 282). This interactive process also protects the R&D project from powerful players' games within large firms' innovation committees, which are typically chaired by corporate leaders. Indeed, players' divergent positions without prior consultation with other actors may be perceived as their desire to get ahead personally and, therefore, presents a high risk of conflict, whose outcome is highly uncertain for the project because the debate could lose its rationality.

Building a common orientation among stakeholders is therefore based on the quality of the interactive process before the decision-making sessions where consensus about the goals of the next project's stage will ultimately be achieved. As the competitive benefit of a breakthrough innovation project is intrinsically unclear at the beginning of the project, it appears that this action / negotiation process between internal stakeholders leads to the collaborative design of the value of the innovation project for the firm. Thus, the identification and commitment process of actors must be led by the following question: how can project leaders know if the actors that they identified as relevant stakeholders are able to explicate and build value for the firm to propose new design rules of product or process?

Research materials and investigation methods

The current research mobilized two longitudinal studies (Yin, 1989) that were carried out with a global car manufacturer between 2005 and 2010. One study focused on the innovation management process and organizational capability for innovation (*Author's references*), and the other focused on the learning dynamics of engineering development departments, especially in the sub-department of Car Body & Assembly (CBA) (*Author's references*). The two studies discussed the issue of the involvement of traditional NPD actors in breakthrough innovation activities from the first steps of design to the implementation of the new design rules in engineering development departments and the benefits of the crossed perspectives of the knowledge that the researchers acquired on stakeholders from the two parts of the organization. The distinctive features of the studied project portfolio lie in its technological and organizational variety, which allows multiple case studies in a unified context. Indeed, R&D projects have very different technical and economic challenges and types of stakeholders. Similar to all global car manufacturers, the partner firm has a range of innovation projects that cover many fields of technologies (mechanics, aerodynamics, air quality, material dynamics and recycling, NTIC, etc.), services (BtoB, BtoC) and business models (unique sell, pooled offer, leasing, rent, etc.) that are more or less intrusive in the dominant design paradigm (e.g., breakthrough R&D projects range from new seat mechanics for a car that is already in the firm's range to new car architecture with some updatable parts that could be purchased later). This diversity of content is also combined with a wide variety of stakeholders' networks involved in breakthrough R&D projects. *In 2007, the engineering department of the partner firm gathered approximately ten thousand people, who were organized into sub-departments.* Both authors collected rich and longitudinal material on breakthrough R&D projects through intervention research methodology (Hatchuel and David, 2007; Radaelli et al, 2012). The first study was conducted with the sub-department of Research of Advanced Engineering (R&AE), whose managers were in charge of the projects and portfolios of breakthrough R&D. The department also possessed specific skills of research and advanced engineering in automotive competitive domains (e.g., electronic, material, architecture, ergonomic). The second longitudinal research was in partnership with the Car Body &

Assembly sub-department, which included one thousand collaborators and a half thousand engineering sub-contractors who were dedicated to the industrial development of the product and process of the body-in-white of all car programs and the painting process. They were subdivided into four technical services (i.e., design, assembly, stamping and painting), which each included up to two hundred people, and four project services (one per range of car programs). Overall, 75% of resources were dedicated to ongoing car program development. Knowers and experts who were needed for their knowledge of R&AE projects were especially placed in those engineering teams. Analyses of the intervention research of the projects were enhanced through in-depth interviews with fuzzy front-end and NPD project managers, technical and marketing experts and decision makers.

Beyond qualitative analysis, our approach differs from the majority of previous studies on the identification of internal R&D stakeholders due to its in-depth analysis of resource allocation and consumption in innovation projects. We accessed detailed accounting data of R&AE projects, budget allocations and expenses and data on the composition and evolution of project teams through the daily time tracking of collaborators. This method allowed us to precisely quantify the effective involvement of actors from all engineering teams. This quantitative analysis was conducted for all breakthrough R&D projects of the firm from the beginning of 2007 to the end of 2009, but we focus on the 2007 data in the current study due to the impact of the worldwide car crisis on engineering investments in 2008 and 2009.

To distinguish breakthrough R&D from conventional R&D, the type of project was labeled in the firm "project of Research and Advanced Engineering (R&AE)" even if the project was in a stage of FFE or innovative NPD. Dedicated project portfolio managers and project leaders managed R&AE projects until their transfer to car program and industrial development teams (i.e., they managed the FFE and first steps of innovative NPD). As engineering resources were disseminated across the entire Engineering department, R&AE teams worked with many technical organizational areas of the firm and consulted and involved the stakeholders of other departments of the firm, e.g., market analysts, industrial designers, and costs economists, to achieve their projects. A breakthrough R&D project was considered in FFE engineering until the competitive target of innovation was clarified and quantified (consumer benefit in the case of innovative products and services; internal performance in the case of innovative industrial process). Then, the R&AE project became a NPD engineering project, but it was still considered a breakthrough R&D activity, as technical solutions and business models remained mainly undefined. R&AE projects only ended when the maturity of the innovation definition reached the expected level for a transfer to industrial development teams.

At the end of 2006, the strategic plan of R&AE projects forecasted 67 projects in FFE engineering and 62 projects in innovative NPD engineering. At the end of 2007, R&AE resource allocation showed 111 active projects (50 in FFE and 61 in innovative NPD). The CBA sub-department was involved in 9 of these projects, 7 as a design partner and 2 as the lead team. The figures below present the repartition of the number of design partners in the portfolio within the engineering department (Table 1) and the number and organizational area of individuals who were involved in the 10 projects with CBA (Table 2).

Table 1. Distribution of accounting entries by maturity level of R&AE projects

			Fuzzy Front-End Engineering		Innovative NPD Engineering		
			Process	Product	Process	Product	
Number of projects analyzed			19	31	8	53	**111**
Meta-divisions of Engineering Department	Research & Advanced Engineering		33	49	21	130	**233**
	Industrial development Engineering	Technical definition Draft	1	1	5	23	**30**
		Engine Engineering	2	4	2	18	**26**
		Car Engineering (including CBA)	11	16	14	84	**125**
	Total accounting entries (per org. area)		47	70	42	255	**414**

Table 2. Amount of design partners in R&AE projects with CBA

Maturity / Innovation Type	Projects	Weight of the project in k€ (real costs)	Number of organizational areas involved		Number of individuals involved	
			All Eng. Dept.	CBA Dept.	All Eng. Dept.	CBA Dept.
FFE-Process	A	285 k€	7	1	16	1
	B	1045 k€	5	1	31	1
NPD-Process	C	1 130 k€	7	2	8	6
	D	306 k€	2	1	11	9
	E	4 750 k€	6	5	56	55
FFE-Product	F	197 k€	2	1	12	10
	G	13 k€	1	1	3	3
NPD-Product	H	243 k€	7	2	7	1
	I	91 k€	7	1	4	0

In addition to accounting analysis, these projects were studied qualitatively from mid-2005 to mid-2010 through intervention research and interviews with project leaders and managers, providing both authors with an in-depth understanding of these projects' management from their initiation as breakthrough R&D projects to their transfer to engineering departments for application in a car program. Thus, the gathered material allowed us to qualitatively and quantitatively discuss the management of internal R&D stakeholders from the view of both the intensity of stakeholders' involvement, across committed and spent resources on the project's budget and resources consumption, and the relevancy of involved stakeholders, across the impact of the actors' involvement on the progress of the project.

Case study analysis: what is expected from an internal stakeholder commitment process for breakthrough R&D projects?

To tackle the research gap on the management of relevant internal R&D stakeholders for FFE and NPD projects, we began our study with a detailed characterization of the actor network that our partner's firm had to build to conduct breakthrough R&D activities. In 2007 and 2008, we conducted two different analyses of the data simultaneously to understand the nature of the network of internal R&D stakeholders of the firm partner that we describe below. The first analysis modeled the network from an organizational approach of collaborators' interactions, and the second analysis quantified the involvement of internal contributors from an accounting approach, monitoring the budgeting and consumption of resources of breakthrough R&D projects. This analytical phase was conducted to understand and model the following three points:

- The characteristics of the internal R&D stakeholders of a breakthrough R&D project (through a systematic description of their official roles in the organization of the firm and in the project);
- How they affected or were affected by the progress of the activity (crossing the framework of (Mitchell et al., 1997) with the approach of spokesperson, experts and knowers or innovative design strategists);

- How intensively they were involved in breakthrough R&D projects and how their resources involvement impacted the progress of the project (in-depth analysis of accounting data).

Building a cartography of internal stakeholders of breakthrough R&D projects

To model R&D stakeholders' interactions within the firm partner, we first used the model of concentric circles of power / legitimacy / urgency attributes developed by Mitchell, Agle and Wood (1997). This typology facilitates early identification of stakeholders because it is very meaningful for managers of R&D projects and portfolios. During interviews, they easily placed concrete actors into these categories, as follows: holders of power were most often resources owners and corporate managers; holders of legitimacy were technical, costs and market experts or experimented leaders; and holders of the emergency were those who bore the risks of the project's failure. In collaboration with the R&AE project leaders and portfolio managers, we mapped the R&D stakeholders according to attributes of the two largest projects in the fuzzy front-end stage and the two largest in the innovative NPD stage in terms of the 2007 annual forecast amount. As stakeholders were identified through corporate status (e.g., project leader, development engineering team, patent analyst), a convergent map emerged from the analysis of the four projects, independent of the maturity level of the project (Figure 1). This is because in the FFE projects, practitioners added some 'shadow' stakeholders because, at that time, they had not identified the adapted individual for the corporate mission, but they knew they had to involve an individual from a part of the organization.

Collaborators from the CBA sub-department appeared few times in this cartography:

- Technicians and engineers were included in technical engineering teams, and fifty of them were central technical leaders (who were 40% dedicated to maintaining the organizational capability of body-in-white architecture and manufacturing processes at a worldwide competitive level through continuous efforts to renew internal expertise);
- CBA's head managers were engineering development top managers;
- For two projects, collaborators of CBA were R&AE project leaders (one in FFE-product and one in innovative NPD-expertise);
- Some customer service pilots, who developed design rules for specific customer expectations

and steered the attained performance in car development programs, came from CBA (vibration, safety (crash test) and perceived quality (geometry aspect, painting and surface quality));

- Some central technical leaders were also members of the suppliers strategy committee (which is the group that selects suppliers and is, consequently, the most powerful authority of the firm because cars are largely composed of components that are designed and manufactured outside of the firm);
- The center competition investigation contained few analysts from CBA;
- The CBA department had its own financial controllers.

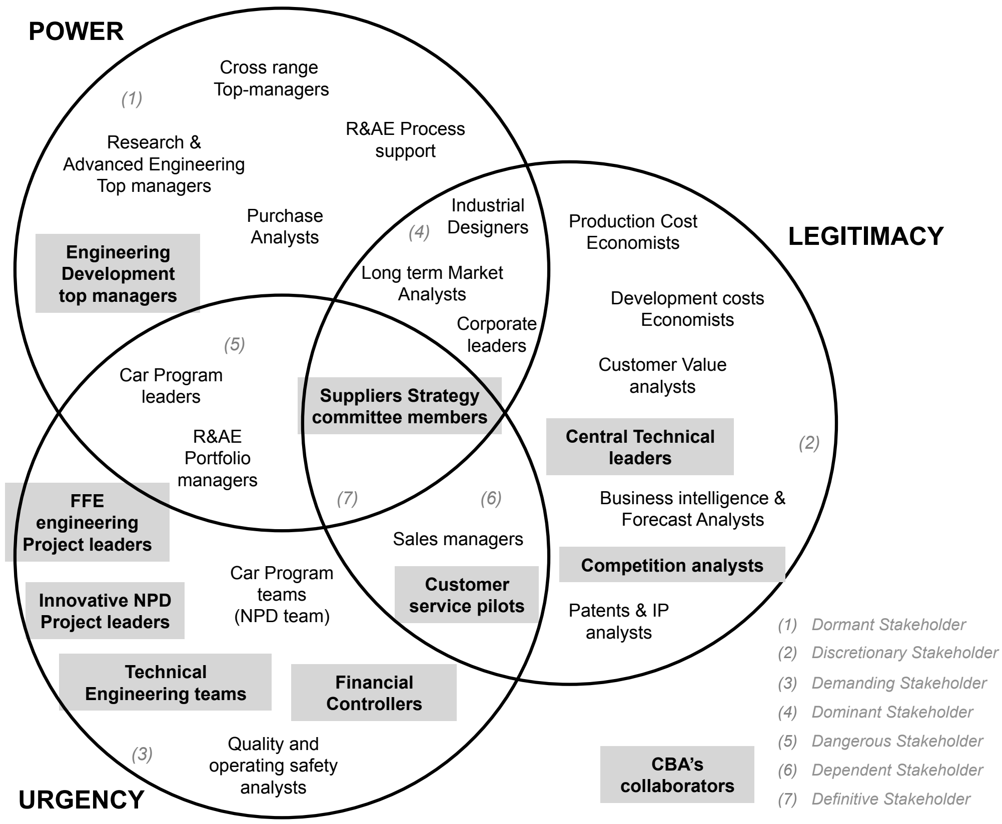

Figure 1: Map of Internal stakeholders of breakthrough R&D projects of the automotive firm (Analytical framework from Mitchell et al, 1997)

Understanding the characteristics of the relevant stakeholders for breakthrough R&D projects

Beyond the mapping of stakeholders' attributes, the exercise generated a fruitful discussion on the expected role of each stakeholder in breakthrough R&D projects, inside and outside the decision-making process, because the mapping underlines disparities in the stakeholders' origin of rights and duties and statuses. This part of the analysis, specific to each project, allowed us to characterize the relevancy of stakeholders according to the framework of spokesperson / experts & knowers / innovative design strategist. For example, as part of automotive projects, the internal stakeholder network included few counterparts of the other firms of the automotive industry, but internal representatives of external stakeholders appeared spread across the firm according to the stake of the external stakeholder that they represented. Thus, members of development teams could express the technical interests of a supplier for technical stakes, while a member of the Purchasing Department would be the spokesperson of the financial requirements and supplier contract.

Thus, the in-depth analysis of the stakeholder's interactions allowed us to highlight the precise characteristics of the relevant players and the players' impacts on the progress of and decision concerning industrial deployment of the innovative product, process or service.

Knowers and experts: This group included holders of design skills and knowledge from fuzzy front-end to new development and validation within the company and active members of many professional networks; they individually and collectively had the technical and business ability to implement the project. As individuals, they largely contributed to the progress of the project. Beyond their personal contribution, they were the only individuals who were able to precisely describe the engineering efforts needed to achieve the breakthrough R&D project. Thus, they were the first to detect when specific knowledge was missing, and due to their experience with car design, they were able to identify other knowers needed for the project. Their membership was essential to convincing the adapted engineering teams to become involved, even if their contributions had not been budgeted, and to contribute to the design of the innovative product, service or industrial process.

Spokespersons: The following three major types of efficient mediators were underlined by project leaders and managers: the experienced engineering managers and expert leaders, who argued about the technical feasibility of innovation and their impact on the firm's competitive engineering capability; the long term market analysts, who represented the end customers throughout the design cycle and were in charge of the definition of the Vehicles Programs' contents in terms of customers' benefits; and sales managers, who demonstrated that the car market expected innovation. Their combined rationales were essential to building and disseminating the value of the innovation projects for the firm throughout the stakeholders' network. They translated the business potential of the innovation into the context of the firm, and they demonstrated their legitimacy in the firm's strategy, either in terms of long-term business or innovation capability.

Innovative design strategists: Project leaders and R&AE managers described two types of innovative design strategists, short-term and long-term strategists. On the one hand, members of suppliers strategy committees and car program leaders were able to illustrate, through design metaphors, their expectations for the next cars of the range. To produce the framing, they combined their vision with sales managers' feedback on customers' needs, innovation trends within the suppliers' spheres and worldwide car offers. One the other hand, R&AE portfolio managers and cross-range top managers produced more conceptual design metaphors for a long-term innovation strategy. They combined their vision with corporate strategy and the data provided by business intelligence and forecast analysts on worldwide mobility.

Across these categories, top managers of engineering departments and car program leaders were highlighted as compulsory stakeholders. Owners of the resources of design partners and the final decision of innovation application in a vehicle, they individually and collectively determined the life or death of the project. All these managers were senior executives of the automotive industry and collaborators of the firm for a long time. They had been selected for the managerial role because they were undoubtedly car design experts but were not systematically relevant stakeholders for breakthrough R&D projects, especially because they were experts of the car industry's dominant design. Facing the substantial pressure of resources allocation and large personal risks in the case of a car program's failure, they were largely averse to the risk exposure embedded in breakthrough R&D projects. Nevertheless, if they supported an R&D project, they could become the best relevant stakeholders because they could gather the skills of a knower, a spokesperson and an innovative design strategist. Their membership allowed the firm to create the context conditions to develop and commercialize an innovative product. Allied to innovative design strategists, their combined powerful positions in the organization oriented and guided the innovation strategies to implement a sustainable strategic vision for the company through the consistent deployment of new products in the range and time through the optimum allocation of resources.

Focus on design partners: Quantitative analysis of resources involvement of Fuzzy Front-End and innovative NPD engineering stakeholders

Repeatedly, project leaders underlined the commitment of competent engineering resources at the right time as the main issue in the management of breakthrough R&D projects. As engineering sub-departments held technical resources, projects were carried out in cooperation with several parts of the organization that had the knowledge and know-how to complete those of the Research and Advanced Engineering project team. The main barrier concerned the expertise held by resources outside the organizational perimeter of the R&AE sub-department. As the R&AE department steered the innovation projects portfolio, R&AE engineers were managed by the same top managers, and resources allocation was easier to commit in breakthrough R&D projects. By contrast, industrial engineering teams did not have the same managers. Project leaders claimed that the most difficult stakeholders to involve were car development experts, such as those in the CBA department, who were both crucial for the success of breakthrough innovation transfer to commercial development programs and extremely constrained by the short-term needs of ongoing development car programs. Project leaders often stated that resources of development engineering dedicated to breakthrough R&D were under-consumed due to the massive disengagement of technical organization areas. According to them, divergences between the forecast scenarios (budget and quarterly reforecasting) and effective resources consumption were strong and repeated across projects. In interviews, they were likely to attribute these variations to the contributory department's (which we refer to as design partners) lack of resources commitment to innovation activity, while decision makers supported the hypothesis of an intrinsic difficulty of innovation related to the hazards of breakthrough R&D design, which often lead to re-scheduling the most costly actions (tests, prototypes).

To quantify the real involvement of design partners in breakthrough R&D projects, we made a detailed analysis of the firm's accounting data. Similar to all the other activities of the firm, R&AE projects had management control of the use of human and financial resources. Thus, all design partners had to enter the following information into the company's accounting system: the number of hours that they had planned to devote to the project during the budget construction and then, month by month and individually, the time that they had actually spent on the activity. Analyzing these data monthly, the network of expertise sought by each project could be quantitatively rebuilt given that the accounting database informed us of the hierarchical engineering sector of the designer and the intensity of his collaboration and the diversity of the organizational areas involved. With these data, we were able to construct engineering stakeholders' network of engineering according to:

- The evolution of project weight in total costs and effective divergence with forecasts;
- The expense distribution in the company following the technical maturity of projects (FFE or innovative NPD maturity);
- The internal skills involved (technical cross-organizational network).

Therefore, we were able to reconstruct the engineering life of the projects that we analyzed. We were particularly interested in differential accounting transactions, as they traced the difficulties of budgeting, engagement and disengagement of the players in correlation with the process of identification and commitment of internal stakeholders.

Accounting sources also contained data related to purchases associated with projects, which allowed us to test the managers' hypothesis. Breakthrough R&D purchases were of the following types: prototypes, study contracts or subcontracting (simulations, specialized engineering, research laboratories, etc.). The cost of prototypes provided information about the maturity level of the project, while contracts spending allowed us to reconstruct the network outside the company that was mobilized by the innovation project team.

Traditionally, this information was delivered through the hierarchical levels of the organization. However, after three months of screening these two sources per breakthrough activity, i.e., at the end of 2006, we consolidated the data and provided it to all R&AE project leaders and portfolio managers on a monthly basis since January 2007. The information that was obtained by the new monitoring tool was discussed with them and management controllers.

First, accounting data consolidation resulted in a quantitative picture of characteristics of the stakeholders of the engineering of breakthrough R&D projects, their weight in the investment and their place in the organization. The deployment of a tool for analysis of resources allocated among the various partners committed to a design project led to a short loop visibility of the movement of disengagement or over-commitment of the sectors.

Then, each accounting entry on a breakthrough R&D project was classified according to the deviance it presented between the budget and the effective consumption of resources. When the difference was less than 50% of the forecasts, we labeled it as limited deviation, and when it was more than 50%, it was labeled as a strong deviation. If it was negative, it confirmed the disengagement claimed by project leaders. If it was positive and it appeared few times, it demonstrated an over-commitment of engineering department not mentioned by project leaders. We also found entries without links to forecast whether the allocated resources had not been spent or, conversely, resources had been consumed without being forecasted. Table 3 synthesizes the effective percentage of organizational areas that had divergences between the budget and effective costs in 2007.

Table 3: Quantitative analysis of the criticality of deviations of accounting transactions

		Maturity stage of breakthrough R&D	
		Fuzzy Front-end	Innovative NPD
% of organizational areas involved in **Disengagement**	Limited*	5,2	15,3
	Strong**	3,4	16,7
	Complete	5,4	24,1
	Total	**14 %**	**56,1 %**
% of organizational areas involved in **Over-commitment**	Limited*	2,7	7,5
	Strong**	2,4	6,8
	Complete	3,1	7,5
	Total	**8,1 %**	**21,8 %**

*Limited deviation (Less than 50 % of the budget), **Strong deviation (More than 50% of the budget)

Quantitative analysis confirmed the R&AE project leaders' intuition concerning the massive withdrawal of engineering resources. The under-consumption of resources was particularly strong when R&AE projects were in the innovative NPD stage, where the lack of the resources expected had exceeded 40% of strong or complete disengagement. Undoubtedly, the uncertain nature of the breakthrough R&D projects could be at the origin of divergences between forecast scenarios and the actual need of design teams, but the top-managers' hypothesis appeared insufficient to explain why such a high percentage of organizational areas were consistently downward. The quantitative analysis allowed us to understand why the leaders' and managers' views differed. Specifically, the non-consumption of resources, although massive in the innovative NPD stage, was partially offset by an over-commitment to other activities and diluted by the equilibrium in FFE engineering. As the accounting information that was given to top managers was consolidated at the portfolio level, the joint balance phenomena hid the range of disengagement in the specific phase of innovative NPD. Consequently, they had the information concerning the partial under-consumption of resources (approximately 20% at the R&AE portfolio level), but they mostly were discovering the heterogeneity and the strength of accounting divergences at the project level. For many of the top managers, the existence of strong over-commitment, even complete (i.e., without having been budgeted), in nearly 20% of the projects in the R&AE portfolio was a surprise.

A focus on the 8 R&AE projects realized with the CBA department helped to clarify the phenomenon from an internal R&D stakeholders' perspective. Table 4 details the divergences between the forecast scenario of the budget that was planned in 2006 and the effective expenses in 2007.

Four main reasons for deviations were highlighted, as follows:

- Punctual contribution of very specific individuals for an unforeseen need of competence (typically, highly specific expertise or technical skills such as calculus), as in projects A, B, D and F. Knowers and experts involved in the project played a crucial in establishing the prompt commitment of the needed individuals;
- Transfer of resource to another design partner whose skills and knowledge were needed to maintain the efficient progress of the project, as in projects D, E, and F. Innovative design strategists were the major players in obtaining the commitment of new organizational areas during the year and pushing their rapid formalization in quarterly forecast updates;
- Positive alignment of design partners that collectively increased their consumption of resources for the project, as in projects C, E, and G. This phenomenon appeared when the entire network of engineering stakeholders placed trust in the industrial competitiveness of the innovation and its viability within the firm's industrial development process.

Consequently, both spokespersons and innovation design strategists played an active role;

- Negative alignment of design partners that collectively decreased their allocation of resources to the project, as in projects D, H, and I. This rejection of the project occurred as soon as one of the design players expressed his fears about the viability of the project within the company. If the R&AE team and relevant stakeholders did not succeed in reversing this feeling quickly, engineering stakeholders largely retracted their resources and reallocated them for other activities with better chances of achievement.

The first two types of deviations operated without largely disturbing the forecasted annual investment in the R&AE project; the two other social mechanisms were at the origin of the deeper deviations.

Table 4. Focus on the sub-engineering department of Assembly & Paint Body

Maturity / Innovation Type	Projects	Weight of the project (k€ of costs)	Weight of CBA in forecast (% of budget)	Weight of CBA in expenses (% of costs)	Deviation between forecast and expenses (%)		Stakeholders' explanation on divergence of resources allocation
					Engineering stakeholders	CBA	
FFE-Expertise	A	285	0	1	-63,4**	1	Solicitation of the entity during the year. The project was in a technical lock-in and asked for the help of a specific technical expert. As none satisfactory solution emerged, most engineering stakeholders re-allocated their resources to other activities.
	B	1045	0	1	-3,1	1	Solicitation of the entity during the year. The project needed a specific technical calculus to validate a hypothesis.
NPD-Expertise	C	1 130	9,1	31	25,8*	327,9**	Strong Over-commitment. Transfer to industrial development started earlier than expected, which accelerated the involvement of CBA resources
	D	306	100	77,6	0,4	-22,4*	Limited disengagement to transfer resources to another organizational area. Facing a specific technical lock-in that could be solved by the experts of another organizational areas, some resources had been transfer to them at the middle of the year.
	E	4 750	100	100	21,4*	21,4*	Limited over commitment but important in financial amount. Strategic project of renewing manufacturing system. Relying on promising results of first 2007 quarter, resources from other activities had been re-allocated to the project during the year to reinforce the assembly team.
FFE-Product	F	197	100	97,8	1	-1,2	Weak disengagement to transfer resources to another organizational area for a specific material analysis by the relevant test team.
	G	13	0	100	100**	100**	Start of the project during the year. The R&AE project was launched at the last quarter of 2007 to solve a technical issue that emerged on a car program.
NPD-Product	H	243	20,6	3,8	-69,9**	-94,3**	Alignment in disengagement. None car program manager declared to want this innovation for his/ her program. Facing a high risk to never been transferred to industrial development, the project loosed quickly its design partners.
	I	91	13,6	0	-72,2**	-100**	Alignment in disengagement. Supplier strategic committee stated that a leading supplier had proposed a similar but less expensive innovation. The R&AE team did not succeed to convince engineering stakeholders of the specific value of their proposals. Engineering teams stopped to contribute to the project in few weeks.

*Limited deviation (Less than 50 % of the budget), **Strong deviation (More than 50% of the budget)

Discussion: what indicates relevancy in the management of internal R&D stakeholders?

The analyses of the organizational study with the internal stakeholders' map (cf. Figure 1) and the accounting study (cf. Table 3 and Table 4) both provided us with fertile background to discuss, qualitatively and quantitatively, our research question concerning stakeholders' relevancy for breakthrough R&D projects.

Stable organizational network within relevant stakeholders dynamically commit individuals

The literature underlines the necessity to identify and involve key NPD stakeholders as early as possible; this process is implicitly considered as achievable by fuzzy front-end and innovative NPD actors. Yet, in the case of disruptive innovations, the degree of unknown about efficient technical contents and competitive business models could be quite high at the beginning of the project. Thus, the progress is fully unpredictable during the first steps of fuzzy front-end. These unknown influences were described by Pich, Loch and de Meyer (2002) as *"Unknown unknowns"* in contrast to *"known unknown"*, which are uncertain but identified dimensions. When these *"Unk Unks"* affect the progress of a breakthrough R&D project, new internal stakeholders may be needed, as was the case for projects A, B, D and F, but new affected actors could also emerge as detractors of the project. Thus, the current study confirmed the dynamics of the network of internal R&D stakeholders that were previously underlined by Mitchell et al. (97) and Elias et al. (2002). Our stakeholders mapping analysis further demonstrated that dynamics primarily operate on the role played by relevant stakeholders — the knowers, the spokespersons and innovative design strategists — rather than on the organizational areas of the stakeholders, which previously remained stable from one project to another (Fig. 1). Indeed, at the beginning of an R&AE project, the following essential actors were needed to make the project launch decision: the owners of resources for fuzzy front-end engineering, R&AE portfolio managers and long-term market analysts. Beyond this first round, a brief analysis of the dominant design dimensions that the project targeted, according to the incomplete innovative goals (Pich, Loch and de Meyer, 2002), allowed us to identify a preliminary set of internal actors that could affect or be affected by the project's achievement. To identify the organizational areas of these stakeholders, front-end actors rely on the organizational segmentation that is typically based on routine development activities and remain stable over the years (Dosi, 88; Henderson & Clark, 1990). The case study underlined that relevant stakeholders played a crucial role in filling the gap between the organizational identification and the involvement of a specific actor. Specifically, experts and innovation design strategists identified individuals, and spokespersons played an active role in obtaining these individuals' commitment to the value definition process.

Moreover, the organizational segmentation must be *a priori* inappropriate to represent the network of internal stakeholders of a breakthrough R&D project precisely because it is the structural transcription of the dominant design that the project seeks to disturb. A successful achievement of a breakthrough R&D project must assume that the entire stakeholders network adopted the new design rules. If the stakeholder network remains stable, as in our case study, the intrusiveness of the innovation project is limited by a core-rigidity at the managerial-level systems (Leonard-Barton, 1992). However, breakthrough innovations exist in large firms, and our case study gathered information about successful experiences of intrusive innovation. Inadequate organization did not impair innovation deployment. One plausible explanation for the ability of firms to overcome a flawed organizational structure is that a set of relevant stakeholders can generate an ephemeral organization to support the innovation project progress through the involvement of appropriate NPD stakeholders with specific skills or knowledge independent of their organizational areas. In our case study, the ability to shift from the dominant design stakeholders network to the breakthrough R&D network was correlated with the technical expertise and business mastery of the dominant design from the first network members mobilized by the project team.

Waves of engagement generated by relevant stakeholders

Analyzing resources consumption for R&AE projects, we found that the effect of the innovative design advancement on NPD organization was similar to waves. Experts that were close to technical lock-in were quickly identified and strongly involved in resources, as the design rules could be largely improve by learning about new solutions, while distant experts were more weakly and later affected.

The detailed tracking of accounting data showed that strength and temporality of the breakthrough R&D project impact could potentially follow propagation logic other than the functional division of the organization. Stakeholders who were identified by an organizational analysis as key actors could be weakly impacted, but we observed that they became relevant stakeholders when they were able to convey useful knowledge to potentially heavily affected actors inside their organization. This deferred identification appeared clearly in the accounting analysis, as some organizational areas left the design activity and were replaced by others. As the speed of the allocation transfer quickened, the relevant stakeholders became more efficient, and we found a correlation between the velocity of the waves and the stakeholders' proficiency in the skills and knowledge content according to the organization of the dominant design. This results leads us to highlight the correlation of the ability to shift from the dominant design stakeholders network to a breakthrough R&D network with the technical expertise of the dominant design of the relevant stakeholders, whether they were Knowers, Spokespersons or Innovation design strategist. They appeared to be able to create strong alignment of the entire network of design partners, with a positive or negative impact on the project, as they knew the information concerning project potential or risks to disseminate in the network to speed up or obstruct the activity.

Conclusion

Facing the issue of establishing sustainable learning dynamics and design partnerships across the R&AE and Industrial development parts of the organization (O'Connor, 2008), project leaders and managers of breakthrough R&D projects must develop an efficient system of managing internal R&D stakeholders (Elias et al., 2002). Our research shows that a stakeholder network in a large industrial firm could be organizationally persistent without inducing the lock-in of innovation capability. Nevertheless, dynamics are numerous and large within the network. First, the roles played by key stakeholders within this cartography shift, and some of the stakeholders, as knowers, spokespersons and innovation design strategists, contribute more than others. Second, engineering resources follow contrasted dynamics of over-commitment or massive dis-engagement within the internal stakeholder network that are hidden by reporting at the portfolio level.

Beyond technical stakes and the major role played by engineering stakeholders, in our case study, knowers, spokespersons and innovative design strategists went beyond support of the project's progress. Their impacts appeared more similar to internal business angels of breakthrough R&D that operate in combination with an intrapreneur (Kelley and Lee, 2010; Borjesson et al, 2014) or architectural manager of the new design rules (Baldwin and Clark, 2000). Thus, the mastery of dominant design seems to be one way to build and maintain an efficient capability for innovation, but it is not the only method. This result needs to be further investigated and deepened in future research. Moreover, the research opens new directions for accounting management adapted to major innovation projects and new accounting tools.

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