Testing whether major innovation capabilities are systemic design capabilities: analyzing rule-renewal design capabilities in a case-control study of historical new business developments

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Track 37.1

Abstract: *In this paper, we empirically test the proposition that major innovation (MI) capabilities are systemic, dynamic capabilities. We rely on design theories and characterize the systemic, dynamic capabilities as design capabilities that renew a core of stabilized design rules.*

For the specific case of projects leading to new business development, we conducted a case-control study of 46 historical projects; 26 of these led to new business development, and 20 do not lead to new business development. Utilizing this sample, we show that our measurement model, based on rule-reuse vs. rule-renewal design capabilities, has a good fit. We find that rule-renewal design capabilities are positively related to new business development, whereas rule-reuse design capabilities (maintaining an invariant set of design rules) are independent of new business development. We discuss different combinations of rule-reuse and rule-renewal design capabilities.

This paper contributes to the literature on MI capabilities. It also theoretically and methodologically contributes to the analysis of the dynamic capabilities of design activities.

Keywords: major innovation, design capabilities, renewal design capabilities, history, project management principles

1- Introduction

In her 2008 groundbreaking paper, Gina Collerelli O'Connor proposed that major innovation capabilities should be considered as dynamic capabilities and should be analyzed in a "systems approach" (O'Connor 2008). This proposition resulted from in-depth empirical case studies (O'Connor and DeMartino 2006) and suggested that a specific set of "routines" – so-called "transformational routines" (O'Connor 2012) – determine major innovation, whereas non-transformational routines are not related to major innovation. Based on the most recent design theories, transformational routines may be analyzed as design capabilities that contribute to renew an invariant core of product development rules, whereas non-transformational routines are design capabilities that contribute to preserve a core of invariant product development rules. As we will show below, this proposition generalizes many previous studies on "major" innovation management. It is also deeply consistent with most recent formal models of innovative design reasoning that offer a theoretical foundation for major innovation activities. However, there has been no empirical, statistical testing of the propositions. That is the aim of this paper.

In the first section, we present the theoretical framework that grounds our hypotheses and builds our analytical criteria. In the second section, we detail our methodology that is based on the analysis of project management principles and their effect on new business creation. We build a case-control study of 46 historical projects; of these, 26 led to new business development and 20 did not lead to new business development. Using this sample, we show that our measurement model has a good fit; we test that the "preservation" design capabilities are independent of new business development, whereas renewal design capabilities are positively related to new business development. In the third section, we discuss different combinations of renewal and preservation in our sample. We conclude with the managerial implications of this work.

2- Research background, research hypotheses and methodological issues

2.1 Major innovation capabilities in light of design theory

Major innovation and dynamic capabilities. After many debates about the definitions of innovation (radical (Leifer et al. 2000), disruptive (Christensen 1996), really new (Garcia and Calantone 2002), etc.), major innovation was proposed to characterize forms of innovation with high uncertainty over multiple dimensions (market or technology) that transform existing markets or industries or create new ones that require approaches that differ from those used in incremental innovation (O'Connor 2008).

For O'Connor (2008), the capabilities required for major innovation are dynamic capabilities, i.e., "*strategic and organizational processes that create value for firms within dynamic markets by manipulating resources into new value-creating strategies*" (Eisenhardt and Martin 2000). In the case of MI, these dynamic capabilities are specified in terms of process and are linked to "structural, cultural, skill-set and strategic elements" (p. 317), i.e., they can only be understood in a "system approach" that characterizes the MI "management system" (O'Connor 2008). O'Connor (2008) then builds on the notion of "system" to propose that the following seven elements characterize "MI dynamic capabilities": 1) a clearly identified organizational structure, 2) internal and external interface mechanisms, 3) exploratory processes, 4) requisite skills, 5) appropriate governance and decision-making mechanisms and criteria, 6) appropriate metrics, and 7) a cultural and leadership context. Thus, dynamic capabilities extend beyond repeatable processes and can be identified as more complex activities. However, they are difficult to observe because each part must be analyzed in relation to the other parts and in relation to the entire system.

Design activity and design theory. To overcome this difficulty, another way to analyze "systems" is to characterize the logic of their actions (Hatchuel 2005). This will also help to clarify certain terminology linked with "dynamic capabilities"; dynamic capabilities seem to lead to certain forms of contradiction because they require routines, i.e., "codifiable, repeatable and generalizable processes", and routines are often thought to breed inertia (Hannan and Freeman 1989; King and Tucci 2002) unless there are certain routines that preserve ongoing change process "on a higher order" (Benner and Tushman 2003; Winter 2000). However, how do these "higher order" routines avoid inertia themselves? The difficulty emerges from the models implicitly used for describing rule emergence; these figures of speech are linked to the *decision making* paradigm used to characterize the firm – be it behavioral (Cyert and March 1963), rational or bounded rational – routines facilitate or constrain decision making, they "enlighten" the (possibly bounded) rational choice or they constrain the actors who are merely effort optimizers and tend to re-use the routines they already know that have been effective in the past (March et al. 2000). The decision-making paradigm discusses the forms, constraints and effectiveness of choices, but it tends to oversee or simplify the logic of *rule emergence*, which is often assimilated in the natural process of mutation and selection. In this model, only strange mutations and adaptations to external conditions can explain the renewal of rules. Dynamic capabilities are thus described as "routines" that "control" mutations and adaptations – but what controls the mutations and adaptations of these higher order routines?

By contrast, MI consists actually of *creating* new products (services) and new competencies, new markets and new meaning – it corresponds to a *design* logic (Hatchuel 2005; Hatchuel et al. 2010), and it might be easier to analyze MI in a design paradigm. Indeed, recent advances in Design Theory have helped clarify the critical relations between decision making and design (Hatchuel et al. 2012). Decision making consists of adopting one rule from a set of possible rules according to a set of known criteria (e.g., problem solving (Simon 1979), statistical decision making under uncertainty (Wald 1950; Raïffa 1968), psychological bias in decision making (Kahneman and Tversky 1979), behavioral decision making, etc.), whereas design consists of *creating new rules* to create a new object that partially meets known criteria and that is unknown at the beginning of the process (Yoshikawa 1989; Shai and Reich 2004; Hatchuel and Weil 2009). It is important to note that "unknown" means more than "ill-defined" or "wicked" problems (Schön 1990). It does not indicate that the object is here but cannot be identified; instead, it indicates that certain attributes characterizing the object cannot be articulated at the beginning of the process, such as a "hypersonic and environment friendly aircraft". Likewise, "unknown" is not uncertain; uncertainty is characterized by a probability space in which the events are known, but its probability of occurrence makes it uncertain. For instance, tomorrow's weather is uncertain. By contrast, unknown means that certain attributes of the object are unknown; the forms that extra-terrestrial life might take are unknown. As a consequence, there can be some decision in design and design in decision but a design process cannot be assimilated into a form of decision making. Nevertheless, it has been shown that there is a form of rationality in design that is "expandable" (Hatchuel 2002). Thus, with design, we have a model of activity that *integrates the logic of rule creation* into a rational model. It also leads to modeling various forms; expandable rationality can be consequential (e.g., try to be as original as possible, try to generate as many solutions as possible, etc.) or procedural (always use identical design competences), it can maximize the explorations or minimize costs, etc.

Design capabilities. Thus, there are specific routines in design that will support or constrain the design process. For instance, recent research in cognitive science has shown the so-called *fixation effect* in design that leads designers to explore only limited areas of the unknown

(Jansson and Smith 1991). This type of bias was also identified in collective processes such as brainstorming in which social influences tend to limit the capacity of the group to explore the unknown (Paulus et al. 2002). In the design model, these biases are similar to cognitive traps in the decision-making process (re-using the same routine for every problem, which leads to suboptimal solutions); in design, the fixation consists in reusing routines that impede the generation of new alternatives. Conversely, it has been shown that collective action in design might be supported by so called "unlocking" rules that force the group to overcome the limits of fixation (Le Masson et al. 2011c). Such "unlocking rules" have been visible in artistic milieux; it has been shown that artistic or industrial design education actually consists in learning rules to "unlock" students and helping them to overcome individual or collective fixation (see, in particular, the analysis on Bauhaus teaching in (Droste 2002; Le Masson et al. 2011b)). Even engineering design might be analyzed as the development of rules to support the exploration of the unknown, as "languages of the unknown" (Le Masson and Weil 2012).
Thus, in a design perspective, the logic of rule creation is modeled as a design activity; the routines that organize activity are *design capabilities,* and these design capabilities may be capabilities for rules creation. Returning to dynamic capability for major innovation, we propose that these design capabilities can be analyzed as "high-order" capabilities supporting action. Moreover, one of the interesting outcomes of research on design theory is helpful for our work on MI. Indeed, historical and formal studies on design methods and organizations have helped to characterize two logics in design that have led to the creation of the following specific capabilities (Le Masson and Weil 2012; Kroll 2012; Reich et al. 2010; Karniel and Reich 2011):

1) On the one hand, there is the necessity to avoid too much exploration, i.e., to *stabilize the system*. In design logic, the creation of rules is the logical consequence of design activity. This is the *re-use* of existing rules that requires a specific capability[1]. Thus, to maximize certain forms of efficiency, a first set of collective design capabilities consists in identifying, preserving and reusing an invariant core of rules as much as possible. These are so-called "*rule-reuse design capabilities*", i.e., design capabilities dedicated to the preservation of a set of rules. What can the set of invariant rules consist of? Similarly, what can be predefined and will not be changed by the design process (invariant by design)? Historical models tend to list the following four main invariants to stabilize a form of "dominant design" or "non-major innovation":
    a. An invariant target: the types of customer requirements (eg "braking distance" for a car) are fixed – only the level can be changed ("less than xx meters at 100km/h); the firm avoids the development of new types of functional requirements for specific customers. This invariant corresponds to stable market representation and is often considered a market cognitive trap (see also (Christensen 1996; Govindarajan et al. 2011)), but it has also been a way to avoid unnecessary product diversity, historically.

[1] This is one of the strongest differences with an approach based on the decision-making paradigm (behavioral or rational); the model of decision making exhibits a "rational heuristic" to obtain optimal (or satisfying) decisions. The issue is choosing the best heuristic. The behavioral model underlines that people and organizations tend to use "exploitation" rules to solve problems. In a design paradigm, these tendencies are only one small part of all the "reuse" strategy; from a design point of view, even the "framing" of the design issue into a "problem" with clear and fixed goals and set constraints is a way to limit the creation of new rules because it avoids the discovery of new goals (and new constraints) during the process.

    b. Invariant competencies (re-use technical skills). This is often considered a capability cognitive trap, but it is also a strategy to avoid the unnecessary creation of competences.
    c. Invariant people resources (re-use identical people in identical networks). This may also be interpreted as an organizational cognitive trap, but it is also a strategy to avoid the (costly) creation of new networks, organizations and relationships.
    d. Invariant list of possible risks (a preconceived list of anticipated risks). There might be uncertainty, but the list of uncertain events is unchanged – only the level of uncertainty is changed. Thus, the set of tests used to evaluate the robustness of the design can be reused to avoid the development of specific robustness criteria and tests (see the notion of "known unknown" in (Sommer et al. 2008)).

In design theory, this perspective is characterized as rule-based design (Le Masson et al; 2012).

2) On the other hand, collective design may be organized to intentionally *renew* the same set of rules regularly; there are design capabilities to renew the invariant core. These are so-called "*rule-renewal design capabilities*". These capabilities can be deduced systematically; capabilities of exploring new types of specifications, capabilities of exploring new competencies, capabilities of identifying new design partners, and capabilities of identifying new types of risk. This is the logic of innovative design (ibid.). These capabilities may also be linked to the following MI capabilities that are identified by O'Connor in a systems approach:
    a. The identification of new customer specifications and the identification of risk are linked to capabilities for exploratory processes (#3) and appropriate governance and decision making mechanisms and criteria (#5).
    b. The exploration of new competencies is related to exploratory processes (#3) and requisite skills (#4).
    c. The identification of new partners related to "identified organizational structures" (#1) and "internal and external interface mechanisms" (#2).

   Notably, these criteria help to check the consistency of the "observation"; it is not necessary to exhaustively describe every aspect of "innovation organization" (an issue raised by MI dynamics identified in a system approach). Instead, an acceptable picture might be obtained by describing the capabilities contributing to evolve the set of design rules. Another remark: despite a strong convergence, there is one slight difference between the system approach and the design approach in the sense that O'Connor (2008) insists on the fact that these capabilities will contribute to "stabilize" the system (the logic of homeostasis), whereas the design framework leads to characterize capabilities that *stabilize a dynamic trajectory of the system* – a logic of intentional system change.

Therefore, in a design perspective, it is possible to analyze MI dynamic capabilities by identifying the *underlying invariant core of design rules* and the capabilities used to manage the core, whether to preserve the core (rule-reuse design capability) or to renew it (rule-renewal design capability).

2.2 Methodological issue – observing projects routines and new business development

O'Connor (2008) proposed that MI capabilities are systemic, dynamic capabilities. Based on the design perspective, systemic, dynamic capabilities are considered as rule-renewal (RN) design capabilities; and we can identify systemic non-dynamic capabilities that are rule-reuse (RR) design capabilities. Thus, the research hypothesis becomes that RN design capabilities contribute to MI, whereas MI is independent of RR design capabilities.

Testing these two research questions requires observing RR and RN design capabilities., i.e., observing the stabilized core and its evolution towards a new stabilized core. This raises at least three critical methodological issues, which are the following:

- How can design capabilities be observed? For March, rules observation should ideally be limited to written rules. For Zollo and Winter (2002), capabilities are characterized by "codifiable, repeatable, generalizable" routines; they are a "learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines".
- How can MI be measured and, in the design perspective, how can a stable core that is successful be ensured? The observation cannot be limited to one punctual success. The new stable core should actually give birth to a new business development in which the range of products is a major innovation compared to other products. Thus, there are two issues, ensuring that the range is a "major innovation" and ensuring that it relies on a new stable core.
- How will the relationship between design capabilities and MI be constructed? There must be a unit of analysis in which we can observe design capabilities and observe related changes in a core of design rules.

To meet these requirements, we rely on one specific observation method, i.e., we study projects and their relationship to new business development. We explain the advantages of this observation method (and its intrinsic limits) below.

- Observing at the level of the project helps to identify design capabilities, we are able to analyze management routines (principles and practices) of a project inside an organization. This is supported by clear project management principles that are used to organize the process; thus, there are explicit routines (codified), these routines are used consistently with the project (repeatability) and these project management principles are also considered to be valid on a broader scale (because they are the project principles of the related organization) (hence generalizability). By doing so, we miss certain types of routines discussed by O'Connor (e.g., the organization at the portfolio level or an organization managing innovative projects). There is one observation bias, which is that we identify only certain capabilities. For instance, we would oversee cases in which MI occurs through project portfolio management without any RN design capabilities at the project level. However, the bias leads to an *underestimation* of the role of RN design capabilities in MI. This is a *non-differential* bias that leads to an underestimation of the relationship. *If we prove the relationship despite the bias, the quality of the result is maintained.*
- We do not measure MI at the project level. It is accepted that MI cannot be observed at the level of one project (see longitudinal studies on major innovations: (Leifer et al. 2000; Van de Ven et al. 1999)); the consequences appear much later in other projects derived from the "innovative" one. We measure MI at the level of the stream of products and projects that can possibly be related to the initial "innovative" project (Maidique & Zirger, 1990). Thus, we observe MI as new business development (NBD).
- Thus, the project provides a clear unit of analysis. On the one hand, we observe design capabilities at the project level; on the other hand, we observe new business

development by analyzing the long-term consequences of the project inside the organization.

2.3. Research hypothesis in the observation framework

Our hypotheses were that RN design capabilities contribute to MI and that MI is independent of RR design capabilities. We will test these hypotheses in the context of project management and NBD. Notably, these hypotheses find many echoes in the literature on project management, innovation and NBD.

The literature on Project Management has long identified key capabilities that contribute to New Product Development success (see for instance the synthesis in (Brown and Eisenhardt 1995)), clear initial vision and clear problems to solve (Imai et al. 1985) (Clark and Fujimoto 1991) (Wheelwright and Clark 1992) (PMI 2004), careful planning, uncertainty front loading to avoid the late discovery of surprises, integrated teams with relevant competences and clear work divisions (Myers and Marquis 1969) (Cooper and Kleinschmidt 1987, 1993) (Zirger and Maidique 1990) (PMI 2004). These capabilities are related to the following dimensions to characterize a design core: invariant targets (a clear set of customer requirements), invariant competencies, invariant people (a stable project team, a clear work division) and an invariant set of anticipated risks. Notably, these factors are all related to organized capabilities to re-use existing design rules; thus, they are RR design capabilities. In the literature, these capabilities are not self-evidently related to new business development; by contrast, new business development requires learning, exploration, risk taking, evolving teams and commitment and dynamic competences (Van de Ven & al., 1999; O'Connor & al, 2008). These capabilities are said to contribute to optimal new product development success and limit useless learning; they focus on clear Quality-Cost-Delay targets and involve the right people to reach this well-established target. Thus, our first research hypothesis is as follows:

H1a: In Project Management, RR design capabilities may be characterized as capabilities to stabilize a target value, to efficiently use a set of given competencies, to stabilize work divisions and to address well-anticipated risks.

H1b: RR design capabilities are independent of the success of new business development.

The literature on innovation and project management helps identify another set of critical capabilities for the successful management of exploratory projects, and these design capabilities may be analyzed according to the following dimensions of the invariant core of design rules (i.e., invariant list of anticipated risk, invariant competence, invariant people, and invariant targets):

1- Beyond the logic of robustness of a set of anticipated risks, innovative projects must prepare for unforeseeable uncertainties (or unknown unknowns) (Loch et al. 2006; Sommer et al. 2008); they can even maximize the exploration of the unknown on a certain issue, for instance identifying the options that maximize variance (Fredberg 2007; Lenfle and Loch 2010; Adner and Levinthal 2004).
2- Beyond the logic of validating well-known solutions based on identified competencies, the exploration is based on creative (but rigorous) methods that help break critical design rules, either through fuzzy front-end phases (Koen et al. 2001; Reid and De Brentani 2004), systematic investigations (Tidd et al. 1997; Verganti 2008) or strongly deviant explorations (frequently described as "moon-landing" initiatives), to *let* be surprised by the results in an organized "reflexive" way (Schön 1990; Le Masson et al. 2011a; Sutton and Hargadon 1996; McGrath 2001).

3- Beyond an integrated team with clear work divisions, the innovation project team is also able to connect, involve and commit relevant stakeholders over time (Akrich et al. 2002; Van de Ven et al. 1999) or even create a disruptive community in its ecosystem that will support the development of the entire business (Le Masson et al. 2011c).
4- Beyond a clear list of requirements and well-defined specifications, the innovative project might require a capacity to "make sense" of different value perspectives (Thiry 2001) or even require a value management (Hatchuel et al. 2005) (Gillier and Hooge 2012) that manages multiple, interdependent exploration alternatives to create multiple and varied types of values (Elmquist and Le Masson 2009; Loch et al. 2006; Van de Ven et al. 1999).

These are RN design capabilities, and they are related to successful NBD. Thus, the second hypothesis is as follows:

H2a: In Project Management, RN design capabilities can be characterized as capabilities to address the unknown (or unforeseeable uncertainties), to break design rules and acquire competencies, to modify team composition and project stakeholders and to explore and create new target values.

H2b: RN design capabilities positively affect the success of new business development.

If H1 and H2 are true, this raises an interesting problem because we should find successful projects that combine rule-renewal design capabilities and rule-reuse design capabilities. How can these capabilities be combined? The literature on ambidextrous organizations has long predicted this phenomenon (Duncan 1976; Tushman et al. 1997). Research on project management analyzed it at the level of projects and suggested a large variety of organizational forms (Shenhar 2001; Shenhar and Dvir 2007; Pich et al. 2002; Lenfle and Loch 2010). Our study confirms this variety. This will be our third research question.

3- Research methodology and empirical material: a case-control study on 46 well-documented historical cases

To test these hypotheses, we require rich empirical data on the project itself to analyze the management dimensions discussed above (risk management, learning strategy, value management and organization) and we must perform long-term analyses of new business creation. Thus, following (Kieser 1994; Pettigrew 1990), we favor historical data. Historical data have previously been used on single innovative projects (Lenfle and Loch 2010; Lenfle 2011). In this paper, we attempt to generalize these single case results to a large sample of 46 well-documented historical cases.
We conducted a case-control study, with 26 cases that led to new business development and 20 control cases (projects without new business development). This method has good statistical power because cohort studies, with which the case-control method is often contrasted, must wait for a 'sufficient' number of 'case' events (new business development) to accrue, which would have been costly in our situation.

3.1. Case selection;
We selected 26 historical cases, in which there was detailed written material available, and in which each case combined two critical features: there was a recognized development of a new business, and this new business development was associated with a project. We selected twenty control cases in which there was a project that did not lead to new business development.

To assess the existence of a project was easy because the authors of the cases themselves discussed it clearly.
To assess the "new business development" variable, we used two criteria. First, we researched where there are "descendants" of the initial project, i.e., products/services sharing similar functions, technologies and architectures. For instance, the initial nylon stockings were followed by several derivatives that built a family of product that shared common values (robust, light, fashionable,…) and common technologies (the nylon fiber and its associated technologies) that progressively built a dominant design (Abernathy and Utterback 1978), with regular improvements. In each case, we analyze whether a "lineage" of products and competencies emerges after the initial proposal. The second criteria is an organizational one: we check whether the new business is associated with a new business unit or even with new department in the organization. In the case of nylons, a new department emerged, in charge of polymer products, and the new corporate research lab acquired such a strong legitimacy that it became institutionalized in the Du Pont organization.
In practice, the three authors assess independently the variables, following a classic 5-level Likert scale (from -2 – strong disagree- to + 2 –strongly agree) (see detailed questions and assessment criteria in appendix).
Notably, these criteria led us to skip one case, Apollo. We initially selected Apollo as a relevant case because of the apparently high legacy of the project (from Apollo 1 to Apollo 17). However, careful investigations led us to consider that there were only few missions that followed the success of Apollo 11, and these were all mainly a copy of the first one (except for the Lunar Rover) with no improvement and with no logic of business growth through improvement and variety. Moreover, there were limited transfers from the Apollo project to later NASA projects (in particular, historians report that Apollo had no effect on the Shuttle projects). For this reason, we did not consider Apollo a relevant case of new business development.

The above-mentioned criteria helped to address one critical issue when relying on historical cases, i.e., how long should one wait before one considers a case as relevant? Should one fix a standard duration (e.g., "more than twenty years")? We prefer to consider that the relevant duration was created by the product development time specific to the lineage in question, e.g., for automotive innovation, innovations such as telematic services or athermic windshields are likely to be implemented for each new car development project launched by the car manufacturer, i.e., typically, one or two per year. Thus, after a couple of years, it is possible to know whether a lineage is installed or not. For this reason, we use relatively contemporary cases, such as Tefal or PSA because it is possible to assess lineage success.
Based on identical criteria, we selected the control cases. We found the control cases in historical books. To ensure that these cases were not at the origin of a lineage of products, we used the same historical logic of following the long term. Moreover, from time to time, we were able to identify cases that were actually inside a lineage created by one of our "new business development" cases (see Saint-Gobain windshields) or in the same organization (see, for instance, the Poseidon and Trident cases). We also relied on studies such as (Clark and Fujimoto 1991), which are powerful syntheses of several project management cases.

In such a process, we had to assure observer objectivity. In quantitative studies based on questionnaires, it is common to separate either the people making the study and the one making the analysis or to separate the questionnaire into two parts – one on the dependent variables and the other on the independent variables – and administered by two different persons (e.g., (Lichtenthaler 2009)). These methods are typically used because the results depend almost solely on the data gathered through the questionnaire, and the issue is typically

to triangulate the data with other sources. In our case, we could strongly triangulate because we rely on much richer material than interviews because we could use complete history written by expert historians or in-depth and comprehensive case studies. Thus, for each data point, we had access to a quantity and quality of data that often far exceeded that gleaned from typical questionnaires.
Conversely, qualitative study recommends separating data gathering and coding, on the one hand, and data analysis, on the other (Yin 2003) (see for instance (Santos and Eisenhardt 2009)). We were able to follow this recommendation because we separated the data gathered by the case historians from the analysis we performed. Moreover, the historical data we use are all published in English so that the reader can refer to the primary material if he wishes.
The list of cases and the published references are given in table 1 in the appendix.

3.2 Project management descriptors

For each case, we analyzed the RN and RR design capabilities of the project management, according to the main variables identified in the literature review provided above. We describe each as grouped into the following four classical organizational dimensions corresponding to the four dimensions of an invariant core of design rules: managing risks (invariant set of anticipated risk), managing learning (invariant competencies), managing a team (invariant people), and managing target value (invariant target type). We detail below these descriptors. In italics, we write the assessment to be accepted or rejected by analyzing the case. The descriptors are not mutually exclusive (for instance, in case of learning, some parts of the project can be based on validation, whereas other parts may be exploratory; see Lenfle & Loch, 2010).

1- Process organization for managing risk (invariant anticipated risks).

1. *Organize a planned process that is robust to a set of anticipated external events (technological and market uncertainties); in the case of surprise, it should react and continue to meet the target.* This is the classical project robustness criteria. For instance, in the case of the F117-Stealth Fighter at Lockheed skunkworks, the authors state, "evidence of good contingency planning […] included actions taken to recover from […]". (p. 162) (Rich and Janos 1994).
2. *The project prepares for unforeseeable uncertainties (unk unk) and/or the project organizes to increase the variety of options.*
   The first part of the proposal refers to criteria introduced by Loch et al. (2001; 2006). It takes the form of a sophisticated sequential and parallel testing of different solutions. The Manhattan Project clearly exhibits this feature (Lenfle and Loch 2010).
   The second part of the sentence refers to the fact that, in the logic of real option pricing, the value of innovative projects increased with the variety of technological and market scenarios they might address such that risk management consisted in exploring the largest technological and market span (and not merely the most "feasible" and "marketable" alternatives) (O'Connor 2008; Adner and Levinthal 2004; Fredberg 2007; Lenfle and Loch 2010). The Manhattan Project also exhibits this feature because several explorations within the project did not aim at validating a technological path but did aim at exploring the technological potential opened by the path (Lenfle and Loch 2010).

The first type of risk management (RR design capabilities) is based on the fact that there is an anticipated set of risks (and risk management is based on these risks), whereas the second type of risk management (RN design capabilities) consists in preparing for unknown unknowns (unk unks) that require the creation of new rules.

2- Managing project costs and resources associated with learning (invariant competences).

1. *Project learning costs are related to tests and validation (based on existing competencies); alternatives are tested and evaluated and the most relevant (or the best) one is kept.* This approach is at the root of project planning and project-as-problem-solving (Imai et al. 1985; Clark and Fujimoto 1991; Wheelwright and Clark 1992). Edison Electric Lighting or the Polaris Missile comprised many such technological validations. Such a validation logic is possible when the technological evaluation criteria are well identified in advance (i.e., *one can identify such a list of technologies and validation criteria at the beginning of the project*).
2. *Project learning (a) uses deviant explorations to be surprised by the results of such explorations and/or (b) uses systematic, comprehensive investigations and/or (c) uses a fuzzy front-end creative phase.*
   a- The first part of the sentence refers to "reflexive" learning, which is more than serendipity in the sense that it is a *provoked* surprise (Schön 1990; Le Masson et al. 2011a; Sutton and Hargadon 1996; McGrath 2001). The polymer synthesis in Du Pont corporate research lab initially followed such logic because it was intended only to create new fibers that were never observed before without any guarantee of success.
   b- The second part of the sentence is relevant when there is an organized design of experiments that is close to a traditional "experimental research" logic (Tidd et al. 1997; Verganti 2008). Edison researched a "good" filament for incandescent lamps by following this logic and systematically trying almost all existing fibers.
   c- The third part of the sentence refers to a preliminary phase that helps to identify multiple paths, including the "moon landing" or crazy paths (Koen et al. 2001; Reid and De Brentani 2004). The Polaris Missile exhibits such a phase that further led to clear distinctions between two types of tasks, one in which a validation logic was sufficient and one in which a more exploratory logic was required.

The first type of learning (RR design capabilities) consists of validating existing routines against existing performance criteria, whereas the second learning management (RN design capabilities) consists of creating new competencies and/or new performance criteria.

3- Coordination means to manage the project team and project environment (invariant people).

1. *The project team is integrated, stable and exhibits clear work divisions. The relationship with the external environment is well codified.* (Myers and Marquis 1969; Cooper and Kleinschmidt 1987, 1993; Zirger and Maidique 1990). Serious development teams are clear examples of this type of organization (Clark & Fujimoto, 1991).
2. *The project team (a) is able to commit new (initially external) actors to its network and/or (b) is able to change its own ecosystem by motivating external actors to create knowledge and competencies to contribute to the future lineage.*
   (a) The first part of the sentence refers to the criteria of an innovation team that were introduced by Actor Network Theory (ANT) research (Akrich et al. 2002); these criteria insisted on the necessity of mobilizing external resources (suppliers, research labs, etc.) and to "translate" the project to adapt to the needs of multiple stakeholders, beyond the project customer. The Edison lighting case successfully involved new actors in the innovator network (Akrich et al. 2002) (the authors use (Hughes 1983)).
   (b) The second part of the sentence refers to a criterion in which the initial project team is "enlarged" for including new stakeholders. In this latter case, the project team only stimulates knowledge creation in the ecosystem that is likely to support the development of the new business (Le Masson et al. 2011c; Le Masson et al. 2009). For

instance, the development of the Toyota Prius pushed several actors in the ecosystem to launch multiple attempts to become competent in power-electronics and energy storage.

The first type of team management (RR design capabilities) (the first part of the sentence) requires stable rules to be able to define ex ante the people to be involved and the tasks to be assigned to each team member. By contrast, the second type of team management (RN design capabilities) (the second part of the sentence) insists on the capacity to adapt the configuration of the team (and the related network and ecosystem) to the discovery of new issues.

4- Managing target value (invariant type of target).

1. *The project target value is given by a clear list of requirements and well-defined specifications.* This helps to organize value division inside the project and project suppliers. The existence of this list of specification is typically easy to assess. For example, in the development of the F-117-Stealth, "the project was tailored to the specific needs of the program objectives" (p. 162) (Miller 1995).
2. *Project target value (a) requires "sense-making" during the project and/or (b) is created during the project.*

   (a) The first part of the sentence indicates that the value is not given at the beginning but results from the progressive aggregation of initially scattered interests (Thiry 2001); in the end, the value is unified. For example, in the Edison Lighting project, the value of light, compared to gas lighting, was only progressively identified. In the Manhattan Project, the true value of the multiple technological alternatives were identified only late in the process after the multiple technological alternatives began to be combined (Lenfle 2011).

   (b) Contrary to the first part of the sentence, in which the value was present but is identified and aggregated during the process, the second part considers that some value is designated during the process, with the logical consequence that there are often multiple, contrasted and even contradictory values that are created during the process and that only one is embodied in the final project. (Van de Ven et al. 1999; Hatchuel et al. 2005; Gillier and Hooge 2012; Elmquist and Le Masson 2009; Loch et al. 2006). For instance, the Toyota Prius project revealed that hybrid engines could be related to a new type of "fun driving" instead of only the fuel consumption reduction. This further led to the development of hybrids for 4-wheee drive cars that have high average fuel consumption.

The first type of value management is based on target values fixed exogenously and that remain stable during the project (RR design capabilities). The project is not in charge of exploring the value itself. The second type of value management is based on the exploration of new values during the project (RN design capabilities).

In the independent variables that describe managerial actions to manage a project, one can distinguish RR design capabilities that are based on fixed design rules (1.1, 2.1, 3.1, 4.1) (realizing existing lists of specifications (while remaining robust to well-identified risks), learning through empirical testing and organizing an integrated, stable project team with clear work divisions), whereas the other set of variables corresponds to RN design capabilities.

For each case, we check the success of new business development with the two indicators below:

A- Lineages. *There is a family of products/services that is new and associated with the first project.* We provide additional indications to answer the above assessment.

   a. Criteria for newness: see criteria of O'Connor et al. for major innovation (O'Connor 2008); other indicators may be added, such as new product name (e.g., Hybrid Synergy drive in the case of Toyota Prius).
   b. Criteria for family: several derivatives with several generations (e.g., Prius models 1 to 4 and derivatives such as Lexus hybrids) and regular improvements and changes in a logic of dominant design (Abernathy and Utterback 1978).
   c. Criteria of association: The first product is used as a reference or the competencies created at the occasion of the first product are widely reused for following projects (e.g., the competencies acquired during the Manhattan Project are reused and improved in other nuclear weapons) (Maidique and Zirger 1985).

B- New organizations supporting the new family of products. *There is a new organization that contributes to the new business development.* We provide additional indications to answer the above assessment.
   a. Criteria for new organizations: new business unit, new function (invention of corporate research labs, of skunk works, etc.), that contribute significantly to the lineage of products over time and with relative stability.
   b. Criteria for newness: the organization was not here at the beginning of the project (we follow here the "misalignment" criteria of Leifer et al. (Leifer et al. 2000)).

All these criteria correspond to the existence of a (new and invariant) set of design rules.

We also add the following control variables that are often mentioned for new business development:

a- *Is there an established dominant design at the beginning of the project in the project field?* This parameter controls for the possibility that the existence of a dominant design would impede the development of new business development (lock-in effect).

b- *What is the relative size of the project organization compared to the entire organization?* This parameter controls for the fact that a project that is relatively small compared to the rest of the organization might be less likely to elicit the emergence of a new business in the organization.

3.3. Analysis

We first test the factors (the latent variables, i.e., "rule-reuse" vs. "rule-renewal" factors) through a confirmatory factorial analysis for the measurement model. We use Stata 11 with the confa package (developed by S. Kolenikov et al. (Kolenikov 2009)). To test H1 and H2, we conduct a logistic regression using two categories based on the latent variables ("rule-reuse_high" vs. "rule-reuse_low" to test H1; and "rule-renewal_high" vs. "rule-renewal_low" to test H2). We take into account the control variables. It appeared that a SEM was not necessary – the "case-control" logic brought enough power to the test based on the logistic regression.

We then conducted a complementary empirical analysis on the cases that exhibit *both* good RN design capabilities and good RR design capabilities. For the cases in these configurations, we analyzed the strategies elaborated to combine good rule-renewal and good rule-reuse in a project.

4- Main results

4.1 Example of a project analysis

We first offer one example of the methodology in which we analyzed the Manhattan project: Formally launched by the US Government in the summer of 1942, the Manhattan Project led to the design, development and use of the first atomic bombs against Japan in August 1945. In record time, engineers and scientist moved from the most meager laboratory data to working devices that constituted historical breakthroughs in the history of technology and opened the atomic age. Our study was interested in the Manhattan Project because it has long been incorrectly presented as the origin of modern project management (Lenfle & Loch, 2010). However, a close look at the management of the project reveals that most of the best practices of modern project management (PMI, 2008) are broken. As explained by the project director, L. Groves [1962, p. 19], "*the whole endeavor was founded on possibilities rather than probabilities. Of theory there was a great deal, of proven knowledge, not much*". Therefore, they "*decided almost at the very beginning* (…) *to abandon completely all normal orderly procedures in the development of the production plants* » (ibid, p. 72). Thus, one cannot find in the Manhattan project the basics of project management because costs were unknown, planning was impossible, risk management was uncertain, etc. Moreover, the project strategy was originally compared to what contemporary textbooks are teaching. Indeed, to manage unforeseeable uncertainties, the project managers decided to adopt a parallel approach, i.e., to explore and implement simultaneously different technical solutions. This allowed the project to succeed in record time (see Hewlett & Anderson, 1962 or Rhodes, 1986 for a complete history of the case and Lenfle, 2011 for an analysis of the project strategy). What is interesting for our analysis are the following three matters:

1. As opposed to the PMI model, instead of defining at the outset the requirements of the weapons which, given the scientific uncertainties, were impossible, the project steering committee explicitly decided to explore multiple scenarios. The goal was twofold, to adapt to the unknown and to reduce delivery time.
2. The entire project was fundamentally an experimental learning process (Loch et al, 2006). Each time there was a new problem (and there were many) they experimented, added new solutions (e.g., thermal diffusion to enrich uranium), explored different approaches simultaneously, attempted seemingly crazy ideas (e.g., implosion weapons), and adapted the project strategy accordingly.
3. They could not rely on existing competencies because there were none. Thus, they had to build an entire industry almost from scratch. To do this, the army set up a dedicated organization with three pillars, the army corps of engineers, scientists and private firms (such as Du Pont, Union Carbide, Westinghouse, etc.). In this sense, the Manhattan Project offers the fundamental impetus for the military-industrial complex.

Finally, the Manhattan Project violated project management best practices but was nevertheless considered a (technical) success. This success must be carefully evaluated; reducing Manhattan results to the bombing of Hiroshima and Nagasaki and the ensuing surrender of Japan is profoundly misleading (Lenfle, 2012). What is striking is that the Manhattan Project gives birth to lineages of new products that improved the initial design (ibid). Moreover, the project generated an extremely rich knowledge base in various fields (nuclear science and engineering, computing, science of explosives, etc.) that would later expand and be considered the cradle of the nuclear industry (military at first but also civilian). Finally, it also left behind organizations (mainly plants and laboratories) that survived in the postwar years through the Atomic Energy Commission, created August 1, 1946 (see Lenfle, 2012).

Our analysis of the unfolding and organization of the Manhattan Project case leads us to the following assessment on a five-level Likert scale. As shown in the table, this case is binary because it violates all the classical principles of project management (therefore scoring 1 on rule-reuse criteria 1.1, 2.1, 3.1, 4.1) and, on the contrary, makes extensive use (5 on the Likert scale) of rule-renewing principles both for the following:

– its managerial strategy (1.2 and 2.2);
– its organization, which was continuously changing according to the project's unfolding (3.2); and
– its management (4.2), which had to constantly adapt to unforeseen events.

Concerning the new "business" development criteria, there is no doubt about the construction of lineages of atomic weapons and the setting up of new organizations. Finally, there was (of course) no dominant design in this case, and the project constitutes the largest endeavor of WWII for the US Army (along with the development of the B29).

	PM descriptors	
1	***Risk management***	
1.1	Organize a planned process that is robust to external events.	**1**
1.2	The project organizes to identify unforeseeable uncertainties (unk unk) and/or the project organizes to increase the variance in the options.	**5**
2	***Project cost and resources associated to learning***	
2.1	Project learning costs are related to tests and validation: alternatives are tested and evaluated and the relevant (or the best) one is kept.	**1**
2.2	Project learning (a) uses deviant explorations to be surprised by the results of such explorations and/or (b) uses systematic, comprehensive investigations and/or (c) uses a fuzzy front end, creative phase.	**5**
3	***Coordination means to manage project and its environment***	
3.1	Project team is integrated, stable and exhibits clear work division. The relationship with the external environment is well codified.	**1**
3.2	Project team (a) is able to commit new (initially external) actors to its network and/or (b) is able to change its own ecosystem by motivating external actors to create knowledge and competencies to contribute to the future lineage.	**5**
4	***Managing target value***	
4.1	The project target value is given by a clear list of requirements and well-defined specifications.	**1**
4.2	Project target value (a) requires "sense-making" during the project and/or (b) is created during the project.	**5**
	New business development criteria	
	There a family of products/services that is new and associated with the first project.	**5**
	There is a new organization that contributes to the new business development.	**5**
	Control variables	
	Is there an established dominant design at the beginning of the project in the project field?	**1**
	What is the relative size of the project organization compared to the entire organization?	**5**

4.2 Result 1: measurement model

The measurement model associated with H1a and H2a is represented in figure 1 below.

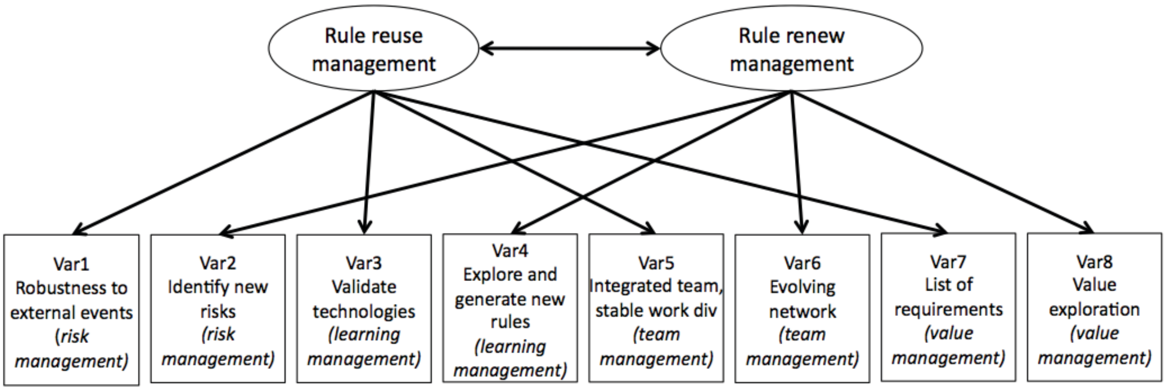

Figure 1: measurement model

We conduct a confirmatory factor analysis (see results in table 2 below). Note that the case-control study may cause violation of normality in situations of strong correlation between factors and cases. Thus, we rely on an alternative method to the classical (quasi-) MLEs estimation (or estimation by the variance-covariance matrix). We chose the so-called Satorra-Bentler "robust" errors estimate, after (Satorra and Bentler 1994).

The reported estimates are as follows: the estimated means of the data; loadings grouped by the latent variables; factor covariances; and variances of the error term. All parameters are freely estimated except for loadings used for identification, which have a coefficient estimate of 1 and are missing standard error.

The final set of the displayed statistics includes likelihood ratios and two specific tests. The second test is displayed against an independence model. The first line is for a test against a saturated model (fit to the model). Note that in the case of the Satorra-Bentler estimation, the test of the goodness of fit with a likelihood-ratio is no more valid. Santorra and Bentler proposed Satterthwaite-type correction Tsc, and Tadj; the first corrects the scale and the second corrects the scale and the degrees of freedom. With this new estimation, the fit is good. These two tests are given in the two last lines.

The second test shows that the current model is a significant improvement compared to the null model, in which variables are assumed to be independent. This confirms the *multidimensionality* of rule-reuse and rule-renewal design capabilities.

The Tsc and Tadj tests show that the model fits well. In particular, the paths from the item to the factors are significant at a 5% level, which supports the *convergent validity* of the model.

This result confirms H1a and H2a, i.e., a measurement model of design capabilities in project management that we built from the literature review and from the design theory perspective. This is a model based on two main factors, rule-reuse and rule-renewal design capabilities, as applied to a 4-facets invariant core of design rules.

log likelihood = -541.18523 Number of obs = 46

	Coef.	Satorra-Bentler Std. Err.	z	P>|z|	[95% Conf.	Interval]
Means						
var1	3.391304	.2205817	15.37	0.000	2.958972	3.823637
var3	3.326087	.2322212	14.32	0.000	2.870942	3.781232
var5	3.76087	.1744145	21.56	0.000	3.419023	4.102716
var7	3.73913	.2026172	18.45	0.000	3.342008	4.136253
var2	3.26087	.2543291	12.82	0.000	2.762394	3.759345
var4	3.630435	.2348607	15.46	0.000	3.170116	4.090753
var6	3.347826	.2305116	14.52	0.000	2.896032	3.79962
var8	3.173913	.250339	12.68	0.000	2.683258	3.664568
Loadings						
R						
var1	1	.	.	.	.	.
var3	.9432382	.1818156	5.19	0.000	.5868862	1.29959
var5	.5303342	.1358387	3.90	0.000	.2640953	.796573
var7	.823764	.1502184	5.48	0.000	.5293414	1.118187
E						
var2	1	.	.	.	.	.
var4	.9261635	.06009	15.41	0.000	.8083893	1.043938
var6	.7341926	.0938248	7.83	0.000	.5502993	.9180859
var8	.8769581	.0728601	12.04	0.000	.7341549	1.019761
Factor cov.						
R-R	1.721485	.4021316	4.28	0.000	.9333219	2.509649
E-E	2.671646	.2918144	9.16	0.000	2.0997	3.243591
R-E	-1.460869	.2975537	-4.91	0.000	-2.044064	-.8776745
Var[error]						
var1	.5167035	.2092214	2.47	0.014	.106637	.92677
var3	.9490239	.3648372	2.60	0.009	.2339562	1.664092
var5	.9151643	.1711965	5.35	0.000	.5796253	1.250703
var7	.7202941	.2231312	3.23	0.001	.2829649	1.157623
var2	.303785	.104609	2.90	0.004	.098755	.5088149
var4	.2456576	.0847136	2.90	0.004	.0796219	.4116932
var6	1.004116	.1499147	6.70	0.000	.7102891	1.297944
var8	.8281578	.1896101	4.37	0.000	.4565289	1.199787
R2						
var1	0.7524					
var3	0.6040					
var5	0.3385					
var7	0.6051					
var2	0.8784					
var4	0.8836					
var6	0.5764					
var8	0.6972					

Goodness of fit test: LR = 42.548 ; Prob[chi2(19) > LR] = 0.0015
Test vs independence: LR = 268.325 ; Prob[chi2(28) > LR] = 0.0000

Satorra-Bentler Tsc = 45.678 ; Prob[chi2(19) > Tsc] = 0.0006
Satorra-Bentler Tadj = 24.207 ; Prob[chi2(10.1) > Tadj] = 0.0073

Table 1: Confirmatory Factor Analysis results

4.3. Result 2: hypothesis testing

We test the simple model represented below (figure 2) under two control variables, dominant design and relative size.

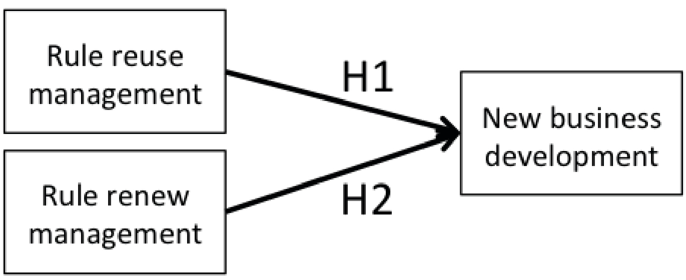

Figure 2: RR and RN design capabilities vs. new business development

Following the CFA, we created two variables, RR and RN, both averages of the items they significantly load. When RR is superior (resp. inf.) to the 3.00 threshold, we consider that the project was RR_high (resp. RR_low); the same holds for RN.
The control variables dominant design (DD) and relative size (relSize) are also coded in 0-1 value at the threshold 3.00.
The hypotheses are:
H1b: The rule-reuse design capabilities are independent of new business creation.
H2b: the rule-renewal design capabilities are positively related to new business creation.
H1 and H2 remain true with the control factors dominant design and relative size.

The result of the logistic regression are given below. They confirm H1 and H2, with the control factors.

```
Logistic regression                               Number of obs   =         46
                                                  LR chi2(4)      =      34.78
                                                  Prob > chi2     =     0.0000
Log likelihood = -14.103078                       Pseudo R2       =     0.5522
```

nBD	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
rulebased	-.9490447	1.500032	-0.63	0.527	-3.889053	1.990964
explo	4.458672	1.377134	3.24	0.001	1.759539	7.157805
DD	1.038004	1.245954	0.83	0.405	-1.404021	3.480029
relSize	.0337635	1.050835	0.03	0.974	-2.025835	2.093362
_cons	-1.475029	1.92862	-0.76	0.444	-5.255056	2.304997

Table 2: Logistic regression for H1 and H2 (rule-based = RR, explo = RN)

Only 4 projects are below the 3.0 threshold, XP-80 Jet Airplane of the Lockheed Skunk Works, the Polaris Missile, IBM 360 and IBM PC. In these cases, the projects are related to new business development, but they do not exhibit a high value for the rule-renewal factor. Returning to the detailed case studies, we found in all four cases the following interesting pattern: rule-renewal often preceded the project. In the case of Polaris (the first US submarine missile), there were previously many building blocks to realizing a missile, and, although there were many challenges for building a submarine-launched thermonuclear missile (including whether the new submarine missile appeared as a “new business” in itself), the rule-renewal could be limited to the design of a new, compact missile warhead and solid propellant. The case of IBM PC is even more interesting; the rule-renewal was actually made by other companies and research labs and the IBM project actually consisted in using the rule-renewal capabilities made by others. Thus, IBM employed a strategy of open architecture using external components (Intel CPU, Microsoft OS, etc.). Thus, it is true that the project was not the place for rule-renewal; however, there was a (hidden) rule-renewal to obtain the new business development.
These results confirm O’Connor's proposition because new business development (more generally, MI) is related to RN design capabilities (more generally, dynamic capabilities of a design system). These results also confirm a less-evident hypothesis because new business development can emerge equally in cases in which there are RR design capabilities or in cases in which there are not.

4.4. Result 3: qualitative analysis
These results lead us to identify several categories of projects (see data points below):

1- We find many projects (11) that are RR_low and RN_high. Project management was more oriented towards rule-renewal than rule-reuse and this might explain why they finally led to new business development. The most extreme project is the Manhattan Project, which exhibits the lowest score in rule-reuse and the highest in rule-renewal.
2- We find in the upper right corner projects that are both RR_high and RN_high. These situations are more counterintuitive because they are good at reusing rules and renewing rules. How could these projects combine these opposite tendencies? We find three projects here, Edison Lighting System, Toyota Prius and Saint-Gobain Windshields with thin coating. When rereading the cases in detail, we find interesting patterns that might explain the positive relationship between RR design capabilities and RN design capabilities. In all three cases, we find series of projects or a portfolio of interdependent sub-projects. Each single sub-project is well driven with clear objectives (resources, specifications, delay, etc.), but the overall project itself is built for an exploratory purpose. For instance, one of the first Prius actions was a concept car for the Tokyo Motor Show and the concept car intended to explore certain customer values and technological alternatives. One of the sub-projects of Edison Lighting consisted of the development of demonstrators for Christmas mall lighting. Thus, the logic of efficient reuse is put to the service of exploration; it supports efficient, well-oriented exploration. This illustrates a form of "probe and learn" inside the entire project (Lynn et al., 1996).
3- In the middle, we find projects in which there seems to be a *trade-off* between rule-reuse and rule-renewal. We find here multiple patterns.
    a. Low scores in rule-renewal may be explained by *front-end exploration*. For instance, the F117-Stealth Fighter and the Stealth family results from explorations run by university mathematicians (for wavelength reflections), by suppliers (surface structure to reflect radar wavelength), by the company and all its competitors (since the end of WW2, every military aircraft designer was working on low radar reflection) and by the "customer" (US army), who had the opportunity to learn by trying multiple proposals.
    b. We find also a logic of decoupling; the project is subdivided into *several building blocks*, and several are rule-reuse and others are more exploratory. This is clearly the case for Polaris, in which the vast majority of the tasks were rule based, except for the warhead (which precisely was not integrated into the PERT). There are similar patterns for Eiffel Tower, Baldwin and Kodak. Low-cost, transportable bridges in Eiffel Tower combine patterns a) and b); multiple preliminary explorations help to design well-delimited exploration areas inside the project in which exploration could be launched with limited risks (using steel instead of iron and new ways to throw the bridges, etc.);
    c. However, the logic of rule-reuse and the logic of rule-renewal can also lead to *limitations in the rule-renewal or limited success in rule-reuse management.* The domination of rule-reuse can avoid certain technological rule-renewals and, conversely, the unavoidable technological challenges might cause dramatic delays in the project (see IBM 360).

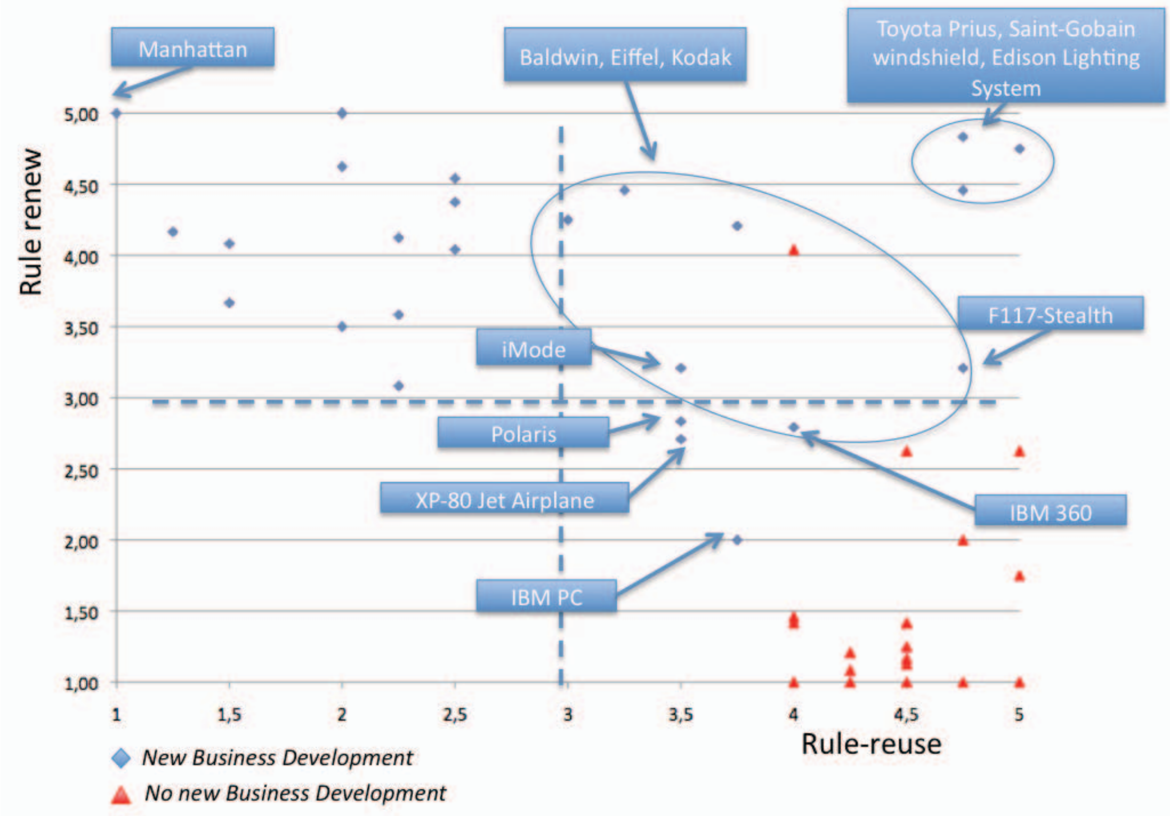

Figure 3: RN and RR design capabilities for projects leading to new business development

5- Discussion and managerial implications

This paper adds to the literature on Major Innovation (MI) capabilities. We tested O'Connor's proposal that MI capabilities are a form of dynamic capability. We built an observation model; relying on design theories, we assimilated MI dynamic capabilities to rule-renewal design capabilities and non-MI dynamic capabilities to rule-reuse capabilities. We use this observation model on the specific case of projects leading (or not) to new business development in a case-control study based on 46 historical cases. This offers us three main results:

1) We tested a measurement model of MI dynamic capabilities. MI dynamic capabilities can be assimilated to rule-renewal design capabilities, and these rule-renewal design capabilities can be measured in project management by four descriptors – renewal of the set of anticipated risks, renewal of the competencies, renewal of the project team members and project stakeholders, and renewal of the target value. By contrast, there are rule-reuse design capabilities that can be characterized as capabilities to stabilize a target value, to efficiently use a set of given competencies, to stabilize work divisions and to address well-anticipated risks.
2) We tested the relationship between MI dynamic capabilities and MI success. More specifically, we tested that rule-renewal design capabilities in project management have a positive effect on new business creation, whereas rule-reuse design capabilities are independent of new business creation.
3) We identified several types of combinations of rule-renewal design capabilities and rule-reuse design capabilities, which open interesting perspectives on the variety of forms of ambidextrous organizations (Andriopoulos and Lewis 2009; Raisch et al. 2009) and on the management of projects (Loch et al. 2006).

There are, however, limits to these research results. The results are obtained in a specific observation system – namely a project that leads (or not) to new business creation, whereas O'Connor proposed, more generally, a model of MI dynamic capabilities at the firm level. For instance, our observation system leads us to neglect cases in which MI dynamic capabilities operate at the level of project portfolio management. This would require further research. However, this bias leads to *underestimate* the role of RN design capabilities in MI. This is a *non-differential* bias that leads to underestimate the relationship. *If we prove the relationship despite the bias, the quality of the result is maintained*.
Beyond testing O'Connor's proposal, our study also confirms the interest of a theoretical background based on design theory, which helped to identify specific capabilities and thus to build reliable "descriptors" of the phenomena. Our research basically shows the interest of assimilating MI dynamic capabilities to rule-renewal (RN) design capabilities and to contrast these capabilities with rule-reuse (RR) design capabilities – *which are also a form of design capabilities*.
A by-product of this research is also to underline the interest in relying on historical material, which brings detailed elements on project *and* a long-term perspective on the effects of one project on the development of an entire business.

Managerial implications.
These results have strong managerial implications:

1- A first series of implications is obtained at the level of project management and new business development:
   a. It appears that project management can be a good way to organize for new business development, on the condition that it is clearly based on rule-renewal design capabilities. Project management may also be based on rule-reuse design capabilities, but it is not necessary and will require management of the combination rule-reuse and rule-renewal. This reinforces the growing body of work on the management of exploratory projects (Brady & Davis, 2004; Loch et al, 2006; Lenfle 2008 & 2011).
   b. The projects that do not follow rule-reuse principles are not necessarily bad. Therefore project evaluations must adopt a dual perspective. For instance, strongly rule-reuse projects should justify that they do not require renew rules and conversely strongly rule-renewal projects should justify that they are really unable to re-use any rule of the organization; they should be managed accordingly (Loch et al, 2006)
   c. This adds a new dimension to project management, the strategic capacity to combine rule-reuse and rule-renewal. Some of our cases echo previously known strategy, such as sequences of rule-reuse heading to rule-renewal, decoupling rule-reuse and rule-renewal in different projects tasks or modules, parallel rule-reuse projects providing pieces for rule-renewal, etc. These strategies might pave the way to new forms of project portfolio management or the management of platforms of projects.

2- A second series of implications is at the level of MI dynamic capabilities:
   a. Rule-renewal (RN) design capabilities appear as a good proxy of MI dynamic capabilities. Even if our descriptors do not encompass all the aspects of MI dynamic capabilities, it clarifies a clear logic of MI management; it is oriented towards the *renewal of a core of design rules*, and it can be described by the following four specific forms of action and by contrast with more classical logic of rule-re-use design capabilities: a specific management of risk (capacity

to go beyond the set of fixed, pre-identified risks), a specific management of learning (capacity to acquire new competencies and not only reusing available competencies), a specific management of stakeholders (capacity to commit new stakeholders in the design process, instead of considering that the stakeholders should be committed right from the beginning) and a specific management of value (the capacity to design the target during the process, instead of relying on a given list of requirements). *This approach synthesizes many proposals on exploration vs. exploitation and gives a clear and consistent logic of action* based on the re-use or renewal of the set of design rules.

b. This approach brings more firm ground to MI dynamic capabilities in a systemic approach. It appears that the "homeostasis" of the system, its equilibrium, may be a dynamic equilibrium, in the sense that the homeostasis is not based on keeping a stable set of design rules but is based on the controlled renewal of the core. The logic of rule-renewal is also the logic for managing the growth trajectory of the firm and its competencies, which balances rule-reuse and rule-renewal. It helps to go beyond the classical oppositions of exploration / exploitation – and beyond the "ambidextrous" approaches – by showing that these are less oppositional than complementary approaches and that the role of management is there precisely to balance them (Raisch et al., 2009)

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