Mission Statement

The Project Management Journal’s mission is to shape world thinking on the need for and impact of managing projects by publishing cutting-edge research to advance theory and evidence-based practice.

Projects represent a growing proportion of human activity in large, small, private, or public organizations. Projects are used to execute and sustain today’s organizational activities. They play a fundamental role as the engine of tomorrow’s innovation, value creation, and strategic change. However, projects too often fail to deliver on their promise.

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It welcomes the following topics, but not limited to: governance; strategy; innovation and entrepreneurship; organizational change, learning, capabilities, routines, information systems and technology; complexity and uncertainty; ethics; leadership; teams; and stakeholder management in a wide range of contexts.

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Product Editor

Roberta Storer; roberta.storer@pmi.org

Copy Editor

Linda R. Garber; linda.garber@pmi.org

Publications Production Associate

Kim Shimmer; kim.shimmer@pmi.org

Publications Production Supervisor

Barbara Walsh; barbara.walsh@pmi.org

Book Review Editor

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Projects and Networks

SPECIAL ISSUE EDITORS:

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John Steen, Australian Institute of Business and Economics, University of Queensland, Australia, jsteen@business.uq.edu.au
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Two basically different perspectives have brought projects and networks together. We welcome contributions from both viewpoints and integrative views. To this end, all papers should be based on theoretically informed and empirically rigorous research using qualitative or quantitative designs and methods.

PROJECTS FROM A SOCIAL NETWORK PERSPECTIVE

Social or organizational network analysis not only provides a means to analyze project networks and develop theories of the flow of information and other resources through projects, it also provides a theoretical lens on control and coordination. There is scope here to extend beyond network analysis and apply network theory (Borgatti & Hann, 2011) to generate broader theories of project-based organization.

PROJECTS FROM A NETWORK GOVERNANCE PERSPECTIVE

Project networks as a specific form of governance are characterized by latent as well as activated ties with project entrepreneurs and/or organizations. In its purest form, project networks embed projects as a form of temporary organization (Jundin & Söderlund, 1995) into longer-term, open-ended networks (Sydow et al., 2016). As a consequence, their analysis requires not only investigations of the particular modes of organizing but also their specific contexts (DeFilippis, 2015).

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Guest Editorial

Christophe Midler, CNRS and 1st Centre de Recherche en Gestion, Ecole Polytechnique, Palaiseau, France
Catherine P Killen, School of Systems, Management and Leadership, Faculty of Engineering and IT, University of Technology Sydney, Australia
Alexander Kock, Technology and Innovation Management, Technische Universität Darmstadt, Darmstadt, Germany

Project and Innovation Management: Bridging Contemporary Trends in Theory and Practice

Innovation is a hot topic in organizations—driven by the need to compete in an era of increasing competition and uncertainty, rapid technological and market change, and escalating requirements for solutions to complex problems. The strong interest in innovation has spawned a vital and productive field of research; innovation management concepts such as open innovation, effectuation, and design thinking have wide appeal and application. In parallel, the same drivers underpin the growing adoption of project structures for an increasingly broad array of activities. In particular, innovation activities are almost always conducted within a project framework, and there is a growing body of research at the intersection of project and innovation management.

This special issue bridges the fields of innovation management and project management by presenting a collection of articles illustrating collaboration and cross-fertilization between these two dynamic fields. In this issue we set out to ask: “How can the project management field learn from concepts and analytical frameworks developed by innovation scholars?” and “How can theoretical developments in the project field contribute to innovation theory and practice?” Nine articles have been selected to address these questions while showcasing a broad array of methodological and theoretical perspectives in a variety of contexts.

A wide and ever-increasing array of methodologies enriches project management research (Müller, 2015). The methodologies represented in this collection of articles include two conceptual articles, one that employs modeling and simulation, five in-depth case studies, and one broad cross-sectional quantitative study. Overall, five of the seven empirical articles adopt a single project perspective, whereas two consider multiproject environments.

Context matters in innovation management as in project management; the importance of tailoring management approaches to the context is a recurrent theme in both fields (Burns & Stalker, 1961; Ettlie, Bridges, & O’Keefe, 1984; McGrath, 2001; Shenhar & Dvir, 1996; Shenhar, 2001; Söderlund, 2004; Turkulainen, Aaltonen, & Lohikoski, 2015; Unger, Rank, & Gemünden, 2014). This issue contributes to this contextual approach by encompassing a variety of innovation project contexts, from explorative and complex product development projects to infrastructure megaprojects. The findings enhance our understanding of how context and management approaches can work together for successful innovation project management.

A recurrent theme in this special issue is the need to manage projects in the uncertain, dynamic, and complex environments that are typical for highly innovative projects. Such environments are often ill-suited for traditional “rational” project management approaches due to unclear goals, shifting milestones, and evolving and unfolding activities. Alternate perspectives and approaches are analyzed in this collection of articles; they provide conceptual inputs, as well as evidence and in-depth empirical understanding of how and when project management structures can provide benefits in managing innovation.

We open the special issue with an invited article by Professor Anne Sigismund Huff entitled “Project Innovation: Evidence-Informed, Open, Effectual, and Subjective.” Anne Sigismund Huff is a major contributor in the fields of innovation management, strategic change, and academic research strategy. Her conceptual article builds on these three domains of expertise to craft a framework, which we have used to provide a perspective on contributions from the articles in this issue. On the epistemological level, Anne Sigismund Huff’s article clarifies our purpose of “bridging” different traditions of management. She warns us against the easy but misguided tendency to believe that progress in a management stream can be achieved by bundling concepts from different fields together without a thorough analysis on the basic underlying assumptions. Four theoretically distinct approaches to innovative project management are identified: The evidence-informed approach (which refers to traditional project management approaches); the open innovation logic; the effectual approach; and, finally, subjective–interactive innovation management. Anne Sigismund Huff characterizes the specific logic behind each stream and illustrates each through iconic examples of innovation successes, such as Procter and Gamble’s “Connect and Develop” program, the Ice Hotel, and Airbnb. In doing so, she paves the way for new avenues for project management studies in a radical innovation context.
In the second article, "Dynamic Capabilities in Complex Projects: The Case of London Heathrow Terminal 5," Andrew Davies, Mark Dodgson, and David Gann show how complex one-off projects benefit from dynamic capabilities. The dynamic capabilities framework (Teece & Pisano, 1994) is a key strategic management concept that addresses the increasing influence of innovation and change. It characterizes the ability of firms to adapt, integrate, and reconfigure their competences, resources, and routines in response to rapidly and profoundly changing environments. Dynamic capability theory has previously been applied to understand how decisions about an organization’s project portfolios can contribute to competitive advantage (Killen & Hunt, 2010; Killen, Jugdev, Drouin, & Petit, 2012; Sicotte, Drouin, & Delerue, 2014; Winch, 2014). In such environments, it is the ability to respond to change by altering the mix of projects in the portfolio and thus reconfiguring resources that can provide advantages. Product development environments also provide examples of dynamic capabilities in practice (Eisenhardt & Martin, 2000; de Brentani & Kleinschmidt, 2015). Andrew Davies and his co-authors make practical and theoretical contributions to the research on dynamic capabilities and projects by exploring yet another context: complex one-off projects. On the practical side, they reveal that innovation within complex one-off projects often appears as a major and largely unsolved problem (see, for example, Flyvhjberg, 2014, on megaprojects). On a more theoretical level, the authors extend the dynamic capabilities concept beyond the context of permanent organizations. Exploring its application in temporary organizations raises the question of how to build such dynamic capabilities from scratch, and how they can operate and be dissolved during the limited time of a project. Building on a deep longitudinal analysis of the Heathrow Terminal 5 project, the authors present a model explaining how dynamic capabilities can be built, codified, and mobilized in a three-phase process to support the strategic management of complex and uncertain projects. This model demonstrates links with the effectuation approach presented by Anne Sigismund Huff and fruitfully complements the dynamic capabilities framework. The authors also provide an important link for empirical development by expanding the scope of the strategic management field to the domain of complex projects.

When innovation is strongly radical, the exploration dimension of the project becomes dominant. Can project management concepts be useful in such a domain? In his article "Floating in Space? On the Strangeness of Exploratory Projects," Sylvain Lenfle answers this question positively and provides support for structuring such exploratory projects. When compared to traditional projects (the “evidence-informed” ones, as depicted by Anne Sigismund Huff), the project explored through this in-depth case study in the space industry is said to appear as “strange” or “floating.” Relying on advances in design theory (Le Masson, Weil, & Hatchuel, 2010), Sylvain Lenfle proposes that this “strangeness” is not a symptom of mismanagement but that it follows a specific “expansion logic” adapted to the discovery situation. By detailing the management practices in a rich case example, he reveals how success was achieved through monitoring knowledge expansion in multiple unknown dimensions of the project (the opposite of an evidence-informed situation in Anne Sigismund Huff’s terms) while retaining the ability to flexibly respond to change and evolve over time. The use of a project management structure, albeit not a traditional approach, provided specific benefits—in particular in fostering communication, collaboration, and coordination among a “community” of actors spread across different disciplines. Importantly, this article reaffirms extant research (Lenfle, 2008; Lenfle & Loch, 2010) showing that managers need to recognize the type of project at the start, resist institutional pressure to adopt traditional “rational” approaches to all projects, and apply an appropriate approach—one that is tailored for the project type. For project academics, this calls for continuing the effort to formulate and legitimate a diversified and contingent theory of project management.

Success stories proliferate in management journals, but the analysis of problematic cases often provides more fruitful learning material. The next article, by Aaron J. Shenhar, Vered Holzmann, Benjamin Melamed, and Yao Zhao, is a case in point. Their article, “The Challenge of Innovation in Highly Complex Projects: What Can We Learn from Boeing’s Dreamliner Experience?”, confirms Sylvain Lenfle’s findings about the importance of a contingency perspective in project management theory through a retrospective analysis of the Boeing Dreamliner case, a project that suffered extensive delays and cost overruns. The article addresses the questions: “What happens when a highly innovative and complex project adopts a standard development project management model?” and “How can we precisely diagnose the nature and uncertainties of an innovative project in order to tailor the project management model?” Vered Holzmann and co-authors demonstrate that the problems in the Dreamliner case resulted from the combination of complexity and highly radical innovation. They draw upon the innovation and project management literature on contingency (specifically models from Geraldi, Maylor, & Williams, 2011; Pich, Loch, & De Meyer, 2002; Shenhar & Dvir, 2007) to propose a methodology to classify projects based on novelty, technology, complexity, and pace in order to guide the design of a suitable project management model.

Aircraft development is also the sectorial background behind the article from Henk Akkermans and Kim E. van Oorschot, who ask whether increasing the level of concurrency in new aircraft development projects could reduce the frequent occurrence of significant delays; their article, "Pilot Error? Managerial Decision Biases as Explanation for
Disruptions in Aircraft Development,” explores managerial decision making in complex environments, and suggests that increasing the level of concurrency can reduce delays. Concurrency in an innovation process has long been advocated, especially for complex integrated product development processes such as those used in the automotive industry (Clark & Fujimoto, 1991; Midler & Navaire, 2004). By overlapping the phases of the process and enhancing communication to enable early information to be considered in advance planning, even before formal close of the earlier phase, concurrent processes have shown improvements in speed, quality, and cost in several studies on the use of such approaches for product development. However, for large and highly innovative complex systems, managers often consider concurrency as too risky and feel it may cause delays. Henk Akkermans and Kim E. van Oorschot model the decision scenario for an airline development using system dynamic modeling. They incorporate multiple factors, acknowledge the special circumstances of complex project management, and explore the effects of different degrees of concurrency. The results of the modeling show that, although downstream phases may require more rework due to flaws in the early information released in a concurrent process, the benefits of enabling the feedback loops between the phases outweighed the risks, and overall a medium level of concurrency minimized project delays. These results confirm and generalize the conclusion of Sylvain Lenfle’s article on the importance of project coordination for exploratory “strange” projects that face many unknown-unknown risks (Pich et al., 2002).

In “The Innovation Journey and the Skipper of the Raft: About the Role of Narratives in Innovation Project Leadership,” Tanja Enninga and Remko van der Lugt focus on project leadership in radical innovation projects. The importance of storytelling and narratives in organizations has already been established in studies of corporate culture, sensemaking, and organizational leadership (Czarniawska, 2014; Kets de Vries, 1998; Weick, Sutcliffe, & Obstfeld, 2005), but little attention has been paid to storytelling in innovative project management. The authors characterize the role of the project leader as an implementer of four intertwined but different and often non-convergent processes: (1) developing the content of radical innovations; (2) stimulating creativity for the projects; (3) meeting time, cost, and quality performance levels; and (4) managing the project group dynamics, internally as well as externally with the key stakeholders. Based on a deep longitudinal case analysis of a radical innovation project in a major beer firm, they demonstrate the predominant role of narratives in these intertwined processes. Their analysis highlights the specific contribution of storytelling and story making within the project team in an approach that could be interpreted as a form of project control in a “subjective–interactive” project management style as typified by Anne Sigismund Huff’s article.

Thus far, the articles presented in this special issue have focused on individual innovation projects. The following two articles adopt a multiproject perspective to extend the scope of this special issue beyond projects as singular objects of analysis. This is especially important in the current intensive innovation context, where business success depends on the capability to multiply the response to the innovative challenge, to go beyond emblematic but singular success, and to achieve efficiencies in repetitive innovative endeavors. In addition, the management of multiple projects offers a higher-level strategic perspective to project and innovation studies. Project portfolio management is therefore a key topic in multiproject management.

Several articles in this special issue emphasize the importance of the upfront creative and explorative phases in the management of innovative projects. The authors of the next article, Alexander Kock, Wilderich Heising, and Hans Georg Gemünden, consider the issue from a project portfolio management perspective. While contemporary developments in innovation research often focus on improving the creative ideation phase (as discussed in the final article on design thinking in this special issue), the upfront (“pre-project” or “fuzzy front end”) phases are often disregarded in project portfolio management practice and research. Alexander Kock and co-authors ask whether attempts to improve creative ideation are worth the effort and test the correlation between upfront phase success and project portfolio performance through a quantitative study reported in “A Contingency Approach on the Impact of Front-End Success on Project Portfolio Success.” The authors furthermore investigate which factors influence the strength of the correlation. On the methodological side, this survey has addressed the challenge of developing rigorous and relevant criteria to evaluate front-end performance. Drawing upon previous research, the authors propose three dimensions for success measurement: effectiveness, timeliness, and efficiency of the front end. The large-scale study (175 project portfolios) found a strong correlation between front-end success and project portfolio success, with the degree of complexity as an important moderating factor. This result has implications for professional practice, and suggests that more attention should be devoted to upfront phases. It is also important for scholars in the project management field because it invites them to enlarge their scope of analysis to new territories, those “strange” projects as Sylvain Lenfle labels them, and to consider ways to enhance the efficiency of such creative activities, not as the result of mysterious genius or serendipity (Van Andel, 1994), but on the contrary, as a domain to be organized through tailored project management approaches.

When developing multiple products, how can managers reconcile the innovation imperative with the push for component commonality, which is a major efficiency lever in most industries? This issue is usually addressed as a trade-off
between two opposing forces. The use of common components in innovative product development processes is seen as a constraint that restricts innovation by enforcing a level of standardization. In their article “Innovation for Multiproject Management: The Case of Component Commonality,” Tuomas Korhonen, Teemu Laine, Jouini Lyly-Yrjänäinen, and Petri Suomala illustrate how the design of common components can be a source of innovation rather than a barrier. This article takes a wide view of the impact of component commonality across a portfolio of projects, and shows how multiproject synergy, once recognized, can justify the development of innovative solutions; common component can therefore be innovative. In the end, the challenge for innovation is to meet the customer’s needs; this article shows how component commonality, when viewed from a multiproject lens, can cost effectively free up the organization to meet customer needs in innovative and responsive ways. This article provides managers and practitioners with a detailed example and the related cost implications across the project portfolio, demonstrating how a wide perspective can be employed to fully reveal the benefits of common componentry in innovative product development.

We conclude this special issue with a conceptual article by Sihem Ben Mahmoud-Jouini, Christophe Midler, and Philippe Silberzahn on the “Contributions of Design Thinking to Project Management in an Innovation Context.” This article explores the potential benefits of cross-fertilization between the project management domain and “Design Thinking,” an approach from the design discipline that is becoming increasingly popular in general management. The authors first summarize the literature on challenges to be addressed by the project management academic community, reflecting the themes identified in several articles in this special issue. These challenges are: developing appropriate project management approaches for exploratory and creative situations (beyond the usual traditional development situation); developing strategic capability as a legitimate and efficient component of the project management role (beyond the traditional implementation capability); and analyzing the role of projects as an important element in the strategizing process of the “permanent” firm (beyond the traditional vision of project selection based on “alignment” to a stable “top-down” firm strategy). Sihem Ben Mahmoud-Jouini and co-authors find that the principles underlying the design thinking concept align with these three project management research challenges. Building on this alignment and their exploration of the ways design thinking concepts can contribute to project management research, they conclude with a set of propositions that could form an agenda for further research on innovation project management.

As a whole, the nine articles offered in this rich and diversified collection converge to address our special issue’s purpose to bridge and cross-fertilize the fields of project management and innovation management. The establishment of such a bridge has opened new perspectives and enriched both fields, paving the way for further cross-fertilization. We look forward to continuing the scientific conversation between those two dynamic fields in a forthcoming special issue of Project Management Journal.” on the management of exploratory projects.

References


ABSTRACT

Entrepreneurship provides promising bases for project innovation in unpredictable settings that require general adaptability rather than responsive variety. However, important theories in this area are based on world views that are antithetical to the causal assumptions that support often-productive theory and practice in project management. This article outlines four entrepreneurial models of innovation, concluding with subjective innovations based on interactively defined lifestyle and ideological values rather than scientific or economic logic. Their adoption requires difficult personal and organizational admissions of failures in current practice as well as recognition that deeply rooted beliefs in causal logic are an impediment in intrinsically unpredictable environments.

KEYWORDS: theoretic bases for project management; intrinsic uncertainty; entrepreneurship; ontology; epistemology

INTRODUCTION

This conceptual article contributes to conversations urging new theoretic bases for innovative project management in complex and uncertain environments (Engwall, 2003; Floricel, Bonneau, Aubry, & Sergi, 2014; Martinsuo, 2013; Packendorff, 1995); at the same time, it recognizes that more traditional, evidence-based project management is a valuable source of innovation in relatively stable environments (Rousseau, 2012; Tranfield, Denyer, & Smart, 2003). The challenge for project managers lies in deciding when innovation requires going beyond the base provided by currently available evidence.

There tends to be a tacit assumption in project management and other fields of inquiry that new theoretic bases can and will be adopted if current theory and practice are shown to be inadequate (Kuura, Blackburn, & Lundin, 2014; Winter, Smith, Morris, & Cicmil, 2006). However, the ontological and epistemological assumptions of current thinking and action are likely to be antithetical to the mindset behind distinctive alternatives, which serve as a formidable barrier to assessing and adopting unfamiliar approaches (Huff, 1981). In addition, adoption requires difficult personal, project, and organizational admissions that previous efforts have failed (Edmondson, 2011; Starbuck, Barnett, & Baumard, 2008). When added to institutional, socio-political, and organizational sources of inertia (Kelly & Amburgey, 1991), it is not surprising that the adoption of new theories is erratic and slow, despite compelling evidence and rhetoric for change.

It is easier to believe that improvements within the current mindset will be sufficient. A recent example of this sentiment can be found in the Project Management Institute’s Pulse of the Profession® In-Depth Report: Enabling Organizational Change Through Strategic Initiatives (March 2014), which states on page 3 that: “It isn’t that project and program management practices don’t work for strategic initiatives; rather it is that additional skills, capabilities and practices need to be integrated with standard project and program management practices.” Or, as the author of another Project Management Institute publication states: “Managing a breakthrough or innovative project requires blending new ways of thinking with familiar processes” (Shaker, 2014).

I accept this approach as a starting point, but suggest that with increasing uncertainty, confidence in past solutions becomes increasingly problematic. Distinctive theoretic additions, in this and other fields, tend to require distinctive ontological and epistemological assumptions. Simultaneous use of theories based on different worldviews leads to actions that are difficult to reconcile within one project or larger program. Different worldviews are also problematic to communicate within a single organization. They are also challenging for the field of project management as a whole given its investment in standard setting and training around rational systems.

Despite these problems, the basic claim of this article is that continually adding to a knowledge base drawn from past success and failure impedes
innovation in unfamiliar, unfolding situations. When uncertainty is very high, a direct response to emerging circumstances without looking back is more likely to succeed. This claim expands on Herbert Simon’s (1996) definition of management as a “design science” concerned with “what can be” rather than “what is” (cf. van Aken, 2004, p. 228). However, one new approach is also unlikely to succeed in complex environments. Instead, this article outlines four entrepreneurial project management approaches that might be used in increasingly uncertain settings.

**Evidence-Informed Innovation**

Evidence-based project management is defined as the ability to respond to new problems by adapting prescriptive knowledge from previous experience. Managers are justifiably motivated to make the most of what they know has worked in the past, especially when relatively incremental innovation is the goal. As jazz musician Charles Mingus said: “You can’t improvise on nothing; you gotta improvise on something” (Kemfeld, 1995, quoted by Weick, 1998, p. 546).

Systematic evidence collection facilitates developing this innovation platform and has been recommended for the field of management as a whole (Rousseau, 2012; Rousseau, Manning, & Denyer, 2008). Project management is ahead of many other sub-disciplines in meeting the demands for systematic review. When innovation is the aim, the outcome is aptly described as an “evidence-informed” project or program that moves “beyond simple construction and dissemination of research” to pragmatically serve both research and practice (Tranfield et al., 2003, pp. 219–220). It draws as much instruction as possible from “field-tested” rules but anticipates the necessity of innovative adaptation to the unique conditions of the project at hand (van Aken, 2004).

David Tranfield, an early champion of evidence-based management for advancing theory and practice in the relatively young and disorganized management professions, spent a good deal of time thinking about how evidence is collected and used in other professions:

[When] considering building a bridge over a river, a civil engineer would ask a series of questions to inform his or her conceptual design, such as: How wide is the river? How fast is the flow? How deep is the water? What is the geology like? What are the temperature ranges, wind speeds? How heavy will the loads be, and how large the flow of traffic? [These questions come from previous professional experience.]

When the designer has the context and specifications formulated, then a conceptual design is produced, often by developing a particular vision from an existing portfolio of known and tested prototypes. For example, the designer may conclude, once a particular situation has been understood, that an appropriate form is more like the Brooklyn Bridge than the Golden Gate Bridge. Next, this concept would have to be detailed, and of course later, the actual building of the bridge would involve considerable crafting. The result would not be exactly like the Brooklyn Bridge, because no other situation exactly duplicates the conditions for which that bridge was designed.

It is in formulating context and specifications, and in applying design knowledge in the subsequent detailing and building, that “art” plays its part. However, even very artful departures from past practice, such as the bridge into Rotterdam that serves as an icon for the city, still rely on the known and tested. (Huff, Tranfield, & van Aken, 2006, p. 416, parenthetical comment added to the original)

It is important to recognize that an evidence base can be drawn upon when no longer appropriate and tested rules can support activities that lead to negative results. Failure thus is a legitimate concern in the project management literature (Cicmil, Williams, Thomas, & Hodgson, 2006; Flyvbjerg, 2014; Hodgson, 2002; Sage, Dainty, & Brookes, 2014), although its definition can be illusive:

One classic example would be the famous Sydney Opera House. This project took 15 years (from 1958 to 1973) and 14 times the original budget (from A$7 million to A$102 million) to build, yet, today it stands proudly as an engineering masterpiece and the symbol of Sydney. The intangible... is so overriding that inadequacies in the project management of this building are overlooked. (Lim & Mohamed, 1999)

In short, deficiencies must be guarded against but do not overshadow the utility of creating and then using detailed descriptions of what is currently known as a causal template (Denyer, Tranfield, & van Aken, 2008; Gasik, 2011). The process of evidence-informed innovation can be briefly summarized as:

1. Specifying project goals and parameters;
2. Assembling needed resources, including a team with desirable capabilities;
3. Searching for context-relevant field-tested rules and guidelines based, if possible, on systematically collected evidence;
4. Adapting past experience to the unique conditions of the current setting and renegotiating problematic parameters as necessary and possible;
5. Testing artfully adapted solutions against project parameters; and
6. Concluding the project with a solution that meets quality standards, on time, and within budget.

This recipe often works, in part because of the flexibility of experienced practitioners when inevitable problems occur (Leybourne & Sainter, 2012; Williams, Klakegg, Walker, Anderssen, & Magnussen, 2012). However, when the steps taken do not closely follow the prescribed sequence, the recipe is often used to communicate and record project processes and outcomes. There are various reasons for and consequences to this behavior. The most important reason for over-rationalization may be that the formula is well-known and...
expected; therefore, using its language and logic facilitates the author’s reconstruction of events in the field and helps others understand their summary. In addition, bureaucratic contexts invite simplification and sometimes require it politically; departing from expectations is not only confusing, it could flag unwelcome scrutiny. Finally, a simplified report can be helpful for newcomers, given the volume of detail that could be provided.

Unfortunately, the simplifications of causal models and reports also can be problematic, especially for newcomers and those who lack experience in the project context. The new and unusual are often left out of the story or underrepresented; as a result, the most useful evidence for further innovation is weak or not reported.

**Entrepreneurial Models That Are Less Dependent on Causal Logic**

Project management has become a dominant method of organizational problem solving and is thus aptly described as an important innovation in how innovations can be achieved (Gemünden, Huemann, & Martinsuo, 2013; Söderlund, 2004). The premise of this article, however, is that additional forms of more radical innovation are needed as organizational and environmental structures and activities become more entwined and their outcomes less predictable. There are significant differences between evidence-informed project management as just described and the logic of projects, following two alternative theories proposed in the next section of this article: open innovation and effectuation.

**Open Innovation**

Open project management can simply be described as seeking solutions to problems from sources outside the innovating unit and its networks. Dahlander and Gann’s (2010) systematic review of the literature on open innovation points to two particularly influential sources describing its nature and importance. Work by Eric von Hippel (1988, 2005) and colleagues (Lakhani & von Hippel, 2003; Von Krogh & Von Hippel, 2003) focuses primarily on innovation by and with customers and/or users and the democratizing effect of new technologies that increase the potential of these inputs. Henry Chesbrough (2003a, 2003b), who coined the term “open innovation,” and his colleagues pay attention to rewards from involving outsiders in the inbound and outbound processes of innovation, primarily within larger firms. The conversations surrounding these two leaders have been largely separate, although West and Lakhani (2000) are recognized for providing an important bridge between the two approaches.

A conclusion from Dahlander and Gann’s (2010) review and a review by Chiaroni, Chiesa, and Frattini (2011) is that open innovation lacks definitional clarity. Further, there isn’t a clear break between prescriptions being developed under this relatively new rubric and what firms have done for some time—form alliances; seek input from customers, suppliers, and others; ask for help from consultants, and so on (Huijingh, 2011).

A second problem is the potential cost of establishing open innovation projects, although some studies, such as those in Deutscher Telekom by Rohrbeck, Hözle, and Gemünden (2009), provide attractive examples of how organizations can benefit from open innovation “without tearing down every wall and opening every door” (2009, p. 429).

The most compelling examples of open innovation are dramatic nonetheless. Evidence of significant gains often begin with a reference to Procter and Gamble’s Connect + Develop program. Vice presidents Huston and Sakkab (2006) describe how:

> By 2000, it was clear that our invent-it-ourselves model was not capable of sustaining high levels of top-line growth. ... Squeezed by nimble competitors, flattening sales, [and] lackluster new launches ... we lost more than half our market cap when our stock slid from $118 to $52 a share. ...

Newly appointed CEO A. G. Lafley challenged us to reinvent the company’s innovation business model. … The strategy wasn’t to replace the capabilities of our 7,500 researchers and support staff, but to better leverage them. Half of our new products, Lafley said, would come from our own labs and half would come through them.

It was, and is, a radical idea. … we estimated that for every P&G researcher there were 200 scientists or engineers elsewhere in the world who were just as good—a total of perhaps 1.5 million people whose talents we could potentially use. But tapping into the creative thinking of inventors and others on the outside would require massive organizational changes. We needed to move the company’s attitude from resistance to innovations “not invented here” to enthusiasm for those “probably found elsewhere.” And we needed to change how we defined, and perceived our R&D organization—from 7,500 people inside to 7,500 plus 1.5 million outside with a permeable boundary between them. (2006, pp. 2-3, emphasis in the original)

The authors go on to outline the development of new networks using company resources, work with intermediaries that had their own techniques for seeking varied inputs, and the creation of strong procedures for internally processing and developing ideas received from external sources. Other evidence shows how these efforts required and stimulated new technology (Dodgson, Gann, & Salter, 2006). The results were impressive. Addison, (2008), another P&G insider, reports that in 2000 “less than 10% of our new initiatives involved external innovation partnerships. … By 2008, the [50%] target had been surpassed and Connect + Develop had become a fundamental part of business within P&G.”

Fifteen years after P&G’s well-publicized commitment, many organizations, including quite a few SMEs (Lee, Park, Yoon, & Park, 2010) have experimented with open innovation projects (Bianchi, Cavaliere, Chiaroni,
1. Recognizing that the organization and its accessible networks do not have the knowledge needed to meet program goals;

2. Framing unmet problems and/or opportunities for broadcast to solvers beyond the normal reach of the organization’s innovation efforts;

3. Waiting for promising answers to the posted problem from volunteers; then possibly facilitating interaction among solvers to improve answers before submission;

4. Evaluating submissions (perhaps with the help of solvers) but also appreciating unexpected solutions with the potential to change the previous definitions of problem and solution;

5. Overcoming not-invented-here resistance within the organization and among its stakeholders to developing and implanting promising solutions from unfamiliar outside sources; and

6. Recognizing solutions to identified problems and also using inputs to reconsider the previous understanding of problem and solution space.

It might seem that developing product ideas in established consumer goods categories or changing the source and language of encyclopedia entries are not radical innovations. But the breadth of content considered in open innovation, the speed and efficiency of increasingly proven processes, and the very large number of information sources utilized provide, by definition, a way of dramatically increasing the previously considered “solution space” for innovation (Von Hippel, 1998, p. 639).

The solution space is especially broad, because the most useful answers to open innovation contests often come from solvers who are the most different from those previously involved in the project; furthermore, successful solvers typically expend very little effort in proposing successful solutions to problems that had stymied smart people for years (Jeppesen & Lakhani, 2010). The reason for both intriguing findings is that solvers with very different experience—sometimes professional but not always—already possess the knowledge to provide an innovative solution to problems that perplex others. This is why new answers from open innovation frequently break the causal logic of past practice and the evidence base it created.

**Effectuation and Path Creation**

Open innovation begins with a well-formulated question that has not been answered with available resources. A different approach to innovation is required when neither the question nor the range of potential solvers can be clearly specified, a project possibility that Turner and Cochrane (1993) identified some time ago. Sara Sarasvathy and colleagues address this situation in varied studies of successful entrepreneurs using the term “effectuation” (Sarasvathy, 2001).

Effectual project innovation can be defined as discovering the goals and means of new innovation by interacting with interested stakeholders who are attracted to an entrepreneurial project as it unfolds. This perspective has radically changed the “distinctive territory of entrepreneurship” (Venkataraman, Sarasvathy, Dew, & Forster, 2012). A dedicated website (effectuation.org) collects a growing collection of academic articles, case examples, and teaching resources. These processes, often used in the creation of new standalone or corporate businesses, are very different than those previously made by researchers and practitioners interested in entrepreneurship (Fisher, 2012).

The Ice Hotel case is frequently used as an introduction to effectuation in practice:

After five years working for a mining company in Kiruna, Sweden, Yngve Bergqvist...took up river rafting. One day, a tourist asked him for a ride on the river. Suddenly, he was in business. He...ultimately resigned from his mining job, and gradually expanded the rafting business to 40 summer employees and 30 boats. But summer in Sweden is short. ... Bergqvist needed to find a winter business to supplement his summer earnings. He had...
heard of Japanese tourists visiting Alaska in winter to see the Northern Lights. ... he travelled to ... Japan for the Snow Festivals, and there he met an ice sculptor. ... The two men planned a winter ice-sculpting workshop in Sweden. [Unfortunately on the day of the exhibition it started to rain and the ice art was destroyed. Bergqvist decided] “Let it be destroyed and we can make something new.” What they ‘made new’ was the ICEHOTEL, which would have a lifespan in tune with the seasons. Employing the skills Bergqvist learnt about during his ice-sculpting projects, the hotel is constructed each winter using ice from the Torne River. ... The business has grown well beyond the size of the original rafting venture, and has further expanded in collaboration with ABSOLUT to create ICEBARS in big cities all over the world. (Society for Effectual Action, n.d.-a)

This case example illustrates key insights, which have been drawn from many studies showing significant decision-making differences between successful entrepreneurs and other managers or novices. First, “projects” that are ultimately described as innovative or entrepreneurial often do not start with clear a priori status. Often actors are motivated by dissatisfaction and dimly perceived opportunities to try informal experiments for a purpose that is clarified only through experimentation. The means or resources initially used for experimentation (where means are broadly described as time, knowledge, social contacts, and other intangible assets, as well as money, materials, and other tangible goods) typically come from what is currently available to the entrepreneur: a principle of effectuation described as “bird in the hand” (Society for Effectual Action, n.d.-b). Partnerships evolve in what is described as a “crazy quilt” pattern of contacts. Dreams of large gain are typically nonexistent or subordinate to concerns about “affordable loss.” It is highly likely that initial efforts are not successful, but those who persist are able to learn from failure (“make lemonade from lemons”). The overall process is clearly not driven by causal logic, but a good deal of attention is given to “piloting the plane” as events unfold.

This way of thinking is very different from the core logic of evidence-informed management and open innovation. The distinction is deeper than process and is based on a different ontology. As noted on the effectuation website, “An effectual worldview is rooted in the belief that the future is neither found nor predicted, but rather made.” (Society for Effectual Action, n.d.-a) or, as Sarasvathy, Dew, Read, and Wiltbank insist: “Effectuators not only design products and organizations, they end up designing the environments they live in” (Sarasvathy, Dew, Read, & Wiltbank, 2008, p. 331).

Effectuation has been explored in several contributions to the project management literature. For example, Midler and Silberzahn (2008) compare the effectual actions of two multi-project startups facing uncertain markets. Morrish (2009) finds principles of effectuation as well as more rational logic when analyzing how 15 entrepreneurs explain the formation of their businesses. Brettel, Mauer, Engelen, and Küpper (2012) examined the effectual and causal aspects of 123 R&D projects. These and many other studies confirm the larger body of work that supports the principles of effectuation. This research also shows that effectual principles are less heavily used as projects mature; yet reemerge as innovation is required for new projects.

Studies focused more generally on organizational change provide additional support for the logic of effectuation. In a particularly important example, Garud and Karnøe (2001) characterize entrepreneurship as “path creation” in tension with path dependence, where “path creation” is based on the assumption that actors can change the world and “path dependence” highlights regularities in the world that affect outcomes independent of actors’ efforts.

An illustrative case can be found in their description of the 12-year process required to bring Post-it® Notes to market. An interview with Spence Silver, the 3M scientist who discovered the weak adhesive that initiated this ultimately very successful product, contradicts simplistic accounts of an innovation that began with a lab failure. Instead, Silver insists that he was deliberately investigating what affected molecule adhesion in his lab. Although this is an observation that does not sit well with a causal story, it is consonant with the idea of an actor being able to make his own future. Silver also notes that he paid attention to the substance that ultimately became the basis of Post-it® Notes because he thought it “looked beautiful” under his microscope (Garud & Karnøe, 2001, p. 13), which again is not typical of causal stories.

Silver persisted in championing the possibilities of his discovery for almost 10 years despite internal and external lack of enthusiasm. For example, a patent was ultimately achieved only with the personal help of 3M attorney Walt Kern; 3M’s patent office was reluctant to persist after the government’s patent office sent a second rejection stamped “THIS REJECTION IS FINAL.” Other early efforts did not go well either. 3M made permanent tape on rolls; therefore it isn’t surprising that Silver’s prototype of a possible new product, a sticky bulletin board, was not enthusiastically received. It would have required developing several new production technologies, as well as a reconceptualized product portfolio (Garud & Karnøe, 2001).

Those who know the basic story will be familiar with the breakthrough insight from Art Fry, another 3M scientist who remembered one of Silver’s presentations when thinking about the frustration of losing the paper markers he’d inserted in his hymnal as a choir member. Almost 10 years after Silver’s discovery, Fry began working on paper notes with a strip of his discovered material on one side. It took two more years, along with the help of several converts from the marketing department who...
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Furthermore, the juxtaposition of these two examples reinforces the idea that effectuation and path creation are known contacts or those known to contacts;

As with open innovation, it may seem that a quirky hotel and a sticky piece of paper are not very revolutionary ideas, but the processes involved and the distinctive offerings developed are unlikely to have been generated from an evidence-base summarizing past projects or from an open call to outsiders for a response to a well-specified problem. Furthermore, the juxtaposition of these two examples reinforces the idea that effectuation and path creation are not theories about individual entrepreneurs; rather they are about collective entrepreneurial action.

Barriers to Change

It is not the purpose of this article to repeat the many ways that individuals and organized entities resist change or might become more open to change. The Project Management Institute's website offers over 150 resources on this subject (see also Bresnen, Goussevskaia, & Swan, 2005). Two issues, however, directly relate to the potential difficulties of adopting new theoretical bases for project management: differences in ontological and epistemological assumptions and fear of failure.

Antithetical Ontological and Epistemological Assumptions

Each of the three approaches to innovation described thus far (evidence-informed, open, and effectual) is based on a different worldview. First, it is widely recognized that the basis of traditional project management is a strong “rational” belief in causal connections, even if local circumstances are expected to vary in detail (Pollack, 2007). Wide acceptance of a rationalist point of view is in part due to widely shared training in using this perspective from a young age. That familiarity and acceptance was needed by a new discipline in order to prove itself (Choi, 2007). Wide acceptance of a rationalist point of view is in part due to widely shared training in using this perspective from a young age. That familiarity and acceptance was needed by a new discipline in order to prove itself (Choi, 2007). Wide acceptance of a rationalist point of view is in part due to widely shared training in using this perspective from a young age. That familiarity and acceptance was needed by a new discipline in order to prove itself (Choi, 2007). Wide acceptance of a rationalist point of view is in part due to widely shared training in using this perspective from a young age. That familiarity and acceptance was needed by a new discipline in order to prove itself (Choi, 2007). Wide acceptance of a rationalist point of view is in part due to widely shared training in using this perspective from a young age. That familiarity and acceptance was needed by a new discipline in order to prove itself (Choi, 2007).
expected to be discovered and created over time. From this perspective, many important things cannot be known with confidence at the outset of a new project. Experimental trials discover not only what is possible, but what might be possible. Epistemologically, what is done now is more important than what is remembered or identified second-hand from the past, which cannot be identical to today’s collection of possible means and ends. This assumption leads to social constructionist methodologies (Sage et al., 2014).

Another important discrepancy between evidence-informed innovation, open innovation, and effectuation involves the agency of leaders. In evidence-informed projects leaders are decision makers in a process that identifies and improves relevant knowledge. Project leaders in open innovation and effectuation projects are more restricted. In open innovation, project leaders are responsible for formulating problems in a language that can be understood and solved by outsiders; they are not problem solvers themselves, though they may judge or participate in judging submitted results. Resistance to this change in perspective has been identified as a reason why open innovation may not be used by managers, even in companies with a strong reputation for innovation (Coles, Lakhani, & McAfee, 2007). Effectuation may seem to offer a stronger “piloting” role to the manager, but from this perspective the objective of the “project” is so tenuous initially that outsiders are needed to help clarify purpose as well as response, which can easily be seen as a further diminution of managerial power.

I believe that these ontological, epistemological, and role differences are dissimilar enough that few if any individuals, projects, or even programs can draw upon them with equal success. Kuhn’s (2012) influential book on the nature of scientific paradigms has facilitated the understanding of different ways of understanding the world and using evidence about it. The recognition of distinct alternatives supports useful but relatively superficial (in my opinion), multi-method and multi-disciplinary projects, the most successful of which allow one perspective to dominate over other contributors. Moving to this article’s focus, my claim is that mastery of different theoretical bases for innovative project management is very important for the field of project management as a whole, but not easy to achieve by individuals or specific projects (Huff, 1981).

Fear of Failure
Theoretically, failure is often seen as a precursor to learning and innovation (Cyert & March, 1963); in practice, it is often not acknowledged, hidden, and overlooked. Starbuck et al. (2008) identify rationalization and defensive behavior on the part of participants as an explanation for this behavior, along with the difficulties of interpreting “noisy feedback” by stakeholders. They also review literature suggesting that success generates replicative structures that narrow attention and limit responsiveness to unanticipated clues from the environment.

Recently, Edmondson (2002, 2011; Detert & Edmondson, 2011) has focused more specifically on the psychological factors affecting individual and team behavior and learning within teams and she has observed that many people learn as children that failure is bad (Edmondson, 2011) and continue to hold this view; McGrath (2011) also points out that failures are often not acknowledged because of career concerns in a world where others simplistically see failure as evidence of personal lack.

A long history of persistent failure and poor performance in organizations confirms these and other problems. Hospitals continue to operate despite long-term unacceptable outcomes; IT systems fail to adequately integrate or protect databases; and construction projects significantly overrun cost and completion promises. Such failures are in part due to structural factors but also caused by individuals who do not raise questions about current procedures; groups and superiors who do not respond to whistleblowers’ (an indicative term in itself) information; and decision makers who fear the
negative economic and reputational consequences of publicizing negative outcomes.

Although more evidence is available (Sage et al., 2014) and needs to be extended, the immediate question is how widespread concerns about project and program failure might be overcome in the most problematic and unpredictable environments. Flyvbjerg (2014), who is concerned about the mega-failures generated by megaprojects, is cautiously optimistic because of “better understanding of what causes failure ... changes in front-end management ... reference class forecasting ... institutional design for better accountability ...” (and) researchers ... feeding their results into the public sphere so they may effectively form part of public deliberation, policy, and practice” (Flyvbjerg, 2014, pp. 15–17). These ideas show promise, but I believe they are limited by their collective attachment to a deviation matching mindset.

Requisite Variety and the Capacity to Invent Something New

Those involved in increasing the evidence-base for successful project management are likely to agree with Ashby’s (1968) summary of the Law of Requisite Variety, especially when project management is referred to in a bracketed elaboration: “ONLY VARIETY [in project response] CAN DESTROY VARIETY [in the problems a project addresses]” (1968, p. 135, capitalization in the original). Rereading Ashby (1968), who focused on the difficulties of identifying relevant variety in a given communication, along with the introduction to a recent reprint of this landmark article by Goldstein (Ashby & Goldstein, 2011) clarifies the problem with Ashby’s dictate, especially when innovation is the goal.

Goldstein identifies the Law of Requisite Variety as a “cornerstone” in first-order cybernetics, yet goes on to say that:

Over the fifteen years after Ashby’s Law of Requisite Variety was first formulated “second” or “second-order” cybernetics came on the scene and emphasis shifted from negative feedback domination to deviation-amplification and self-organizing systems (see Maruyama, 1963; Von Foerster, 2002). This trend has [in turn been] dramatically expanded in contemporary research into emergence, which ... represents the inverse of regulation. Whereas Ashby’s Law of Requisite Variety pointed to a threshold of variety up to which regulation had to keep pace, emergence is founded on an opposite threshold of variation below which emergence will not ensue. (Ashby & Goldstein, 2011, p. 197)

This is a compelling argument for why evidence collection and synthesis are ultimately an insufficient strategy for innovation. As Goldstein puts it:

In the case of emergence, unlike that of regulation, the meaning of goal attainment would need to move beyond that of whatever purpose the system was previously attempting to reach to a more general adaptability. This is because ... emergence adds to the variety of the regulator in order to keep up with increasingly diverse and unexpected disturbances. (Ashby & Goldstein, 2011, p. 198)

By extension, a primary reason for paying attention to open and effectual models of project management is that they can illustrate how a virtually inexhaustible source of variety that is not based on past project goals and experience might be accessed and used for innovation in uncertain and unpredictable circumstances. There are, of course, practical limits to creating and processing variety. Early efforts with open innovation in particular show that it is possible to overload an organization with information from outsiders without yielding compensatory benefit. It is important to remember, however, that experience with open innovation also illustrates how outsiders can do more than provide input; they also can be involved in development and evaluation (Velamuri, Schneckenberg, Haller, & Möslin, 2016).

Ashby and followers in cybernetics and more recent complexity theory believe there is an underlying ontological “system” that may not yet be known but that, in principle, is understandable. Open Innovation as a paradigm generally concurs. Effectuation assumes, on the other hand, that significant portions of the project environment can “become” something that has not existed before. A few sources in the project management literature also assert that at least some aspects of project environments are always becoming something new (Cicmil et al., 2006; Chia, 1995; Linehan & Kavanagh, 2004, cited in Winter et al., 2006). From this “becoming” ontological perspective, as already noted, the past is likely to be a problematic anchor for decision making. More important, when there is not a “given” and understandable context, as Ashby (1968) and many who follow him presume, it does not make sense to develop a “given” set of responses, no matter how flexibly defined. The remainder of this article develops this idea that intrinsic unpredictability requires more unfettered and subjective forms of innovation.

Subjective Project Management

Pollack (2007, p. 267) points out that, in addition to the “hard paradigm” of project management based on positivist and realist philosophies which emphasize control, there is growing acceptance of a “soft paradigm” that attends to social process, interpretivist philosophies, and learning. Svejvig and Andersen (2015) concur. In their review of 74 articles that discuss how project management might be restructured, they “identified a total of 6 papers as objectivistic and 62 as subjectivistic, while 6 papers from the literature review [were] not classified as either”; their conclusion is that those interested in reforming the field “generally subscribe to the subjectivistic soft paradigm” (Svejvig & Andersen, 2015, p. 285).
A dictionary definition of “subjective” includes “existing in the mind; belonging to the thinking subject rather than to the object of thought” and pertaining “to the subject or substance in which attributes inhere; essential” (Subjective, n.d.). Subjective project management might therefore be defined as based on intuition, creativity, belief, values, memory, interpretation of experience, and other cognitive sources, rather than objective, “scientific” logic and evidence that attempts to eliminate the human observer as a component of analysis. This is an individual definition but, more important for project management, it is also a collective definition. The promise of subjective project management is that by explicitly including subjective assessments, the field as a whole might be able to deal with the more essential aspects of projects and programs.

Including soft and subjective evidence and reasoning vastly expands the scope of the profession, because for every “objective” issue raised, there will be many, not necessarily overlapping, “subjective” observations. Further, subjective project management introduces issues that are likely to be ignored by traditional project management. For a quick illustration, consider David Tranfield’s example of bridge building cited above:

[When] considering building a bridge over a river, a civil engineer would ask a series of questions to inform his or her conceptual design such as: How wide is the river? How fast is the flow? How deep is the water? What is the geology like? What are the temperature ranges, wind speeds? How heavy will the loads be, and how large the flow of traffic? (Huff et al., 2006, p. 416)

Subjective questions about the project might include:

1. Should a bridge be located here, given width, depth, geological issues, etc.?
2. What considerations should be added in response to how the ecology of the river might be affected?
3. What might be the consequences of a new bridge for the communities on either side of the river?
4. What kind of design makes sense given existing bridges as well as other structures on either side of the river?
5. Could a bridge facilitate multiple functions, like foot traffic or the movement of boats?

Most project management seems to assume that “someone else” should consider subjective issues. A similar siloed assumption is made by professions involved in other aspects of complex projects. Contractual networks obfuscate responsibility for project framing, implementation, and possible negative outcomes. Does it make sense to assume that human and social concerns will be adequately considered in the political domain alone, given extensive evidence to the contrary? I strongly believe that moral issues and practical concerns are the shared responsibility of individuals, groups, organizations, and professions involved in projects (Huff & Huff, 2001), despite the inevitable increase in complexity that acknowledged responsibility creates.

In fact, subjective interpretations are part of all decisions, whether made explicit or not, and have long been part of the landscape of management theory (Burrell & Morgan, 1979). As projects become more complex and uncertain, it is more important that subjective evidence and theoretic perspectives be made explicit. Sacrosanct measures of timely completion of projects will suffer, but that loss must be balanced against the large number of project failures and negative outcomes from projects carried out from a narrower perspective.

Approaches to Subjective Project Management

Developing a formal typology of subjective project management is far beyond the scope of this article. One promising approach is likely to focus on achieving subjective consensus within a project team (Foss, Klein, Kor, & Mahoney, 2008). A second promising form of subjective project management is likely to focus on collecting and effectively responding to the opinions of stakeholders (Atkinson, Crawford, & Ward, 2006). A third approach might consider possible impacts on future stakeholders. Although there tends to be a hopeful vision of dialectic resolution of different subjective responses raised by such projects (Seo & Creed, 2002; Pascal, Thomas, & Romme, 2013), a more likely outcome is a time-consuming and continuing “multilectic” (Huff, 1981) contest (Bresnen, 2015). From a subjective point of view, this ongoing debate has the value of creating and maintaining a larger gene pool of understanding for future experimentation and decision making. Arguably, subjective project management innovation that creates and responds to unknowable and unpredictable contexts or environments is an even more important contribution to a gene pool that might improve project management in the future.

In a globalizing world, two contextual factors urgently require more project management attention. First, unpredictable interactions among loosely connected institutions and actors are increasingly influential but difficult to anticipate. Debates about the possible global consequences of a significant downturn in the Chinese economy or removing sanctions on the sale of Iranian oil provide examples of how difficult it is for those immediately and less directly involved to agree on the causes and consequences of current and future conditions, much less collectively define goals, strategy, and how to implement them.

A second increasingly important contextual influence on project management innovation comes from the unpredictably contagious responses of individuals and groups, which are magnified and/or ignored by fragmented public media and made more personal by social media. Political contests, such as the incredibly long battles preceding
election of the president of the United States, are examples of influential reverberations between events, media attention, polls, and interactive commentary on social media. Companies are similarly feeling the consequences of interactive media. For example, after decades of a sluggish response to consumer concerns, the public response to an open complaint letter from singer Taylor Swift surprised many when it influenced Apple Computer to reverse its decision within a few hours of announcement and begin paying artists during the trial period of its new streaming music service (Sisaro, 2015).

Project management innovations in environments that are influenced by complicated connections and social interaction might take many forms, but three possibilities seem especially likely: First, innovations led by a creative charismatic leader (e.g., Steve Jobs); second, actions based on ideology, values, or “lifestyle” (environmental movements, religious movements, special interest groups, and so forth); and third, innovative actions that emerge from subjective responses to emerging conditions (e.g., Occupy Wall Street and related movements). All three components are likely to be present to some extent in subjective innovation. The following two examples, chosen for their dramatic and important impact, suggest what might be involved.

**Airbnb**

Consider the world of vacation accommodations. Even as major hotel chains and boutique alternatives continue to innovate around past successes, their world is being transformed in ways that exceed their span of control. In a short period of time, a surprising number and range of travelers have begun to choose more varied and personal accommodations, the kind now available through airbnb.com, a company founded in 2008 that four years later was offering accommodation choices in over 190 countries. Other sites—homeaway.com, tripping.com, rentasofa.com, homeexchange.com, petholidayswap.com, and many more—offer an astonishing number of additional overnight alternatives that respond to and help create an illustrative corner of a “sharing economy.”

**Human connection is critical.** As Rachel Botzman says, radical change in overnight stays is:

using the power of technology to build trust between strangers. This side of Airbnb really hit home to Sebastian [an Airbnb host] … during the [2011] London riots. He woke up around 9 … checked his email and … saw a bunch of messages all asking him if he was okay. Former guests from around the world had seen that … riots were happening just down the street, and wanted to check if he needed anything. Sebastian actually said to me … “Thirteen former guests contacted me before my own mother rang” (Botzman, 2012)

Some of the processes and activities behind Airbnb’s strong interpersonal connections will be familiar to project managers, especially those interested in service delivery. For example, in 2012 co-founder and CEO, Brian Chesky developed a way to organize the team around the pursuit of a perfectly smooth Airbnb experience. He hired a Pixar animator to create illustrations of each stage of what they imagined would be the ideal Airbnb trip, from both the host’s and the guest’s perspectives. They include steps like “browsing for the right place,” “checking out,” and “feeling prepared and ready for guests.” The company divides into teams to tackle the various steps, to bring real life closer to the dream experience drawn in the pictures, which are hung around the office. (Helm, 2014)

This is one of many initiatives that Chesky initiated as he quickly moved on. Despite occasional bad press from hosts, visitors, neighbors, and city officials that called attention to some negative consequences of the rapidly increasing number of Airbnb arrangements, in 2014, Chesky confidently decided that Airbnb will become nothing less than a full-blown hospitality brand, one that delivers a seamless end-to-end experience when its customers travel. Reimagining “the entire trip,” the US$6 trillion travel industry itself … is an audacious goal. (Carr, 2014)

At the beginning of 2015, Airbnb listed over one million rooms in over 190 countries, whereas Intercontinental Hotels Group, the largest traditional hotel chain, offered 674,000 rooms (Intercontinental Hotels Group, n.d.) in “nearly 100” locations around the world. An industry website summarized the discrepancy:

Sites like Airbnb and HomeAway … are the vampires of the hospitality industry, slowly drawing blood away from the hotels, one traveler at a time. They pull out millennia of profit and, as they grow in popularity, they’re only going to make hotels less relevant. (Martin, 2015)

I believe this blunt assessment is not blunt enough. Airbnb and other examples of the sharing economy (e.g., Uber, Zipcar, Kickstarter, and Task Rabbit) are highly valued companies that are rapidly and actively making peer-to-peer transactions a viable alternative to transactions with more traditional service providers. Although regulation and taxation are having some impact on business model details, these newcomers are examples of a more flexible and subjective way of operating that is likely to become much more common in a world where technology has increased the options for individual agency, economic pressures motivate more intensive use of resources, and most people participate in and are strongly influenced by social media.

Airbnb’s ongoing innovations included the November 2014 introduction of Pineapple, a quarterly “lifestyle magazine” sent to Airbnb hosts, where honest stories are told by the unexpected characters of our community. It is a crossroad of travel and anthropology; a document of community, belonging and shared space … to capture the adventure and bring the people, places and communities of

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The company also created a new logo, available on custom postage stamps and as a template for hosts to modify for their own logo (Retrieved from https://create.airbnb.com/en/tool) in late 2014. The rebranding effort was a short-term embarrassment ridiculed by misinterpretations on the Internet (Vinjamuri, 2014). Perhaps for that reason, the second issue of the quarterly magazine did not appear in spring 2015; yet, Airbnb did move in several other directions. “Instant Book” makes it possible to talk immediately with a host about arrival dates without the lengthier process of web-based negotiation. The company also launched a business site, which urges corporate travelers to “be at home, [with] comforts and amenities you are used to ... be closer, with over 500,000 locations ... [and] get inspired ... with your team ... in an inspiring place” (Retrieved from https://www.airbnb;com/business-travel). In addition, the company is advertising at the upper end of the market (https://www.airbnb.com/wishlists/ultimate-luxury-vacation-rentals) and the new company logo is a central part of all these efforts.

It is not surprising that hotels and travel agents and other observers have found it difficult to understand or counter the sharing economy and tend to underestimate its threat. In part, this is an old story of industry evolution led by outsiders with a more up-to-date understanding of what some segments of the market value (Huff, Huff, & Barr, 2006; Porac, Thomas, & Baden-Fuller, 1989). It is not surprising that the profitability and disruption of such efforts lead to coordinated resistance and calls for increased regulation and taxation. But the way in which the Airbnb “project” (or program) is being accomplished does seem new to me. First, sharing innovations have impacted the economy with astonishing speed. A key factor is that they involve varied “participants” in carrying out roles that are carried out by paid workers in other organizations. Airbnb hosts, for example, are centrally involved in designing and advertising attractive lodging; they go beyond concierge services in advising travelers in response to their individual circumstances, sometimes even accompanying them on outings, and they often clean the guests’ rooms when they depart. Similarly, guests search, book, housekeep, and take over other tasks that would have been provided by hotels if their stay had been more traditional. Both parties are actively involved in describing and ranking accommodation experience and each other. Management control, the key to traditional project management success, is present but incomplete and tends to be discrete. Social control, by hosts and guests largely outside of the company’s direct control, is central.

Intangible appeal is critical to success in subjective project management and in this case goes well beyond the provision of less expensive, more varied, and potentially more spacious accommodation. Airbnb is about lifestyle: its website emphasizes “a sense of belonging” as well as inspiration, adventure, and the unexpected. Finding the right accommodation on the site makes it possible for travelers to feel like natives in an unfamiliar but attractive place. Alternatively, the company offers a wide range of accommodations that create a unique experience—from castles to tree houses.

Hosts appreciate the extra income received from an asset they already own or rent; in some cases, this allows hosts to remain in increasingly expensive housing. Many hosts also enjoy the Airbnb lifestyle. They like to “stage” and then see their home on the Internet, and they enjoy the experience of sharing their unique location and local knowledge. Some hosts travel themselves, comparing and improving what their home offers on the basis of what they experience (Yannopoulou, Moufahim, & Bian, 2013). There have been a few inevitable examples of homes damaged, hosts who do not deliver on their promises, and increasing complaints of neighbors who dislike the impact of transient occupancy as Airbnb becomes more popular. As sharing alternatives grow, there also is a more coordinated complaint from hotels about shared accommodations avoiding the regulations and taxes they face. Governments understandably want more control and taxes. But Airbnb continues to grow rapidly. In June 2015, seven years after it was founded to help conference participants find a host willing to let them sleep on an air mattress, the company was valued at US$25.5 billion and raised US$1.5 billion in private funding for further expansion (Demos, 2015).

**Same-Sex Marriage Referendum in Ireland**

A second and more briefly recounted example of an interactive, values-based project that surprised many in and outside the country with its dramatic success can be found in the organizing behind the Republic of Ireland becoming the first country in the world to legally accept same-sex marriage by popular vote. Strongly influenced by the Roman Catholic Church, homosexual acts were not decriminalized in Ireland until 1993; yet in a 60.5% turnout of eligible voters in May 2015, just over 62% voted for the same-sex marriage amendment. The strength of the outcome was attributed to rapidly changing public views about same-sex marriage and declining influence of established religion—in Ireland and around the world—but also to a very effective campaign.

On the Yes side, we had an Obama 2008-style campaign mixing traditional ground campaign tactics with crowdfunding and a highly motivated online following. On the No side, we had a traditional campaign played out over the airways and in the papers with paid-for online advertising. The Yes message stressed positivity, equality, and personal stories, with multiple heavyweight participants. The No message was negative, about sowing doubts with few heavyweight participants.
...The Yes campaign was an amalgamation of a wide range of groups under the Yes Equality banner. ... After an inauspicious start the joint set-up proved a success. ... Groups of 40 and 50 new campaigners, young and old, gay and straight, came together night after night. The central group met every Wednesday to decide on central messaging but in reality it never really changed: keep positive: ask for people's help. ... What mobilised this vote?

Another writer in the *Irish Times* also suggested:

It was not just the messaging. Yes campaigns [and they included political parties] used social media very effectively to encourage younger voters to register [and some 65,000 did] ... One such campaign was the #hometovote phenomenon, which had huge purchase with emigrants. In its own way, this imaginative innovation was the perfect illustration of the way in which the Yes campaign had captured public imagination and popular support. (Suiter, 2015)

While the outcome was a cause for celebration in the Yes community, there was also recognition from many who participated that more work needed to be done in employment equality and other areas. However, within two months supporters also celebrated legislative passage of a gender recognition bill ... [that] makes Ireland only the third European country [and fourth in the world] ... to allow transgender people aged over 18 to change their legal gender without intervention. Ireland's human rights watchdog welcomed the passage of the legislation as the “latest outsourcing” of the recent marriage equality referendum vote. (McDonald, 2015)

On June 26, 2015, the U.S. Supreme Court ruled that same-sex couples have the right to marry in all 50 states, and the Pew Research Institute published a report that indicated “there has been a dramatic shift ... in Americans’ attitudes about gay marriage, with support for same-sex marriage rising from 37% in 2009 to 57% in May 2015” (Maschi & Motel, 2015). The ruling meant that a total of 21 countries around the world, primarily in Europe as well as North and South America, legally accept same-sex marriage.

The academic literature on social movements provides useful frameworks for understanding important aspects of this transition, but there are also interesting parallels with the rapid growth of successful organizations in the sharing economy, such as Airbnb. These include participant involvement in shaping and achieving objectives that require trust, social evaluation and controls, personal appeals to increase involvement, positive frames for action, and fluid strategies.

**Subjective–Interactive Values Based Innovation**

*walker, there is no road,*

*the road is made by walking*

Translation from the poem *Cantares* by Antonio Machado (2003)  
Quoted in Spanish by Stafford Beer (2004, p. 863)

Subjective–interactive project innovation can be defined as interactively communicating and modifying compelling principles from which actions new to the project setting “logically” flow. The distinctive characteristics of this kind of project innovation can be summarized as a process of:

1. Observing environmental changes in the project context;
2. Articulating irresistible opportunity or unacceptable threat/failure in human terms;
3. Interacting with participants to define and promote values-based principles and consequent actions;
4. Mixing values-based strategic activities with proven tactics for change;
5. Altering tactics, goals, strategies, leadership, alliances and so forth as the context unfolds; and
6. Institutionaizing gains to increase the likelihood of continued activity.

This way of acting is based on a world view that is distinct from entrepreneurial approaches discussed thus far. It takes advantage of instabilities created by increasingly complex economic and socio-political connections but is not overwhelmed by them. Unpredictable, potentially contagious interactions magnified by social media are a source of continuing but not overwhelming complexity. Leaders exercise important agency, although they are not really in control of the ongoing flow of events, which is why institutionalization is important as unanticipated opportunities and threats continue to emerge and new responses must be invented. The emerging Possibilities of this kind of subjective, interactive innovation in intrinsically uncertain settings are exciting for those who are energized by its values and vision. But the continuing uncertainty and potential scale of transitory projects is likely to be disconcerting for those affected by new activity they often find hard to understand or counteract.

Ontologically and epistemologically, what happens and what can be known about the future cannot be predicted in these contexts. Rather than looking for stable and objectively defined entities and relationships, it therefore makes sense to focus on process.

Process philosophy is based on the premise that being is dynamic and that the dynamic nature of being should be the primary focus of any comprehensive philosophical account of reality and our place within it. ... While process philosophers insist that all within and about reality is continuously going on and coming about, they do not deny that there are temporarily stable and reliably recurrent aspects of reality. But they take such aspects of persistence to be the regular behavior of dynamic organizations that arise due to the continuously ongoing interaction of processes. (Seibt, 2011)

In comparison with evidence-informed innovation, open innovation, and even effectuation, responding to the current situation and experience,
continues to be critical in these subjective projects, whereas data from the past are likely to be distracting. Furthermore, an expressed “end state” (Lundin & Söderholm, 2013) of the project is not very important. As Karl Weick (1977, p. 225, p. 250) might say, interactive projects rely on sensemaking “punctuation” constructed by actors in a loosely connected ongoing world—a stopping point that is often reconsidered.

A Portfolio of Innovative Project Management Practices

Figure 2 depicts project management innovations as they might evolve in a world of continuing and volatile changing connections and unpredictable social media contagion. If this were a description of the world of project management as it is now, the size and detail of the two interactive circles in Figure 2 would be reversed, with the large amount of available project management practice and research on the left side of the figure overwhelming a smaller circle on the right. But this article is about how project management might become more innovative as “industry clockspeed” increases with continuing changes in “products, processes, and organizational variables” (Nadkarni, Chen, & Chen, 2015), and unpredictable changes in economic and social conditions become more influential.

Figure 2 does not capture the difficulty of shifting from one way of thinking to another. As discussed earlier, inertial forces—including antithetical ontological and epistemological assumptions and fear of failure—are likely to deter movement by individual and social groups. Yet, as complexity and unpredictability increase, acting on the basis of the well-known is likely to be more dangerous. Most individuals are likely to find it difficult to move around the circle, but I believe strongly that project management and other management fields need increased capacity to collectively imagine and create the possible by increasing the diversity of organizational practices.

In support of this objective, Table 1 summarizes the four approaches to innovation described in this article and suggests desirable outcomes for each. The four approaches can be seen as a sequence, though not an exclusive one—other forms of project management innovation are assumed. These theoretical bases from entrepreneurship are chosen as particularly important in intrinsically uncertain environments and they illustrate the increasingly subjective approaches that do not assume the future will necessarily echo the past.

Summary

The growing number of projects focused on innovation in unpredictable environments is likely to push project managers beyond evidence-informed strategies, even if they do not feel the pull of their appeal. Arguably, the experience of trying to innovate in more complex and uncertain settings where available guidelines are not helpful is the best way to learn how to proceed with fewer causal expectations. The hope may be
that once a successful new approach is identified, new field-tested rules can be specified; in fact, the evidence-base for project and program management is expanding to include less generic and more context sensitive guidelines. One contribution of this article may be its support for the continuing importance of these efforts to increase the theoretical base for evidence-informed innovation.

Nevertheless, my basic argument is that objective logic is very likely to be an impediment in unpredictable, disruptive settings. In this context, “unfreezing” past understanding about the world and how to achieve desired outcomes is required, but there is little likelihood of refreezing as contexts and processes continue to unfold. Thus, Lewin’s (1989) influential language is problematic in unpredictable environments (Bartunek & Woodman, 2015) and so are almost all theoretic bases that project managers depend on.

An important question to ask is: Are intrinsically unpredictable environments becoming more dominant? I think they are. A second question is: Can project management as a field overcome significant barriers to change and develop the capacity for more subjective, interactive, and interpretive innovations that appear to be more effective in these settings? Or, will a different set of pioneering actors emerge and begin to professionalize using a more appropriate set of innovative approaches?

### References

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<thead>
<tr>
<th>Evidence-Informed</th>
<th>Open</th>
<th>Effectual</th>
<th>Subjective</th>
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<tbody>
<tr>
<td>We have relevant knowledge and processes to innovate</td>
<td>We can search beyond known resources for innovative solutions</td>
<td>We can collectively clarify ends and means for innovative solutions</td>
<td>We can interactively shape compelling value-based and ideological innovations</td>
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<tr>
<td>Specify project goal and parameters</td>
<td>Recognize that the organization and its accessible networks do not have the knowledge to meet project goals</td>
<td>Tentatively define opportunity on the basis of personal/local skills and experiences</td>
<td>Observe environmental changes in project context</td>
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<tr>
<td>Assemble team and other needed resources</td>
<td>Frame problem/opportunity for broadcast to specified population of unknown solvers</td>
<td>Attract the interest of others primarily from known contacts or those who are known to contacts</td>
<td>Articulate irresistible opportunity or unacceptable threat/failure in human terms</td>
</tr>
<tr>
<td>Search for context-relevant, field-tested rules or guidelines</td>
<td>Wait for volunteers, then facilitate interaction among the most promising to improve performance</td>
<td>Clarify ideas through interaction with potential stakeholders, organizational contexts, and markets</td>
<td>Interact with project participants to define and promote personal actions consistent with value-based principles</td>
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<td>Develop possible solutions informed by past experience</td>
<td>Evaluate submissions (possibly with help of solvers), while also appreciating unexpected solutions</td>
<td>Limit risk and respond to inevitable failures by redefining ends and means</td>
<td>Mix value-based strategic activities with proven change tactics</td>
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<td>Test solutions against project parameters, renegotiating as necessary</td>
<td>Overcome not-invented-here resistance within the organization</td>
<td>Focus on controlling actions rather than predicting the future</td>
<td>Alter goals, strategies, leadership, alliances, etc., as context unfolds</td>
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<td>Conclude project on time, within budget and other parameters, then add information to database</td>
<td>Solve identified problems but also expand view of problem and solution space</td>
<td>Specify outcomes that can be further developed with causal logic</td>
<td>Institutionalize gains to increase the likelihood of continued activity</td>
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<tr>
<td>Increase variety and detail of knowledge base for future action</td>
<td>Increase ability to coordinate internal and external resources</td>
<td>Increase capacity to organically create sustainable outcomes</td>
<td>Increase the number who accept and promote our world view</td>
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Table 1: Four theoretically distinct approaches to project management innovation.


Nadkarni, S., Chen, T., & Chen, J. (2015). The clock is ticking! Executive temporal depth, industry velocity and competitive
Project Innovation: Evidence-Informed, Open, Effectual, and Subjective


Anne Sigismund Huff is Professor of Strategic Innovation Research Development at Maynooth University, School of Business, Maynooth, Co Kildare, Ireland. She is also an Academic Director of CLIC, the Center for Leading Innovation & Cooperation, at HHL Leipzig School of Management, Germany. Her research interests and publications focus on open innovation, cognitive aspects of strategic change, and the processes of academic research publication. She can be contacted at annehuff1@gmail.com
INTRODUCTION

Firms rely on dynamic capabilities to survive, grow, and compete in an evolving technological, market, and regulatory environment. Dynamic capabilities refer to the strategic innovation processes used to adapt, integrate, and reconfigure a firm’s internal and external competences, resources, and routines in response to rapidly changing and volatile conditions (Collis, 1994; Eisenhardt & Martin, 2000; Helfat, 2000; Helfat & Peteraf, 2003; Pisano, 2000; Schreyögg & Kliesch-Eberl, 2007; Teece, 2007, 2012; Teece, Pisano, & Shuen, 1997; Winter, 2000; Zollo & Winter, 2002). Research suggests that dynamic capabilities are required to support organizational ambidexterity by exploring innovation and adapting to rapidly changing environments, while at the same time exploiting current capabilities and routines under stable and predictable conditions (O’Reilly & Tushman, 2008). Despite their centrality in the field, dynamic capabilities remain an amorphous concept for many researchers and managers, which is rarely empirically grounded. Reviews of the literature, including Easterby-Smith, Lyles, and Peteraf (2009) and Winter (2012), call for more in-depth qualitative studies of how dynamic capabilities are created and applied over time in different organizational contexts.

In this article, we respond to a call for further work to understand how dynamic capabilities emerge, evolve, and are applied in different project-based domains (Davies & Brady, 2016; Winch, 2014). Prior research neglects to consider the possibility that organizations establish dynamic capabilities to manage a large, one-off complex project (e.g., airports, urban railway systems, big science experiments, global sporting events, and other large-scale projects) in which many independent organizations work jointly on
a shared activity over a defined, yet often extended period of time. This type of project is led by a client organization that relies on formal contracts and shared collaborative goals to coordinate the activities of multiple parties involved and encourage them to solve unexpected problems or respond to opportunities that may arise. We conducted a longitudinal study of how the British Airports Authority (BAA), a project owner and operator, developed and applied dynamic capabilities to design and deliver the highly complex and uncertain £4.3 billion (US$8.5 billion) Heathrow Terminal 5 (T5).

Although the T5 case is addressed in previous research (Brady & Davies, 2014; Davies, Gann, & Douglas, 2009; Gil, 2009; Gil, Miozzo, & Massini, 2012; Gil & Tether, 2010), none of these studies has examined how dynamic capabilities were developed and deployed to manage the project. When the T5 project started in 2002, the investment was equivalent to approximately two-thirds of BAA’s capital value. The project was crucial for the firm’s survival. It is a compelling case, because the project had to be delivered in a radically new way to avoid the huge delays and cost overruns experienced on other major UK civil engineering and international airport projects in the years preceding it. In response to this challenge, BAA created a separate organization and embodied its dynamic capability in the “T5 Agreement,” a set of flexible, adaptive, and collaborative structures and processes for dealing with uncertain and changing conditions. By balancing innovation and routine action over a fixed period of time, BAA’s dynamic capabilities contributed to the successful construction of the project, but were unable to prevent the chaotic handover to an operating terminal building.

Our study contributes to the project management literature by identifying the three phases in a process—learning, codifying, and mobilizing—showing how firms create dynamic capabilities to manage a large complex project. By highlighting the contested role of dynamic capabilities and their vulnerability to breakdown, we emphasize their continuing fragility. We also contribute to the dynamic capabilities literature by providing an in-depth case study emphasizing the fluidity of dynamic capabilities and their balancing role with respect to demands for stability and change in complex, uncertain, and volatile environments.

Dynamic Capabilities and Project-Based Organizing

This section introduces the main theoretical perspectives underpinning the concept of dynamic capabilities and its application to project management research.

Theoretical Perspectives on Dynamic Capabilities

Dynamic capability is an important and influential concept in management research. Yet research on the topic is often criticized for the lack of consensus on basic theoretical elements, conceptual ambiguity, and scarce empirical evidence (Easterby-Smith et al., 2009; Peteraf, Di Stefano, & Verona, 2013). The majority of the published research on dynamic capabilities is grounded in the resource-based view of the firm (Barney, 1991; Penrose, 1959; Wernerfelt, 1984) and inspired by two main papers (Eisenhardt & Martin, 2000; Teece et al., 1997). Another important stream of research is influenced by evolutionary theory and research on organizational routines (Helfat & Peteraf, 2003; Nelson & Winter, 1982; Zollo & Winter, 2002). Both theoretical perspectives emphasize that dynamic capabilities are learned, patterned, and repetitive activities embodied in strategic processes and routines.

Dynamic capabilities research informed by the resource-based view perspective falls into two main clusters of literature (Peteraf et al., 2013). The first is associated with Teece et al. (1997) and focuses on technology, firm performance, and strategy. Originally developed by Teece and Pisano (1994) and Teece et al. (1997), the concept of dynamic capabilities was introduced to extend resource-based view research by showing how firms adapt, integrate, and reconfigure their internal and external resources to deal with rapidly changing environments. More recently, Teece (2007, 2010) maintains that dynamic capabilities depend on efforts to sense, seize, and reconfigure assets and competencies to keep pace with the rate of change in the environment.

The second cluster builds on Eisenhardt and Martin (2000) and their interest in organizational design and contingency theory. These authors maintain that there are two distinct types of dynamic capabilities, depending on the degree of change and uncertainty in the market environment. In stable and moderately dynamic markets, change in the environment is frequent but largely predictable. Dynamic capabilities based on tacit knowledge, experience, and internally consistent routines built up over years are relied upon to address recurring and predictable conditions. In high-velocity markets, change in the environment is rapid, continuously evolving, and unforeseeable. Dynamic capabilities in this context depend on simple routines, structural principles, real-time learning, and improvisation to master rapidly shifting, unpredictable, and emergent situations (Danneels, 2008, 2010; Eisenhardt & Martin, 2000; Eisenhardt & Sull, 2001). Eisenhardt and Martin (2000) emphasize the fragility of dynamic capabilities, which are “continuously unstable.”

Evolutionary scholars distinguish between dynamic capabilities and operational capabilities (Helfat & Peteraf, 2003). In what is known as the “dual-routines framework,” dynamic capabilities are the “higher-order” strategic processes used to modify or create new “lower-order” operational capabilities in a changing environment (Coriat, 2000; Helfat & Peteraf, 2003; Helfat & Winter, 2011; Knott, 2001; Winter, 2003; Zollo & Winter, 2002). Operational
Dynamic Capabilities in Complex Projects

Dynamic capabilities refer to the stable and predictable tasks that a firm performs by producing and selling existing products or services. Firms engage in a search process of experiential and cognitive learning when current operational capabilities are no longer appropriate in a changing environment and there is a perceived need to adjust or replace them (Gavetti & Levinthal, 2000; Tripas & Gavetti, 2000). Experiential learning is conducted “online” by creating, implementing, and assessing the performance of alternative practices, experiences, and adjustments to existing processes. Cognitive learning involves generating and assessing “offline” analysis, consultations, and experiments without actually implementing new practices or changing the process. Online learning from a series of trials or previous experiences is interspersed with moments of offline deliberation and evaluation.

In an extension of resource-based view and evolutionary research, O’Reilly and Tushman (2008) claim that prior studies have neglected to examine how dynamic capabilities facilitate exploration and exploitation (March, 1991). Dynamic capabilities are not simply about generating change and novelty, but also about performing and maintaining existing operating capabilities. O’Reilly and Tushman (2008) argue that organizational ambidexterity—the strategic processes, behaviors, and specific actions taken by senior managers to mobilize for exploration and exploitation—is a form of dynamic capability. As illustrated in Figure 1, the “simultaneous balancing” of exploration and exploitation involves knowing when to maintain current routines under predictable conditions and when to change them to keep pace with an evolving and uncertain technology and market environment.

The complexity and rate of change facing many firms depends on their ability to exploit and explore at the same time, with distinct sub-units, business models, and alignments for each (O’Reilly & Tushman, 2004; Tushman & O’Reilly, 1996, 1997). Adler, Goldoffas, and Levine’s (1999) study of the Toyota production system identified how metaroutines (associated with dynamic capabilities) are required to balance efficiency and flexibility (Adler et al., 1999). Eisenhardt and Tabrizi (1995) distinguish between two different types of product development projects: a compression model of new product development based on rational, predictable, and sequential processes with predictable outcomes and an experimental model that relies on improvisation, flexibility, and the real-time learning required to deal with uncertainty. Within an ambidextrous organizational architecture, these units are held together by a “common strategic intent, an overarching set of values, and target structural linking mechanisms to leverage shared assets” (O’Reilly & Tushman, 2008, p. 193).

Project-Based Organizing

A stream of research has begun to consider how dynamic capabilities can be applied to various domains of project-based organizing (Winch, 2014). Projects are a form of temporary organization, ranging from standalone complex projects involving multiple participants and independent organizations, to multiple projects that are fully embedded within a firm (Bakker, 2010; Jones & Lichtenstein, 2008; Schwab & Miner, 2008). Much of the prior literature has focused on how project-based firms rely on dynamic capabilities to manage a portfolio of embedded projects (Brady & Davies, 2004; Cattani et al., 2011; Davies & Brady, 2000; Ethiraj et al., 2005; Gann & Salter, 2000; Shamsie et al., 2009; Söderlund & Tell, 2009). A project-based firm conducts the majority of its routine and innovative activities in projects for internal clients and/or external customers (Davies & Hobday, 2005; Gann & Salter, 2009; Keegan & Turner, 2002; Whitley, 2006). There is an emerging stream of project management research on ambidexterity (Pellegrinelli et al., 2014; Pellegrinelli, Partington, & Gerald, 2011; Turner, Maylor, & Swart, 2013; Turner et al., 2014), but it has not yet engaged with the concept of dynamics capabilities.

Several studies recognize that contrasting types of project structures, capabilities, and processes are required for exploitation and exploration (Eisenhardt & Martin, 2000; Pich, Loch, & De Meyer, 2002; Lenfle, 2008). Exploitation projects are organized to achieve predefined goals with a given set of resource constraints. They depend on traditional forms of project management...
based on compressed sequencing tasks and pre-specified instructions. Exploration projects are organized to achieve goals that cannot be easily defined or foreseen at the outset. They require a break with prior routines and capabilities and depend on experiential search processes, real-time learning, and the pursuit of multiple solutions until the best one can be selected (Lenfle, 2008).

While this research helps us understand how dynamic capabilities are deployed by firms to manage multiple embedded projects (e.g., new product development and routine capital projects), it does not consider the possibility that such dedicated capabilities are required for complex, one-off, and lumpy project investments such as in weapons systems, oil and gas platforms, energy networks, rail transportation links, nuclear power plants, airports, manufacturing plants, and research facilities (Flyvbjerg, Bruzelius, & Rothengatter, 2003; Miller & Lessard, 2000; Morris, 2013).

Projects are complex when they are composed of a large number of interdependent components, subsystems, and systems, and when it is difficult to predict how the component parts will interact when joined together as a system. The most complex type of project is large in scale and comprised of a collection of interrelated systems produced by many independent organizations and designed to achieve a common purpose, such as a mass transit urban railway system and major sporting event (Brady & Davies, 2014; Davies & Mackenzie, 2014; Shenhar & Dvir, 2007). What is common to them is the need to coordinate the activities of multiple contracting parties; the high degree of uncertainty at the outset about a project’s goal and the means to achieve it; how much it will cost and how long it will take; and what forms of contract and process are required for dealing with changing conditions and converting uncertainty into certainty as the project progresses toward completion (Hirschman, 1967; Loch, De Meyer, & Pich, 2006; Pich et al., 2002; Shenhar, 2001; Shenhar & Dvir, 2007; Sommer & Loch, 2004).

The challenge of balancing stability and change is clearly important in prior studies of complex projects involving a variety of predictable and highly uncertain conditions (Baccarini, 1996; Brady & Davies, 2014; Brady, Davies, & Nightingale, 2012; Davies & Brady, 2016; Geraldi, Maylor, & Williams, 2011; Williams, 1999). A variety of standardized routines have to be established for dealing with stable, predictable, and known risks, while having the flexibility to adjust plans and modify routines when conditions change (Brady & Davies, 2014; Davies & Mackenzie, 2014; Davies et al., 2009; Lenfle & Loch, 2010; Sapolsky, 1972; Sayles & Chandler, 1971). Sapolsky (1972, p. 250) introduced the concept of “disciplined flexibility” to identify the how certain processes had to be firmly fixed at the outset, while others had to be kept open to address unexpected situations.

Winch (2014) calls for more research on how dynamic capabilities are assembled by owners and operators to manage large, complex projects. Two contrasting types of project owners and operators have been identified in previous research (Brady & Davies, 2014). The first is a permanent client organization, such as BAA, Network Rail, and the London Underground, responsible for executing many routine capital projects and a few less frequent complex projects. These organizations have an opportunity and incentive to develop and apply dynamic capabilities and capture the learning to improve the performance of large, complex projects over many years. The second is a temporary client organization established to execute a single large complex project, such as the Channel Tunnel Rail Link (High-Speed 1), London 2012 Olympics, and Crossrail suburban railway system (Davies, MacAulay, Debarro, & Thurston, 2014). In these projects, a separate operating company (e.g., Crossrail Limited) has to be created for the project to have an owner, and dynamic capabilities are developed from scratch, in a limited period of time, and are dissolved on completion of the project (Dodgson, Gann, MacAulay, & Davies, 2015). In each case, there are pressurized deadlines for project completion, and dynamic capabilities have to be built, codified, and mobilized to deliver a project that may take several years.

**Methods and Data**

Our research design meets several of Yin’s (2003) rationales for undertaking a single-case study and generalizing the findings to theory. Following Alvesson and Sandberg (2013), our study was a critical case for problematizing the theoretical assumptions that dynamic capabilities are restricted to the conditions found in firms responsible for multiple embedded projects and considering whether some alternative or additional explanation is required to explain their use in large-scale and infrequent complex projects. Several papers have studied the T5 project (Gil, 2009; Gil & Tether, 2010; Gil et al., 2012) but none of them has focused on dynamic capabilities. Our case study is revelatory because we had an opportunity to observe and analyze how dynamic capabilities are created and applied in a rich empirical context (Pettigrew, 1990). Our longitudinal study of a single case enabled us to identify how dynamic capabilities for complex projects evolve over a defined period of time.

Our study was conducted between 1998 and 2009. Undertaking a single case extending over such a length of time is difficult, and in our study of BAA we were fortunate in being able to examine key stages in the T5 project’s evolution. Between 1998 and 1999, one of the authors was involved in a research study of small capital projects undertaken by BAA during the planning of the T5 project. While not envisaged as part of a longer-term project, involvement in this prior research was fortuitous because it provided access to real-time data of projects executed while BAA was preparing the approach it used to deliver T5.
Dynamic Capabilities in Complex Projects

This initial study stimulated our interest in how firms develop the capabilities to manage large, complex projects, and our subsequent research was deliberately designed to examine and capture real-time and retrospective data on T5.

Data collection for the fieldwork was undertaken during two periods. In the first period of real-time research during the construction phase (2005–2006), we interviewed 30 people at multiple levels, including the project client’s and contractor’s senior managers and past and present CEOs, project directors, and project managers, and prepared a case study report as a narrative chronology for subsequent analysis and to serve as a validation tool (Langley, 1999). In the second period of retrospective research after project completion (2009–2011), we conducted 10 interviews to capture insights and reflections over a year after the project opening in 2008, including a final interview in 2011, to assist our interpretation of the problems during the operational opening of the terminal. Interviews were conducted primarily with senior managers engaged in creating, installing, and enacting a set of dynamic capabilities. Interviews were conducted with BAA, contractors, and British Airways (BA), the occupier of T5. Interview questions focused on how and why the T5 Agreement was created and applied.

Our methodology involved data triangulation using in-depth semi-structured interviews, documentary material, and participatory observation (Pettigrew, 1990). In the latter case, for example, we attended public presentations on T5, and frequently visited its site. Documents, including the project contract and guide book, company PowerPoint presentations, government reports, project audits, newspaper articles, and the trade press were analyzed. In total, we carried out 57 interviews (including a systematic analysis of 39 recorded transcripts of approximately 60–180 minutes each). Interviews (see Appendix) were based on semi-structured exploratory questions and our initial interpretation of BAA's creation and application of the novel approach for executing the T5 project. Real-time interviews conducted during 2005 and 2006 were manually coded by the author involved throughout the research, which resulted in a 68-page case study report that brought together our findings prior to the project’s completion. A shorter version of the report was shown to several managers involved to verify the accuracy of our findings. A second phase of data analysis included the retrospective interviews conducted in 2009 and a final one in 2011. Our analysis of real-time and retrospective transcriptions was supported by the computer-aided program, NVivo, and coded by an independent researcher who did not take part in the field research. Interviewees are anonymous to preserve confidentiality but identify each individual’s affiliation when he or she was involved in the project.

In an attempt to theorize from our data, we were inspired by Langley’s (1999) call to design process research combining deductive (theory-driven) and inductive (data-driven) methods: “that selectively takes concepts from different theoretical traditions and adapts them to the data at hand, or takes ideas from the data and attaches them to theoretical perspectives, enriching those theories as it goes along” (Langley, 1999, p. 708). We started out deductively by identifying core dynamic capability constructs, including resource-based view and evolutionary perspectives, to formulate our research question; gather “rich” longitudinal data on these perspectives in the setting of a firm responsible for a large, complex project; and make sense of the interpretations used by informants.

We then proceeded inductively by interplaying between data collection and analysis, based on how well the data fitted our emerging understanding and its relevance to the observed phenomenon. Inductive research provides a data-driven way of surfacing new concepts and generating new theories (Gioia, Corley, & Hamilton, 2013). Our informants repeatedly emphasized the importance of the T5 Agreement—a set of collaborative processes, behaviors, and actions to promote flexibility and adaptation. Upon consulting the literature, we realized that our informants were describing how a dynamic capability had been created and applied to balance appropriate responses to stable and changing conditions. Our access to longitudinal data enabled us to identify how firms create dynamic capabilities in a three-phase process that may be applicable to other large and complex projects.

The Case Study

The global airport industry is being transformed by rapid growth in passenger numbers and increasing number of budget airlines, the application of new digital technologies, and concerns for environmental impact and terrorist threats. Airport operators have responded to these and other changes by developing the flexibility to “adjust their plans and designs dynamically over time to accommodate the variety of futures that may occur” (De Neufville & Odoni, 2003, p. 81).

BAA was established as a state-owned organization in 1965, privatized by the Thatcher government in 1986, taken over by an international consortium led by Grupo Ferrovial in 2006, and renamed Heathrow Airport Holdings in 2012. At the start of the T5 project in 2002, BAA owned and operated seven large airports in the United Kingdom. Most of its revenues were generated by charging landing fees to airlines and ancillary operations such as retailing. In addition to operating airports, BAAs large in-house capital projects organization and external framework suppliers were responsible for managing a large program of small-scale routine projects to design, construct, and maintain its airport terminals and facilities. When constructing new airports (e.g., Stansted Airport) or major expansions of existing airports (e.g., T5), BAA established
large standalone and relatively autonomous projects organizations in attempt to manage and contain the high risks involved in such undertakings. The T5 project was established as a separate organization with a direct line of reporting to BAA’s corporate management.

The new terminal was built to be the home of all of BA’s domestic and international passengers at Heathrow Airport with an annual capacity of 30 million passengers. The T5 complex is on a 260-ha site between the northern and southern runways at the western end of Heathrow. It is comprised of a large four-story terminal building (Concourse A), a satellite building (Concourse B) connected to the main building by an underground people mover transit system, and 62 aircraft stands. A second satellite building was completed in 2011. Additional airfield infrastructure, including a 4,000 space multi-story car park, a large hotel, and an 87-meter (95 yards) high air traffic control tower has been constructed on the site. T5 is connected by road links to the neighboring M25 motorway. An underground railway station with branches of both the Heathrow Express and the London Underground’s Piccadilly Line provides transportation to and from London.

T5 was a significant risk for BAA. As BAA’s former CEO put it: “in facing up to this project we knew that any major overrun in cost or time could very easily bankrupt the company. So it was a very high risk project” (BAA interview, 2009).

The project faced a variety of uncertainties and challenges as it progressed through four main stages of its life cycle between 1986 and 2008 (see Table 1).

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<td>3. Construction</td>
<td>July 2002 to March 27, 2008</td>
<td>3.1 Build: Construction started in July 2002 for a planned opening date of March 30, 2008 (later brought forward to March 27, 2008)</td>
<td>Construction of T5 through one entrance on a constrained site, presented huge challenges for logistics, assembly of major constructs (e.g., the roof and air traffic control tower) and safety and efficiency. At its peak, 8,000 people worked onsite</td>
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Table 1: Heathrow Terminal 5 project life cycle.
Dynamic Capabilities in Complex Projects

buildings from July 2001 to March 2008, and the integration of systems and retail fit-out from January 2006 to March 2008. A large network of suppliers, including 60 first-tier, 500 second-tier, 5,000 fourth-tier, and 15,000 fifth-tier suppliers participated in the project, which was divided into four groups of activities: Buildings, Rails and Tunnels, Infrastructure, and Systems. These groups were responsible for 16 major projects and 147 sub-projects, ranging from the smallest, valued at £1 million to larger projects, such as the £300 million extension of the Heathrow Express underground rail station. The project faced a huge logistical challenge of having only one entrance and exit for rapid flows and high volumes of materials, components, and people to a site, adjacent to Europe's busiest motorway, with limited space for storage. At its peak, the project had to manage the logistical problems of dealing with 8,000 workers onsite each day and nearly 250 deliveries of materials per hour. Work had to be undertaken within confines bounded by the daily operations of Europe's busiest airport, operating at over capacity.

During the operational readiness phase, a joint BAA and BA team worked for over three years to prepare systems, people, and processes for the opening. The "start–finish" team worked intensively during six months of systems testing and operational trials prior to opening, including 66 trial openings, each involving 2,500 people, to prepare workers, processes, systems, and facili-
ties for the public opening at 4:00 a.m. on March 27, 2008, three days earlier than planned. Despite these preparations for the opening, in the five days after opening, BA misplaced 20,000 bags and cancelled 501 flights, incurring costs of around £16 million. The terminal achieved the first full schedule of operations 12 days after opening. Although the project experienced significant problems when it opened for service, causing considerable reputational damage, it is perceived to have achieved its goals of designing and building high-quality infrastructure exactly on schedule, within budget, and with a satisfactory safety record.

Findings

This section describes how BAA developed and used dynamic capabilities to create a flexible, fluid, and responsive approach to deal with the conditions encountered during the execution of the T5 project. Written as a novel form of contract and supporting guidebook, the T5 Agreement included the systematic, relatively predictable procedures and structured principles that BAA intended to use on T5 and subsequent major airport infrastructure projects. The T5 Agreement was designed to help managers decide what to do under stable conditions and sense when project tasks had to be modified or replaced.

Based on our coding of the data, the case study narrative is organized into three phases to describe the processes involved in the creation and applica-
tion of the T5 Agreement: (1) a learning phase when BAA recognized the need to change its current practices and engaged in a search to discover and assess alternative ways required to cope with uncertainty associated with the T5 project; (2) a codifying phase when the results of the prior learning were incorporated in the T5 Agreement, creating the principles, structures, and procedures designed to help managers in the integrated project teams address a variety of conditions; and (3) a mobilizing phase when dynamic capabilities were used in practice. The locations of these phases in the literature and analysis of our data are summarized in Tables 2 and 3. Table 3 includes a range of quotations from respondents illustrating the value of the T5 Agreement, but also the tensions within it and resistance to it.

Learning Phase

The first phase in the evolution of the T5 Agreement began when BAA recognized that its existing practices and traditional project management approaches couldn't cope with the uncertainties involved in delivering the project. BAA engaged in a deliberate learning process to create a new set of dynamic capabilities, which involved scanning the environment for alternative ways of doing things, learning offline from previous experiences, and conducting online trials to assess the benefits of implement-
ing the new approaches.

When BAA first began to prepare for the delivery of T5, Sir John Egan (BAA's CEO from 1991 to 1999) found that its suppliers had limited experience in managing a project of this scale, complexity, and uncertainty. As the author of an influential government report identifying major reasons why UK construction projects continually failed to achieve time, cost, and quality objectives, Egan believed that contractors could not be relied upon because they had poor track records in constructing major projects (Egan, 1998). The future operational conditions and uncertain-
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"At outset you didn’t know what the secu-
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Previously the CEO of Jaguar Cars, the automobile manufacturer, Egan wanted BAA to achieve improvements in performance made possible by the lean production techniques used in the Jap-
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the T5 Agreement. In 1993, BAA introduced partnerships called “Framework Agreements” to work with first-tier suppliers on a long-term basis and BAA’s existing projects proved to be a useful testing ground to experiment with elements of the T5 Agreement on a small-scale. This trial-and-error process of experiential learning ensured that any obstacles to effective performance could be detected, diagnosed, and solved. In 1995, BAA created a standardized project management process written as a guidebook, incorporating concurrent design, project planning, and modularity to establish the operating routines required for small capital projects. Although these and other operating processes and procedures (e.g., digital design tools found in aerospace nuclear power, offsite prefabrication in oil and gas, just-in-time logistics in automobiles, and modular store builds in retailing) were adapted for use on T5, BAA was unable to identify an existing approach that could be imported wholesale to manage such a large and risky project.

A search was initiated to create a new way of successfully delivering the T5 project. BAA brought together a core team of managers and consultants with in-depth experience gained on other complex, high-risk projects, such as the Hong Kong International Airport and North Sea oil and gas projects. Successive T5 project directors were headhunted by BAA because “they had a track record for completing projects and thrive on the cross-sharing of capability from best practices found in other industries” (BAA interview, 2006). Members of the team embarked on field trips to other firms, industries, and projects throughout the world to discover how successful practices, technologies, and ideas worked and might be transferred to create a way to deliver T5.

Lessons about bearing risks and working collaboratively in integrated project teams were learned from one particularly large and complex project. While preparing for T5, BAA was involved in the Heathrow Express project connecting the airport with London’s Paddington Station. The project was brought to a halt in October 1994 when one of the main tunnels collapsed after a period of heavy rain. At one point, the project was 24 months behind schedule. Under a traditional fixed-price contract, the prime contractor was accountable for this risk and solving any emergent problems. A typical response to a crisis of this kind would be to sue the contractor for breach of contract. However, BAA recognized that it was ultimately responsible for carrying the risk, because it

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<th>Codifying Phase</th>
<th>Mobilizing Phase</th>
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<tr>
<td><strong>Key activities</strong></td>
<td><strong>Assess the organization’s capabilities and current routines for dealing with future conditions (degree of uncertainty, threat to survival, etc.)</strong></td>
<td><strong>Capture learning gained by deliberate efforts to articulate what works and doesn’t work</strong></td>
</tr>
<tr>
<td><strong>Consider alternatives and learn from other contexts and own experience, consider alternatives, and conduct trials</strong></td>
<td><strong>Design dynamic capability written as simple rules, structural principles, and formal mechanism for promoting possible action under varying conditions</strong></td>
<td><strong>Maintenance of dynamic capability requires learning, tacit knowledge, and ongoing training and capability development</strong></td>
</tr>
<tr>
<td><strong>Search, internally and externally, to test, evaluate, and select components of innovative combination (Nelson &amp; Winter, 1982; Teece et al., 1997)</strong></td>
<td><strong>Codify understandings of prior learning and performance implications in written guidelines, processes or tools (Zollo &amp; Winter, 2002)</strong></td>
<td><strong>Consciously learn, evaluate, and periodically change operating routines to deal with changing conditions (Zollo &amp; Winter, 2002)</strong></td>
</tr>
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<td><strong>Clear need to change routines to resolve a threat to the survival of the organization (Winter, 2000)</strong></td>
<td><strong>Design a systematic procedure, simple rules, and guidelines to reduce task autonomy and variety compared with unfettered innovation (Adler et al., 1999)</strong></td>
<td><strong>Appropriate action depends on environmental conditions, stable and moderately dynamic versus high-velocity (Eisenhardt &amp; Martin, 2000; Eisenhardt &amp; Sull, 2001)</strong></td>
</tr>
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<td><strong>Develop informed judgments “working hypotheses” about future conditions using data, facts, and anecdotes learning offline and from online trials, which are updated as new evidence emerges (Gavetti &amp; Levinthal, 2000; Teece, 2007)</strong></td>
<td><strong>Cognitive representation (e.g., lean production) does not fully specify particular actions to be performed, although it does offer guiding principles, or an outline, for possible action (Gavetti &amp; Levinthal, 2000)</strong></td>
<td><strong>Strategic routines govern how managers intervene and search for solutions (Coriat, 2000; Teece et al., 1997)</strong></td>
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**Table 2**: Three phases of dynamic capabilities in a complex project.
Dynamic Capabilities in Complex Projects

Learning Phase

“I was involved in 1994. I went to BAA and my job was to run the development and construction program and develop the way they did their project, to put in place arrangements for developing projects and implementing projects that would enable them to show continuous improvements in performance. What we were doing was preparing for T5.” (BAA interview, 2005)

“A very clear objective was to make BAA the best client in the country and to have a fabulous team at the center of all that. We realized we had a big change program on our hands. We did this survey upfront to benchmark where our starting point was and we asked our business partners and our customers in the airport what did they think of BAA as a client. We had it done professionally and it came back with a horror story: the client from hell, incompetent, no process. We knew where our base was.” (BAA interview, 2005)

“John’s [Egan] view was go out there into the world and find out what’s best in construction and bring it back here. So I had like £2 million budget for development. We used to spend a lot of time with the Lean Construction Institute in California and we went out and really found out what was going on.” (BAA interview, 2005)

“T5 was about bringing together lessons from many places and [its] success is more because of the breadth of capability we brought together and this willingness to bring in the already known stuff [that] were already being tried in a number of other industries…It was the leap of faith that said we’ll put this lot together.” (BAA interview, 2009)

“What the frameworks brought about was a group of delivery partners that got used to working with one another, working in a completely different methodology, being far more open and transparent, and as a consequence enabled getting better process. These kinds of things are common practice or common place in parts of the automotive industry and aircraft industries and many others. But in the construction industry, it wasn’t the normal route.” (BAA interview, 2009)

“Don’t forget, prior to T5 we’d had a very successful experience of this [collaboration and sharing risk] with our Heathrow Express rail project and on a number of smaller projects along the way. We regarded many of them as sort of training exercises, getting the teams ready to collaborate well, to work out things of sharing pain and reward, ways of sharing risk. So it wasn’t as though it was a clean sheet of paper. We’d tried all these processes before T5 started.” (BAA interview, 2009)

Codifying Phase

“What we wanted to do was to create a form of contract, the T5 Agreement, that actually converted risk into being a positive, where people applied their most capable individuals to understand the dimensions of risk and then how you would mitigate it, how you would manage that risk away…” What we tried to do is say right, risk is something that we need to make transparent.” (BAA interview, 2009)

“The T5 Agreement was a very good mechanism to be able to bring in lessons, to be able to share those lessons for to people to be accountable on our behalf, managing it on our behalf, without the traditional behaviors around worrying about the commercial consequence.” (BAA interview, 2009)

“It was really a document, which defined the way we wanted to work. It was based on very positive things about rewarding success, not penalizing failure and this in turn was based on BAA really carrying all the risk, all the time…At the same time you have to have mechanisms whereby the members of the supply chain that do not perform come under scrutiny and if necessary eliminated.” (BAA interview, 2006)

“It was about behaviors. It was about managing change. We needed to something substantially different and we designed the T5 Agreement, for which for a lawyer was a nightmare because it was full of diagrams as opposed to line items as to what to do when things went wrong. This was a contract to tell you what to do to make sure things don’t go wrong and how you need to behave in integrated teams. It was based on people’s ability to work as a team and people’s ability to trust each other.” (BAA interview, 2009)

“Our design director got the people who had a commitment to delivering T5 to write the processes in the spirit of the T5 Agreement. So it’s thinking very consciously about making a process that would work for all the different parts of work that we had…The tricky bit is keeping the processes “live” and having people who are committed to making them work.” (BAA interview, 2006)

“The T5 Agreement is unique because it’s never been tried and tested in court. The checks and balances that are needed come through years and years of refinement of a normal contract. So to some extent we have to make it up as we go along, the detail of the processes to support the principles within the T5 Agreement. If you don’t display the principles, you don’t consistently apply them, then you can’t expect people to believe in them. So it’s the whole thing about being a disciple of belief and carrying that forward.” (BAA interview, 2006)

“We were very processes-focused [before T5] and not terribly behavior-focused. There was a lot of effort that went into defining the process, writing it down. I just see it as a total change in the way we approach things now…So it was progressive, a realization. We took the step to organize it. So there was this process side which said this was how you were going to live with your project, but we also looked at the way we organized BAA and the supply chain. The behavioral side very much just evolved. I think the difference now is we’re putting a change program. You say “what behaviors can underpin this.” (BAA interview, 2006)

Mobilizing Phase

“When Tony [project director] first came in, I asked what are the three things you want me to handle? [He said] ‘the T5 Agreement, the T5 Agreement, the T5 Agreement,’ because that is the differentiator between us and other projects. Take the commercial risk off people’s shoulders and you have an opportunity to get the right people round the table and different behaviors.” (BAA interview, 2006)
“BAA created an environment to do things differently. They insisted people integrate, co-locate and had a cost model that was fair and equitable and transparent. If you read the T5 Agreement it talks a lot about best practice and world-class performance. We [LOR] invested heavily and worked with our supply chain to support these approaches. Nobody’s really done it and made it successful, so people and suppliers were quite resistant.” (LOR interview, 2005)

“We were building up a framework as to how we were going to tackle various bit and pieces of the project. So you’re really trying to learn individual techniques. We knew the overall approach we were going to take and actually how do you do various parts of it.” (BAA interview, 2006)

“If you know the hierarchy of the T5 Agreement, the suppliers sign a T5 Agreement and they all signed up in 1998. Each supplier gets a supplemental agreement. Everybody else at T5 employs suppliers to design or construct their element of the work through the T5 Agreement. Huge chunks of work are delivered for me and I’m accountable for cost by suppliers with whom I contract.” (BAA interview, 2006)

“Because the client says the ultimate risk lies with me, you’re prepared to be bolder and more honest than you would in the traditional instance. By getting those people [contractors] in early you build a trust relationship with them.” (Rogers Partnership interview, 2009)

“The intervention in this particular case [the air traffic control tower] was to bring all of the parties involved together and to remind themselves of the T5 Agreement, which made quite clear ultimately I held all the risk all the time and what we needed now was a smart solution. That allowed, I think, sanity to prevail and everybody then to concentrate their efforts on finding a way forward that mitigated the problem in hand.” (BAA interview, 2009)

“We’re going to have to compromise here; we’ve got something that’s not working, and make sure that we actually just got the balance right…You get a new tension. There’s a danger that you revert to a traditional approach with the supplier.” (BAA interview, 2006)

“It’s very flexible. We can shuffle things around a lot, which allows us to change things, move things on, much more than you would on a very standard contract form.” (BAA interview, 2006)

“It helps a lot if you have a flexible contractual arrangement. And that is all about knowing when to go from being flexible to actually firming it up.” (BAA interview, 2006).

“When things go wrong, that’s when the quality and robustness of the team is tested and that’s when you either come together to solve a problem or break apart.” (BAA interview, 2006)

“They design are Mott McDonald’s. They work to their program. They are flexible in some ways, but in others they got a program pattern and they need to be sure to be doing that…Working together, we are the design team and we prioritize and re-prioritize work. Basically, I re-prioritize Mott McDonald’s program if there’s a need for it…So in a sense it’s a reality check on the program.” (BAA interview, 2006)

“So coming from an environment from where we had to expose everything we did commercially and production wise, working in a collaborative environment was to say the least a huge culture shock. About 9 months into the program I recommended that we actually got out of the framework when LOR signed up to the T5 Agreement.” (LOR interview, 2005).

“I could not get cross, I did in the end, but it took me a long time, the fact that risk transfer is complete avoidance, it’s not management of risk. [BAA] were two or three years ahead of us [British Airways] in managing this project and in understanding how the joint work and the T5 Agreement actually works and functions. They know the pitfalls and they know the advantages. We would be extremely foolish to go in and pretend that we can do it as well as they can.” (British Airways interview, 2006)

“What I need is, when it goes wrong, because it will, is actually everybody comes together to find a solution, rather than everybody comes together to write a sophisticated book of excuses.” (BAA interview, 2005)

**Table 3: Evolution of the T5 Agreement: illustrative quotes.**

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and contractors over responsibility for scope changes. Poor systems delivery and integration (e.g., in baggage handling), and inadequate operational trials were identified as the main reasons why international airports failed to open on time. BAA predicted that without a radically different delivery strategy, T5 would be £1 billion over budget, one year late, and result in six fatalities.

**Codifying Phase**

In next phase, efforts were made to articulate and codify the knowledge and experience gained from the learning phase with a fundamental reassessment of how the delivery of the project should be managed and recognition that it needed to “change the rules of the game” (BAA interview, 2005). The T5 Agreement was produced to provide a set of simple processes—rules, procedures, and structural principles—to help managers to know when and how to modify or replace its practices and procedures when faced with changing and unexpected conditions. It comprised two written documents: a short and accessible contract and a project delivery handbook.

The T5 Agreement identified the behaviors, processes, and procedures required to create a disciplined but also flexible, responsive, and collaborative organization. The T5 Agreement identified the processes required to deal with change and uncertainty, but also recognized that a project involving a large proportion of planned, recurring, and predictable activities would depend on the ability of managers to know precisely if, when, and how project tasks needed to be performed as originally intended.

The T5 Agreement was based on two structural principles: the client always bears the risk and works with partners in integrated project teams. The 60 first-tier suppliers, which accounted for approximately 75% of the project’s total cost, were all engaged under the T5 Agreement. The project was conceived as a series of customer products delivered by integrated projects teams, including the client and various contractors assembled for each of the 147 sub-projects. The aim was to create a supply chain composed of teams often working in co-located offices.

The T5 Agreement reflected BAA’s decision that the project’s risk should not be transferred to a contractor organization because it was impossible to predict or control all eventualities from design through construction to operational handover. Suppliers were repaid their costs on a transparent open-book basis and incentivized to improve their performance and innovate by bonuses for exceeding previously agreed target costs and completion dates. This flexible contract created “an environment within which our suppliers can actually find solutions” (BAA interview, 2005).

The T5 Agreement specified that work on the project would be conducted in collaborative integrated project teams involving BAA and first-tier suppliers. The contract did not specify in detail the work to be undertaken, but rather was a commitment from suppliers to provide high-caliber people with the skills and capabilities required to perform specific project tasks at the right time, irrespective of their parent company’s needs. Working in tandem with the T5 contractual approach, the collaborative team structure was set up to undermine attempts to transfer risks or apportion blame by holding an individual supplier responsible for failure to achieve an objective. The Agreement specified how the teams were expected to work constructively toward achieving project goals by solving problems, responding to opportunities, and acting on any learning gained, rather than “allocating blame or exploiting the failure or difficulties of others for commercial advantage” (Wolstenholme, Fugeman, & Hammond, 2008, p. 12). The success of each team depended on efforts to improve performance and create solutions when unforeseen problems were encountered, rather than seek additional payments or enter into legal disputes.

BAA strived to ensure that contractual and collaborative principles were clear and unambiguous, so that that they could be communicated and understood by members of the project. The T5 Agreement delivery handbook illustrated how project teams were expected to behave:

“Conventional project logic seeks to predefine all requirements and banish change once the project has started. Yet flexibility and adaptability are key objectives for T5. Conventional processes and solutions are therefore not tenable. It will require flexibility of approach: flexibility of solutions; latest responsible decision making, etc. For this reason processes, practices and deliverables will be firm up in stages.” (British Airports Authority [BAA], 1999)

Essentially, the document was drafted as simple rules and procedures to promote desired practices and behaviors, rather than fixed procedures and detailed instructions that had to be adhered to. It was designed to provide safeguards to correct dysfunctional behaviors and incentives to encourage individual project teams to find innovative solutions to unexpected problems or opportunities.

**Mobilizing Phase**

In the final phase, the T5 Agreement was mobilized so that managers knew when and how planned project tasks and schedules had to be enforced, modified and changed depending on the conditions encountered. As soon as the project began, the “theory of the T5 Agreement was tested” (Egan, 2008); as one project director clarified: “for a number of years we’ve been rehearsing the big game. This is the big game.” (BAA interview, 2005)

The T5 Agreement had to be actively applied and maintained by a large stand-alone project organization established by BAA to run the project that, at its peak, included 300 managers, engineers, and consultants. This level of cohesion and adherence was necessary, because the multiple participants involved were expected to adopt the new behaviors,
and the application of the T5 Agreement often challenged the established operating routines that each participant organization brought to the project.

Informants in our study emphasized the continuing role of the T5 Agreement as an “umbrella” framework and set of principles presiding over and guiding behavior and performance over the course of the project. Our interviews identified a variety of project processes and procedures, ranging from standardized and repetitive construction tasks to deal with known and predictable risks (e.g., project management, production, just-in-time logistics, and operational trials) to more complex design tasks used to help project teams respond in a structure and consistent way to emergent events, such as “progressive design fixity”; a procedure used to avoid freezing designs too early and incurring costly revisions at a later stage (Gil & Tether, 2010). The T5 Agreement created the context within which operational capabilities was performed. For example, digital technologies and practices were adopted to anticipate many problems in advance and coordinate the design, integration, and testing of components during the design and construction phases. The enactment of design practices was overseen by the T5 Agreement: “Ultimately the single model environment flows from our decision on how we’d manage risk and the T5 Agreement attempted to take the normal risk of contracting off the table” (BAA interview, 2009).

Our research revealed that it took time for many participants to understand the new principles and behaviors espoused by the T5 Agreement, and the continual need to reassert its principles reveals its fragility. When first introduced, the T5 Agreement was open to interpretation because many individuals and organizations had little or no experience with the alternative ways of working. As one manager explained: “So our role in BAA is to almost continually reinvigorate, tease out and reinforce that learning, the culture, the way we work together” (BAA interview 2006).

Collaboration, integrated project teams, and risk sharing: challenged current routines, authority structures, and interorganizational relationships. Senior BAA managers intervened on many occasions to encourage project teams to abide to the T5 principles and put them into practice when tackling specific operational situations. BAA invested a great deal of time and resources in communicating how the principles embodied in the T5 Agreement could help project teams to achieve or exceed their targets for performance. As the project progressed, BAA put in place an “organizational effectiveness” program to promote consistent and regular patterns of collaborative behavior across the first-tier supply chain. Providing training and building trust among members of the project were critical contextual factors (Adler et al., 1999) underpinning the implementation of the T5 Agreement.

Interviewees in BAA and suppliers emphasized the importance of “working within the spirit of the T5 Agreement.” While many individuals and firms willingly adopted the behavioral principles enshrined in the T5 Agreement, some actively resisted it. It was designed to provide a stable reference point ensuring that project team practices adhered to uniformly agreed on norms of behavior. Teams that deviated from desired standards of conduct had to be “brought back into line.” As the Project Director at the time observed, BAA was attempting a “change program on an industry-wide scale, against institutionalized learning, and behavior for decades” (BAA interview, 2005). He estimated that one-third of the people on the project understood the behavioral changes required by the T5 Agreement, another third claimed they understood but in practice “they are still on a journey of transition,” and the final third continued according to the “old rules of commercial contracting” (BAA interview, 2005).

BAA tried, not always successfully, to prevent contractors on T5 from resorting to traditional commercial contracting methods by continuously using the T5 Agreement to promote flexibility and reinvigorate collaborative behavior (BAA interview, 2005). For example, in a team led by the main contractor Laing O’Rourke (LOR), Mott MacDonald (an engineering consultancy) had fallen behind schedule in delivering design drawings. When LOR turned to the client for advice, BAA instructed the team to find a resolution “within the spirit of the T5 Agreement” (LOR interview, 2005). After some initial resistance, LOR and Mott MacDonald learned how to work collaboratively and succeeded in finding an improvised solution using 3D modeling to produce digital prototype designs.

The T5 Agreement served as a template and normative goal, providing an opportunity for managers in the integrated project teams to assess whether existing operational routines were appropriate, consider alternatives, set new priorities, and decide what managerial action was required to enforce, modify, or replace them. Two vignettes illustrate how the T5 Agreement was used to generate innovative solutions to unexpected problems or opportunities.

First, the “roof team,” including designers, suppliers, and fabricators, was responsible for one of the most complex and uncertain sub-projects on T5. Guided by the Agreement, the team was encouraged to identify and expose the risks and safety concerns associated with the challenge of erecting roof abutment structures with spans of over 150 meters (164 yards) on site. Their solution was to test the erection of the pre-erected roof structure in advance in an offsite location in the North of England. The pilot trial identified 140 lessons, each with a preemptive risk mitigation plan to enable rapid construction onsite. As one manager put it: “A key success factor on T5—enabled by early involvement with the suppliers and integrated working—is the first run studies and prototyping because getting people early allows you to plan your approach and one big success on that would be the roof” (BAA interview, 2006).
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Although the prototype cost £3.5 million to build, the project was delivered three months earlier than originally planned and saved an estimated £5.5 million (National Audit Office, 2005, p. 5).

Second, the team responsible for erecting the 84-meter high air traffic control tower had to create a novel approach to overcome the challenge of its construction and erection in the short period of time during the night when the airport was not in use. As a NAO (2005, p. 6) report found: "The clear confirmation from the project director was that ‘this is BAA’s problem, not the suppliers,’ which allowed the entire integrated project team to concentrate solely on problem-solving." The T5 Agreement played its role by encouraging the team to collaborate and engage its own localized search by adopting offsite pre-assembly techniques from the oil and gas industry (Matthews, 2008). Delays to the project were minimized and a solution was found without resorting to adversarial practices. "The control tower has got to be an example of where the integrated team working and flexibility was delivered three months earlier than expected (BAA interview, 2006)."

Despite these successes, we found that when faced with conditions that should have prompted reflection and reconsideration of their operational capabilities, interviewees noted that some organizational members consciously ignored the T5 Agreement, preferring to respond by executing past ways of operating, even when things were not working well. Again reflecting its fragility, on many occasions BAA had to intervene forcefully to correct behavior outside of the T5 Agreement.

The application of the T5 Agreement in the supply chain varied during the life of the project. During its first half, the supply chain was composed of 10–15 suppliers with a long history of working with BAA. They were considered “match fit for T5” and ready and willing to work collaboratively when the project got underway (BAA interview, 2005). During the second half, “the landscape started to look quite different, with more suppliers on site, many of them wanting to work in a much more traditional, short-term, transactional way” (Doherty, 2008, p. 239). These problems compounded the difficulties experienced during the final operational handover phase of the project, when the Agreement was not used effectively to reflect on the adequacy of existing operational capabilities and their compliance with the principles of collaboration and risk sharing, and act to prevent the chaotic opening of the terminal.

Interviews conducted at mid-point in the project revealed that BAA was fully aware that the opening could be disrupted by the failure to follow pre-specified operational routines for systems testing, staff training, and familiarization. BAA recognized that the opening could be delayed by a “passive operator [British Airways] who will just stand back,” rather than one who “gets in early, operates early, steals this off you, takes all the learning, does final commission, and witnesses all the testing” (BAA interview, 2006). Although the T5 Agreement was confined to BAA’s first-tier suppliers, BA was expected to understand the importance of working collaboratively and flexibly to achieve a successful outcome.

The T5 Agreement provided BAA’s operational readiness team with an opportunity to review the adequacy of the operational routines established to prepare for the opening and consider whether more effort was needed to enforce or revise them before serious damage was done. Reflecting on the outcome of the project, one of BAA’s senior managers believed that the early success of the T5 Agreement during construction may have contributed to a growing managerial hubris and expectation that the project could not fail. A government review concluded that the tumultuous opening could have been avoided through “better preparation and more effective joint working” between BAA and BA (House of Commons Transport Committee, 2008). A major cause of the problem was BA’s decision to press ahead with the opening in the knowledge that its staff had insufficient training and familiarity with the terminal’s facilities and baggage handling system (Brady & Davies, 2010; Done, 2008; Williams & Done, 2008). In retrospect, one of BAA’s project directors recognizes that more effort should have been made to build collaborative relationships with BA: “It would seem so simple looking back that that was probably the most important relationship of all. It was avoidable” (BAA interview, 2009).

The T5 Agreement’s twin-principles, which worked well during construction, broke down during the handover, with partners blaming each other and no attempt to share responsibility. BAA was confident that the T5 Agreement was easily understandable and transferable, but BA was unwilling to formally adopt it and had not invested in the learning, experience, and tacit knowledge required to make use of it. The problem was eventually resolved when BAA and BA adopted the T5 principles of integrated team working and flexibility that contributed to a successful second batch of moves from Terminal 4 to T5 on June 5, 2008.

BAA’s investment in the creation of the T5 Agreement was considered worthwhile, because the original intention was to develop and apply this dynamic capability on its next major project, to renovate and rebuild existing terminals at Heathrow. BAA aimed to “maintain the wisdom of the organization” (BAA interview, 2006) by reflecting on the learning gained during the mobilization of the T5 Agreement and retaining successful insights, improvements, and tacit knowledge. Despite the efforts invested in creating and maintaining its dynamic capability, BAA jettisoned the approach typified by the T5 Agreement, a decision...
that surprised many in the UK construction industry. The company had been taken over in June 2006 by Ferrovial, the Spanish-owned transport infrastructure company, and in a complete reversal of strategy decided to revert back to the traditional role of client as procurer rather than project manager, relying on “risk-shifting contracts,” detailed up-front specifications, and inflexible routines (Oliver, 2009). 

**Discussion and Conclusions**

**Contributions to the Literature**

This article makes three main theoretical contributions to the literature: (1) it contributes to project management research by identifying how new dynamic capabilities (associated with BAA’s T5 Agreement) are developed through a three-phase process to support the strategic management large complex projects; (2) it draws attention to the contested role of dynamic capabilities and their vulnerability to breakdown, revealing their continuing fragility; and (3) it contributes to the mainstream management literature by emphasizing the fluidity of dynamic capabilities and their balancing role in dealing with the stable and predictable, as well as rapidly changing, volatile, and uncertain conditions. 

We offer new insights for project management research by identifying the three-phased process through which dynamic capabilities are developed to manage a large and complex project involving multiple parties. BAA’s dynamic capabilities were specifically developed to deliver the T5 project and subsequent projects at Heathrow. During the learning phase, BAA used the lessons gained from other projects and industries, as well as its own experience and internal trials to identify the reliable processes, technologies, and collaborative practices that could be used to coordinate the large number of contractors involved in the T5 project. During the codifying phase, efforts were made to articulate a set of flexible, adaptable, and collaborative processes embodied in the T5 Agreement to support the delivery of the project. During the mobilizing phase, BAA had to apply and maintain the T5 Agreement, support specific integrated project teams, and help them balance routine and innovative action in a changing and uncertain project environment.

We suggest that dynamic capabilities is a useful concept for understanding how organizations develop the strategic organizational processes required to manage varying degrees of uncertainty in many large and complex projects. In their study of North Sea oil and gas projects, Stinchcombe and Heimer (1985) argue that firms have to depend on standardized project routines to address predictable conditions and known risks, but they must also be able to innovate when faced with unexpected problems, emerging opportunities, and rapidly changing conditions (Stinchcombe & Heimer, 1985, p. 248). In other words, the extent to which such complex projects rely on routine action or innovation is contingent on the degree of uncertainty present (Shenhar, 2001; Shenhar & Dvir, 2007). In-depth case studies in the past suggest that organizations responsible for complex projects develop the disciplined flexibility—a form of dynamic capability—to maintain consistency, while responding flexibly to coping with changes in technologies, user requirements, and the operating environment (Sapolsky, 1972).

Despite the importance of dynamic capabilities to the successful delivery of a project, their fragility is revealed in the extensive efforts required to mobilize them. Although the T3 Agreement was embraced by most participants and organizations involved in the project, some traditional suppliers were less willing to comply with the core principles of innovation and collaborative team working. When innovation was required to address unexpected problems or opportunities, these firms often fell back on their existing non-collaborative routines and risk-averse, adversarial behaviors. BAA’s senior managers often had to intervene to ensure that the collaborative intent of the T5 Agreement was continuously reiterated. The poorly executed handover from the project to operating airport terminal underlines the vulnerability of dynamic capabilities. Insufficient effort was made to enforce the operational processes for testing the systems and handover trials that were carefully developed in advance to prepare for the opening. In retrospect, managers agree that the T5 Agreement should have been used to review those routines and consider the possibility of revising them when things started going wrong. In the opinion of one manager, the very success of the early stages of the project may have contributed to the hubris and degree of comfort that led to the lack of subsequent lack of attention at later stages. Such misplaced assurance has been noted in the “Icarus paradox” of Miller (1993) and the movement from core competences to core rigidities by Leonard-Barton (1992).

The fragility of dynamic capabilities is further revealed in the way the extensive efforts to learn, codify, and mobilize them with a view to their use in subsequent projects were negated by the company being subject to an overseas acquisition, and the new owner’s decision to resort to traditional approaches—a similar consequence of acquisition for dynamic capabilities was found in the study of Narayanan, Colwell, and Douglas (2009).

By situating our research in a project context we emphasize the role of dynamic capabilities in supporting organizational fluidity. Concerned with identifying contrasting ideal types (Eisenhardt & Martin, 2000), resource-based view research does not fully capture the more nuanced ways in which dynamic capabilities work in fluid situations when stable conditions become volatile or when rapidly changing and uncertain situations become more stable and predictable. Evolutionary research recognizes that the line between dynamic capabilities and operational capabilities is unavoidably
Dynamic Capabilities in Complex Projects

blurry (Helfat & Winter, 2011), but the rigid and rather static assumption that dynamic capabilities are confined to generating change static assumption need for contingent and balanced responses including knowing when to enforce existing operating routines when conditions remain stable and predictable: that is, when not to change.

Our research contributes to debates about fluidity versus efficiency, innovation versus routine action (Eisenhardt et al., 2010; Farjoun, 2010; Schreyögg & Sydow, 2010), confirming the argument that these are not mutually exclusive activities and showing that dynamic capabilities are specific identifiable processes for achieving organizational ambidexterity (O’Reilly & Tushman, 2008). Our study responds to recent calls for research that studies the “pursuit of consistency and change in contexts where variability and change appear to dominate” (Turner & Rindova, 2012).

Our understanding of dynamic capabilities meets Nelson and Winter’s (1982, p. 106) requirements for “flexible performance in which an organization does different things at different times” and responds “with a wide variety of performances to variation in the environment.” As our case study reveals, dynamic capabilities are required to achieve organizational fluidity and flexibility by balancing routine and innovative action as conditions change rapidly, slowly evolve, or stabilize, variously and simultaneously in different parts of the firm. In complex projects, they offer the disciplined flexibility to ensure that original objectives are met within a changing and uncertain environment.

Limitations and Future Research Opportunities

It would be helpful if future research could engage in careful testing of our conceptualization of dynamic capabilities, and explore their actual manifestations and dynamics in other complex projects and enduring organizations that do not have a fixed beginning and end. We recognize that firms deploy dynamic capabilities to balance routine and innovative action not only within one complex project but also across other projects (Davies & Brady, 2016). Research might consider how firms learn how to hone and improve dynamic capabilities to enhance performance from one large, one-off project to the next.

Whereas our research focused on a firm—a repeat client—responsible for a continuing stream of large infrastructure and small capital projects over many years, it would be interesting to explore how dynamic capabilities are assembled by temporary client organizations to deliver one-off projects, such as the delivery partner organizations established to execute many of the United Kingdom’s largest public infrastructure projects.

Given their significance as identifiable, strategic activities, there clearly remains a need for more theoretical and empirical research to advance our understanding of dynamic capabilities in complex projects and how to simultaneously organize for stability and change. There still remains a tendency among researchers and managers to distinguish dichotomously between the routine action in a stable environment and innovative action in changing one (Farjoun, 2010; Schreyögg & Sydow, 2010), but the challenge in most organizations is one of “proportion and simultaneity rather than choice” (Weick, 1998, p. 551), and we show how dynamic capabilities mediate that balance. We hope that our study encourages future research that offers a deeper understanding of the complementary, interdependent, and mutually reinforcing relationship between routine and innovative responses to changing conditions in complex projects. Our research shows how future theorizing about dynamic capabilities could valuably explore their role in providing organizational ambidexterity in project organizations, and should incorporate understanding about their continuing fluidity and fragility.

Acknowledgments

We are grateful for sponsorship from the United Kingdom’s Economic and Social Research Council and Engineering and Physical Sciences Research Council (GR/R95371/01). We thank the many individuals associated with BAA’s T5 project, whom we interviewed and who gave valuable comments on previous versions of this article. The authors thank Gerry George, Niels Noorderhaven, Ray Levitt, Richard Scott, Nuno Gil, Ryan Orr, Lars Frederiksen, Amnon Salter, Jonathan Haskell, Anita McGahan, Markus Perkmann, Richard de Neufville, Michael Schrage, Thorval Haerem, Sam MacAulay, Jonas Söderlund, and seminar participants for valuable comments on the article and presentations of our research at the University of Queensland, Stanford University, Norwegian Business School, the UK Innovation Research Centre (Imperial College London and Cambridge University), the DRUID conference, June 2009. We also thank Jennifer Whyte, Catelline Coopmans, Tim Brady, and Howard Rush who worked on different research phases of the T5 project with us.

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Pettygrew, A. M. (1990). Longitudinal field research on change: Theory and


Williams, I., & Done, K. (2008, April 5). BA optimistic after that was the week that was. Financial Times.


Dynamic Capabilities in Complex Projects


**Mark Dodgson** is Professor of Innovation Management at the University of Queensland Business School, St. Lucia, Queensland, Australia and earned his PhD from Imperial College, London, England. Over the past 30 years, Mark has researched and taught innovation in over 60 countries and has been a director of Nestlé Australia, Thiess Pty Ltd., and the Think, Play, Do Group. He advises companies on their innovation strategies and has been a member of numerous government policy bodies throughout his career. He has written 12 books and over 100 academic articles and book chapters on innovation. Mark is Editor-in-Chief of *Innovation: Management, Policy and Practice*, a journal he founded 16 years ago and is a member of seven other editorial boards. He can be contacted at m.dodgson@business.uq.edu.au

**David Gann** is Vice President for Development and Innovation at Imperial College London and holds the Chair in Innovation and Technology Management at Imperial College Business School and the Department of Civil & Environmental Engineering, London, England. His research focuses on innovation in the digital economy, new business models, and innovation strategy in technology firms. He has worked extensively on innovation in construction in the built environment and was Group Innovation Executive at Laing O’Rourke from 2007 through 2011. He can be contacted at d.gann@imperial.ac.uk
## Appendix: Interviews

### Period 1

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<tr>
<td>04/02/98</td>
<td>Stuart Henderson</td>
<td>BAA</td>
<td>Project Manager</td>
</tr>
<tr>
<td>05/03/98</td>
<td>Chris Ctori</td>
<td>BAA</td>
<td>Project Manager</td>
</tr>
<tr>
<td>27/04/98</td>
<td>Joanna Nice</td>
<td>BAA</td>
<td>BAA Development Manager</td>
</tr>
<tr>
<td>01/05/98</td>
<td>Leon Chasteauneuf</td>
<td>BAA</td>
<td>General Manager</td>
</tr>
<tr>
<td>01/05/98</td>
<td>Michele Soper</td>
<td>MACE</td>
<td>BAA Project Coordinator</td>
</tr>
<tr>
<td>28/05/98</td>
<td>Mark Reynolds</td>
<td>MACE</td>
<td>Project Manager</td>
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<tr>
<td>28/05/98</td>
<td>Amanda Smith</td>
<td>BAA Heathrow Airport Ltd (HAL)</td>
<td>HAL Retail Manager</td>
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<tr>
<td>28/05/98</td>
<td>Karon Taylor</td>
<td>BAA HAL</td>
<td>HAL Property Manager</td>
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<tr>
<td>29/05/98</td>
<td>Glen Tripper</td>
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### BAA Terminal 4 Baggage Handling ABF2 Project

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<td>Mike Nolan</td>
<td>British Airways</td>
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<tr>
<td>05/03/98</td>
<td>David Frazzell</td>
<td>BAA</td>
<td>Development Officer T4</td>
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<tr>
<td>16/04/98</td>
<td>Kevin Petisa</td>
<td>Turner and Townsend</td>
<td>Quantity Surveyors</td>
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<tr>
<td>10/04/98</td>
<td>Morris Felps</td>
<td>Fluor Daniels</td>
<td>Project Controls Manager for the ABF2</td>
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<tr>
<td>13/05/98</td>
<td>Emie Bardircks</td>
<td>Siemens</td>
<td>Project Manager</td>
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<tr>
<td>26/05/98</td>
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<td>BAA</td>
<td>Support Services</td>
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<tr>
<td>04/02/98</td>
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<td>Fluor Daniels</td>
<td>BAA Project Manager</td>
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<tr>
<td>16/04/98</td>
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<td>MACE</td>
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### Period 2

### Heathrow Terminal 5 Project: Within Project Interviews

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<td>Formerly BAA Group Technical Services</td>
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<td>22/10/05</td>
<td>Tony Douglas</td>
<td>BAA</td>
<td>Managing Director T5</td>
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<tr>
<td>29/11/05</td>
<td>Nigel Harper</td>
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<td>Director Performance Improvement</td>
</tr>
<tr>
<td>10/01/06</td>
<td>Andrew Wolstenholme</td>
<td>BAA</td>
<td>T5 Project Manager and Project Director</td>
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<tr>
<td>18/01/06</td>
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<td>10/02/06</td>
<td>Ian Fugeman</td>
<td>BAA</td>
<td>Head Rail and Tunnels T5</td>
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<tr>
<td>13/02/06</td>
<td>Bill Frankland</td>
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<td>15/02/06</td>
<td>Timm Wellens</td>
<td>LOR</td>
<td>Phase 2 Production Leader</td>
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<td>Nigel Harris</td>
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<td>Tony Blackler</td>
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<td>15/02/06</td>
<td>Gavin Milligan</td>
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<td>Matthew Prentice</td>
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<td>Spiros Tsakonas</td>
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### Period 2

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<td>Liz Daily</td>
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<td>John Harris</td>
<td>BAA</td>
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<td>30</td>
<td>14/06/06</td>
<td>Norman Haste</td>
<td>Formerly BAA, now LOR</td>
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### Period 3

**Heathrow Terminal 5 Project: Retrospective Interviews**

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<td>British Airways</td>
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<td>04/08/09</td>
<td>Norman Haste</td>
<td>LOR</td>
</tr>
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<td>3</td>
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<td>Simon Murray</td>
<td>Geoffrey Osborne Ltd</td>
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<tr>
<td>4</td>
<td>17/08/09</td>
<td>Tony Douglas</td>
<td>LOR</td>
</tr>
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<td>5</td>
<td>14/09/09</td>
<td>Nick Gaines</td>
<td>Volkswagen</td>
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<td>6</td>
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<td>7</td>
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<td>Severn Trust</td>
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<td>8</td>
<td>21/09/09</td>
<td>Mike Davies</td>
<td>Rogers Stirk Harbour &amp; Partners</td>
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<td>Andrew Wolstenholme</td>
<td>Balfour Beatty</td>
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<td>10</td>
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<td>Mike Forster</td>
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Floating in Space? On the Strangeness of Exploratory Projects

Sylvain Lenfle, University of Cergy-Pontoise (THEMA - UMR 8184), Cergy, France & Management Research Center, Ecole Polytechnique (i3-CRG, UMR CNRS 9217), Palaiseau, France

ABSTRACT

This article deals with the management of exploratory projects and relies on a case study of the space industry to study their supposed strangeness compared with more traditional projects. Indeed, exploratory projects seem to be floating because they lack clear objectives, carefully defined work packages and phases, risk management plans, and so forth. We rely on advances in design theory to demonstrate that exploratory projects actually follow a different logic of expansion that can be managed. We conclude by discussing the contribution of the project mode to the structuring of exploration processes.

KEYWORDS: exploration projects; design theory; space industry

INTRODUCTION

The strategic role of innovation in today’s competitive environment has triggered a revolution in the way firms organize the design of new products. Project management plays a central role in this process (see, for example, Fujimoto, 1999, for a study of the evolution of project management in the automotive industry). Projects constitute an efficient way to organize the innovation process; however, there are well-known limits to the dominant, rational approach to project management. Its underlying hypothesis has been criticized (Hodgson & Cicmil, 2006; Nightingale & Brady, 2011), as has its “one-size-fits-all approach” (Shenhar & Dvir, 2007). In particular, the “rational” view of project management as constituting the accomplishment of a clearly defined goal within a specified period of time, and in conformity with certain budget and quality requirements, does not fit with the logic of innovation that is characterized by divergence, discovery (Van de Ven, Polley, Garud, & Venkataraman, 1999), and unforeseeable uncertainty (Loch, De Meyer, & Pich, 2006). This unsuitability gives birth to a research stream on the management of exploration projects (Brady & Davies, 2004, 2014; Frederiksen & Davies, 2008; Lenfle, 2008, 2014; Loch et al., 2006). In exploration projects, neither the goals nor the means to attaining them are clearly defined from the outset, since “little existing knowledge applies and the goal is to gain knowledge about an unfamiliar landscape” (McGrath, 2001, p. 120). The literature helps, as we will see, to define exploration projects, identify management principles, and discuss their organization.

However, we are still at the beginning of the research on exploratory projects. Case studies are rare and, therefore, we have not developed an understanding of the specific logic underlying the unfolding of exploratory projects. Following Hällgren, Nilsson, Blomquist, and Söderholm (2012), we believe that this understanding should be grounded in an analysis of what is really going on in projects—that is, of their actuality. The goal of this article is to contribute to the study of exploratory projects by focusing on the actor’s practices to manage these “strange” projects. Indeed, compared with the ingrained, rational approach to projects and its stage-gate logic, exploratory projects look strange. They lack clear objectives, carefully defined work packages and phases, and risk management plans. In other words, they seem to be floating. By investigating this strangeness further, we demonstrate that exploratory projects are strange only if we retain a rational perspective that, historically, is rooted in decision theory (Söderland, 2011). This article is in line with those who, like Verganti (2009), Le Masson, Well, and Hatchuel (2010), or Hobday, Boddington, and Grantham (2011, 2012), argue that in order to fully grasp the logic of innovation we have to abandon “the traditional view of the firm as a rational, machine-like entity by drawing on the social and creative character of businesses revealed in design thinking” (Hobday et al.,...
Floating in Space? On the Strangeness of Exploratory Projects

2012, p. 18). The same is true for project management research. Therefore, a switch to design theory (Hatchuel & Weil, 2009) helps us understand the specific logic of exploratory projects. Through this perspective, we show that these types of projects are not floating at all. On the contrary, they follow a logic of expansion of concepts and knowledge that can, in fact, be managed (Lenfle, 2012; Gillier, Hooge, & Plat, 2014). However, to do that, we will have to dig deep in order to understand the design reasoning of the project participants. To study this question, we conduct research in the space industry that lies (with the military) at the origins of modern project management and, as we will see, can be considered an archetype of the dominant model of project management. The emergence of new types of exploratory projects in this context raises important questions that will help us improve our understanding of their specific features.

This article is organized as follows: The second section provides a brief overview of the literature on exploration projects. The third section presents the context of the space industry and research design. The fourth section deals with the emergence of "strange projects" in space telecommunications. In the fifth section, we dig deeper into two archetypal cases of strange projects. The cases are further analyzed in the sixth section in light of design theory. Finally, the seventh section discusses the contributions of this research to the literature on exploration projects.

Literature Review

A rich body of literature exists on the limitations of the rational approach for innovation and the management of exploratory projects (Davies, 2013; Nightingale & Brady, 2011). Since the landmark contribution of Shenhar and Dvir (2007) on the limitations of the "one-size-fits-all" approach to project management, a growing body of research has focused on the management of exploration projects that seek to develop radical innovations. This research stream leads to important results. In this brief review of the literature, we emphasize five principles (extending upon Lenfle, 2008, 2010):

1. In line with the literature on ambidexterity, it is necessary to differentiate the management of exploratory projects from that of more traditional, exploitation-oriented projects (Tushman & O’Reilly, 1996; Christensen, 1997; Burgelman, 2003; Shenhar & Dvir, 2007). Indeed, the blind application of a single, control-oriented method to all projects would surely reduce innovation. This is particularly true of the stage-gate process of project management. Sehri and Iqbal (2008) demonstrate the irrelevance of this process, now widely used, in situations where radical innovations are being made. They show that stage-gate processes lead to what they call "project inflexibility"—that is, the inability to change the project’s goal after initiation. This, they argue, leads ultimately to failure. Thus, the literature on exploration projects emphasizes the need to differentiate between types of projects—for example, by setting up a dedicated and autonomous project team to manage radical innovation, as was done with the famous Skunk Works® invented by Lockheed during World War II. However, the literature on Skunk Works is very sparse, to say the least (Rich & Janos, 1994), and more information is needed on the inner working and governance used for the project (Lenfle, 2014). More recently, Dugan and Gabriel (2013) have offered an inside look at the functioning of the (very) exploratory projects carried out by the Defense Advanced Research Projects Agency (DARPA).

2. Experimentation plays a central role in exploratory projects. This is in line with the literature on innovation management (Van de Ven et al., 1999; Thomke, 2003) and corporate venturing (Frederiksen & Davies, 2008). In particular, the work of Christoph Loch and his colleagues demonstrates the irrelevance of classical risk management when projects are confronted with what they call unforeseeable uncertainties (or "unk unks") (Loch et al., 2006; Sommer, Loch, & Dong, 2009). In such cases, it is impossible to identify the risks. Therefore traditional risk management methods crumble, requiring organizations to identify different managerial strategies to handle these situations—namely, selectionism (experimenting with different situations simultaneously) and learning (trying different solutions one after the other). Instead, organizations may conceptualize projects as “experimental learning processes” during which the goals and the means to reaching them are progressively defined during the course of the project. Such experimental learning strategies actually have older roots (e.g., Brady, Davies, & Nightingale, 2012; Klein & Meckling, 1958), but they had largely been forgotten during the institutionalization of project management (Lenfle & Loch, 2010).

3. Another important principle points to the need to explore the technical and market dimensions of the innovation simultaneously. Gastaldi and Midler (2005) coined the term concurrent exploration to define this strategy. The goal is to avoid the symmetrical traps of useless technology and inaccessible needs.

4. The fourth important principle is that the “results” of exploratory projects are different from those of traditional projects. Exploratory projects do not necessarily lead to physical objects. They help to map an “unfamiliar landscape,” build new competencies, or explore original concepts. Rather than convergence toward a predefined goal, what is important in exploratory projects is to identify promising concepts that will be developed later (Lenfle, 2012). Reflecting on the journey is...
fundamental, and projects should be evaluated from the “products” they deliver as well as the knowledge they create (Jansiti & Clark, 1994).

5. The last challenge identified in the literature follows from the previous point. Because exploratory projects are “experimental learning processes,” it is important to develop managerial methods that will help managers assess the “progress” of the project. Reflection in action (Schön, 1983) is fundamental because the goals will be defined during the project. In particular, the challenge is to manage the expansive nature of these kinds of projects (Gillier et al., 2014). No doubt this constitutes a major question for future research.

These are all important contributions that lay the foundations for a model of exploration project management. However, we are only at the start of research on this question. We have to dig deeper to understand the difficulties encountered by actors in charge of this type of project as they manage in environments that, generally, are ingrained with a rational approach. The implementation of these principles in practice is far from evident. As we will see, these principles require a change in design reasoning. In the next section, we present the context of the research, the space industry, and our methodology.

Context and Research Design

Research Method

This research takes place within the French space agency (known as the Centre National d’Etudes Spatiales, or CNES). In cooperation with partners (industrial firms, research laboratories, public agencies), it is in charge of the definition and implementation of French space policy (both civil and military). Created in 1961, CNES is one of the world’s leading space agencies, with an impressive record of success, among which are the Ariane rocket (now the leading launcher in the world), the SPOT lineage of imaging satellites, and the development of operational oceanography, starting with the Topex-Poseidon mission.

Our research unfolds in this context. It is part of a long-term research project that started in 2010 and is still going on. The general goal is to study the strengths and weaknesses of current innovation process at CNES. Indeed, CNES is confronted with important changes in its environment, the most important being the emergence of new competitors such as SpaceX in launchers and the growing demand from diversified stakeholders (government, NGO, and regional and global agencies) to provide “services to society,” in particular in the domain of climate monitoring. This is especially true for space telecommunications, which represents by far the biggest market of the space industry (more than 50% in terms of revenue) and in which innovation plays a central role. This was the focus of the third phase of the research.

Data collection was performed during a 12-month period from February 2013 through January 2014. As we will explain below, we focus our research on the portfolio of telecom projects over the past 15 years in the telecommunications industry. Our goal was twofold: first, to understand the logic of the entire portfolio, and second, to study in more detail some projects we consider representative of the ongoing evolutions. To do this, we rely on two types of data:

- We conducted 12 semi-directed interviews with nine people involved in the management of these projects (see the list in Table 1). They belonged to functional department (technical or strategic) or were project managers. The interviews lasted from 1 to over 5 hours. They were tape-recorded and transcribed. Email exchange or follow-up interviews were used when necessary to clarify some points; and
- We had access to CNES annual reports from 1980 to 2012 (with the exception of 1989, 1992, 1993, 1996, and 2009) to cross-check the interviews and get a global picture of the evolution of the CNES telecom strategy over the long run.

Following the paradigm of grounded research (Eisenhardt, 1989; Miles & Huberman, 1994; Yin, 2003), our analysis was built on interview transcripts that were compiled into case studies for the different projects. This process was iterative. The cases were updated after follow-up discussions with respondents. The final research report was reread by key informants and discussed during

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<td>FLIP Project Manager</td>
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<td>02/12/2013</td>
<td>Mr. JPD</td>
<td>AGORA Project Manager</td>
</tr>
<tr>
<td>11/12/2013</td>
<td>Mr. HG</td>
<td>Manager—Strategic Planning Department</td>
</tr>
<tr>
<td>11/12/2013</td>
<td>Mr. JPA</td>
<td>Head of Telecom Research and Technology Studies</td>
</tr>
<tr>
<td>11/12/2013</td>
<td>Mr. DP</td>
<td>Manager—Telecom Research and Technology Studies</td>
</tr>
<tr>
<td>11/12/2013</td>
<td>Mr. JS</td>
<td>Senior Technical Expert</td>
</tr>
<tr>
<td>13/01/2014</td>
<td>Mr. JPT</td>
<td>FLIP Project Manager</td>
</tr>
<tr>
<td>13/01/2014</td>
<td>Mr. CA</td>
<td>Head of Telecom Strategic Planning Department</td>
</tr>
</tbody>
</table>

Table 1: List of interviews.
research meetings. These meetings simultaneously enabled the results presented to be confirmed and the directions taken by the research to be discussed.

The Space Industry as an Archetype of Rational Project Management

The context in which this research takes place is of particular significance for our argument. The space industry constitutes an archetype of the rational approach of project management. We can even argue that the rational model has its roots in the aerospace industry. Most of the current tools of contemporary project management come from the U.S. aerospace sector, be it military (the Department of Defense) or civilian (National Aeronautics and Space Administration, or NASA). Most notably, Stephen Johnson (2002a, 2002b) documented the rise of the system approach in U.S. ballistic missile projects and the transfer of these practices to NASA during the Apollo project (see also Seamans, 2005). This gave birth to a model of project management that emphasizes the control of project execution through a phased approach; the use of managerial tools to control time, cost, risk, and quality; and the setting up of strong project structures to implement this approach.

This method of project management is still dominant in the space industry today. The goal of a typical space project is to design a new object (typically, a new satellite) with requirements that have been defined by the customer (e.g., the government, a private firm, or scientists). And there are good reasons to follow a phased approach, given the following: (1) the technical complexity of the objects, (2) their very high cost (€300 million for a typical satellite), and (3) the irreversibility induced by the launch in space (i.e., if the satellite/launcher fails it is forever lost). The phased approach is thus a wise solution to ensure the quality of the design work and the reliability of the object from the drawing board to the launch pad. In this logic, each stage is able to reach a higher Technology Readiness Level (the famous TRL, that originated in the space industry). Projects typically unfold in this manner at CNES; the actors frequently refer to it as “tunnel logic.”

As explained in the previous section, the strengths and weaknesses of the rational project management approach are well documented in the literature. The great strength of this type of approach is the application of process control techniques developed for production to the design work. Such processes have been shown to improve control of the convergence toward the predefined goal in terms of cost, quality, and delay. For complex, high-cost projects such as those mentioned above, there probably is no alternative to the rational project management approach. But problems arise when this approach is blindly applied to all kinds of projects (see Sehti and Iqbal’s 2008 discussion of project inflexibility in the previous section). At CNES, the problem appeared with the emergence of “strange” projects at the end of the 1990s.

The Emergence of “Strange Projects” in Space Telecommunications

Our interest in space telecommunications was triggered by a presentation by Mr. FP, the head of the navigation and telecommunications projects at CNES, during a one-day workshop dedicated to innovation management in the agency. During his presentation, Mr. FP explained that in the telecommunications sector, CNES was increasingly encountering what he calls “strange projects.” In order to illustrate his idea, he presented a slide with Hieronymus Bosch’s famous painting, The Garden of Earthly Delights (see Figure 1). He used the unexpected and confronting nature of the elements in the painting as a metaphor for his perception of a mismatch between the “strange projects” and the phased approach that typify project management at CNES. Indeed, the projects he supervised looked nothing like those defined in classical project management frameworks: The goals were not clear in the beginning, the projects worked on new concepts and not necessarily with objects, it was hard to define deadlines, and they were frequently changing.
occurred in space telecommunications, which constitutes, by far, the most important application of space technologies.¹

Four points are worth noting:

- First, the deregulation of the 1990s transformed the space telecommunications sector from a monopoly-dominated industry to a highly competitive one, dominated by private firms (primarily from the United States but also including European firms). The major consequence of this shift for CNES was the loss of its traditional customer: France Telecom. The shift also raised the question of what role a public agency should play in this context.

- Second, innovation plays a central role for firms in maintaining a competitive position, particularly in Europe, which does not benefit from large contracts from the U.S. Department of Defense. If a firm fails to develop a technical innovation, it could be excluded from the market. In space, telecoms innovation has been, at least up until now, clearly sustaining (Christensen, 1997). Over the past 40 years, the logic has been to regularly increase the power of satellites (from 40W in the 1960s to 20kW in the 2000s) to satisfy new uses (typically, TV diffusion, communications, and so forth). Doing this, however, raises huge technical challenges (such as more precise machining of antennas, complex management of radio frequencies, heavier and bigger satellites, and so on) and explains the relative slowness of the innovation process: For example, it took 10 years to change from C & KU to KA band frequency, which is more useful for broadband Internet applications. Indeed, given the high costs of a telecom satellite, operators are reluctant to invest in a technology with fuzzy uses and unclear market potential.

- Third, the space telecom ecosystem is extremely complex, with at least three different levels: (1) the space segment (that is, satellites and their control centers); (2) the ground segment (telecom networks and the associated devices); and (3) regulating agencies (the International Telecom Union for the management of radio frequencies). Consequently, each innovation proposed by space telecoms must be compatible with all the elements of the ecosystem. Furthermore, some blocking points may appear in “odd places”; far from CNES’s core competencies, these blocking points typically involve mobile devices that must be able to receive space satellite signals.

- Last, but not least, the problems are complicated by the mismatch of temporality between space telecoms, with their long development cycle, and ground telecoms, which have very short development cycles. Although the development cycle of satellites themselves is quite short (approximately 36 months), satellites are designed for 15 years of life in space. Therefore, given the 10 years of research necessary to develop a new technology, the challenge, as one CNES engineer explained, is to “design now a satellite which will still be useful in 25 years.” (interview with Mr. CA)

A New Logic at CNES: From Satellite Design to Concept Exploration

Historically, as is clear from the interviews and annual reports we used for our research, the main role of CNES was to act as the chief designer of satellites. These included operational satellites (such as Telecom 1, launched in 1984) or technical demonstrators (prototypes that incorporate the latest technologies to demonstrate their usefulness and feasibility) (see Figure 2). The focus on hardware design has ended now as a result of

¹Satellites are mainly used for TV diffusion (TVs represent 68.7% of the revenues of Eutelsat, the main European operator), but they are also used for communications or to bring Internet access to remote areas.
the growing role of private firms in satellite design and because demonstrators are now considered too costly and risky. Indeed, the last of them, called Sten-tor, exploded with Ariane 5, 7 minutes after launch in December 2002 after a 10-year development process and more than €300 million spent. This accident had major consequences for CNES. Its role has evolved from chief designer to a more ambiguous position of “support for industry competitiveness,” as explained in CNES reports. CNES’s role now encompasses all the activities needed to help the space telecommunications industry maintain its technological potential in a context where intense competition limits private firms’ R&D spending. This evolution, which is actually a rather broad and fuzzy mission, raises major questions for an organization that was originally structured to design satellites. Indeed, this triggers a fundamental change in the design process, which shifts from designing objects (satellites) to exploring concepts that may be interesting to support competitiveness. The immediate consequence of this evolution has been a radical change in the content of CNES’s projects, which have shifted from hardware design to concept exploration and/or competence development. It is beyond the scope of this article to describe in detail all the telecommunications projects launched by CNES during this period. It is nevertheless useful to provide an overview of the portfolio projects (Figure 3) and their content (Table 2).

Figure 3 and Table 2 show that the content of many projects has shifted from hardware design to concept exploration and that the exploration focuses simultaneously on satellite payload and the telecom system as a whole. This change has led CNES to gradually map the innovation domain, develop its competencies, and build legitimacy for the industry as a whole. It is possible to identify three lineages of projects—that is, a succession of projects focused on the same applications:

1. The first lineage is oriented around the development of competencies and the study of generic questions (such as flexibility). These projects allow CNES to partner with industrial firms. This category includes the ATF, BV, FLIP, FAST, and GEICO projects.
2. A second lineage is centered on space telecommunications for Internet access in remote areas. These include the AGORA, ATHENA, MM2G, and THD-SAT projects.
3. The third lineage focuses on mobile broadband access and includes the SDMB, A-TVS, SWIMAX, and SMILE projects.

Our data reveal that this rich and fruitful exploration has been made possible by the (rare) convergence of four factors:
The operators wanted to reallocate frequencies, change the coverage area, and modify the power of the satellite, but it was unclear how to best do this, especially as it needs to be done without raising the costs of the payload. With this in mind, the FLIP team started the project. They had requirements defined by the strategic planning department, as well as “research and technology” studies that identified some promising new technologies. Because the goal was to complete the project quickly, the team decided to start the project directly with the detailed design (known as B-phase in the CNES project process—that is, the proof of concept is already done). However, they quickly became dissatisfied with the initial requirements and the technologies proposed by the Research and Technology Department, which seemed promising but were not ready for development. Therefore, in 2007, they decided to start a new round of interviews with operators to get a better understanding of their needs. This process lasted 18 months and led the team to identify 27 types of missions, which they grouped into seven different families (including, for example,
Concerning the antennas, a central component for enhancing flexibility, the project team decided to reconsider the way antennas were designed. The dominant design was mechanical, with an extremely precisely molded antenna designed to cover a predefined area that was completely nonflexible. To overcome these limitations, the team explored electro-mechanical designs. Here again, different solutions were studied, some of them not appropriate for short-term applications but still worth exploring because they allowed the development of fundamental competencies for future antennas. This is the case of the X-antenna: It was too heavy and too expensive but it led to the development in France of new production processes that, until now, had been mastered by only one U.S. firm.

Finally, FLIP give birth to multiple results: It delivered a product for short-term needs, developed new process technologies, mapped customer needs, built competencies for payload design, created generic products, and new chips that will be developed by another project (FAST, 2012–2017).

**SMILE** (Satellite Mobile Innovation Laboratory and Engineering)

The SMILE project (2012–2017), like FLIP, is an archetype of the strange projects described previously. It is part of a larger reflection on the role that space technologies could play in the rapidly expanding domain of mobile communications. Although satellite phones have existed for 15 years, they remain part of a small market niche. The development of space technologies toward mass-market applications is therefore a strategic question first studied at CNES by the SDMB project (2004–2006). The goal was to develop a solution to broadcast multimedia content directly to mobile phones in remote areas. The feasibility study conducted by CNES was so promising that Alcatel Alenia Space (AAS), a leading aerospace manufacturer, joined the project. The B-phase was thus co-financed by CNES and AAS. It led to the creation of a joint venture between the operator Eutelsat and AAS to develop a new payload. Launched on the W2A satellite in 2009, it unfortunately suffered from technical problems after launch that will limit the satellite to experiments. The project nonetheless demonstrated space technology’s interest in multimedia broadcast on mobile phones and the competencies of CNES within this domain. Following SDMB, CNES has launched several feasibility studies on various aspects of the question (ATVS: TV on mobile, SWIMAX: Internet access, technical standards), but none of them has led to a B-phase. Considering the potential of these applications, however, CNES launched the SMILE project in 2012 to continue the exploration. Given the relentless evolution of the fast-paced telecom industry, the goal was twofold: first, to ensure that space technologies remain a solution for the industry (indeed, if regulators decided that the frequencies dedicated to space telecoms are reallocated to other uses, then the space industry would be ruled out of the ecosystem), and second, to study technological solutions in order to be ready if a window of opportunity opens.

Indeed once a user is convinced of the relevance of a space solution, firms have to act very quickly. Because time is of the essence, CNES must invest upstream to be able to satisfy the short development time of telecom satellites (36 months). These two objectives explain why SMILE consists of four parts:

1. Regulations—in other words, lobbying to keep the S-band for the space industry;
2. Standardization in order to be able to insert the space solution in future telecom standards that suppose both technical work and lobbying;
3. Collaborative projects with telecom operators, component providers, and so forth to demonstrate the relevance of space technologies by building prototypes and organizing collaborative events with potential partners; and
4. Competence building: developing the necessary competencies and design tools to accelerate the design process if a window of opportunity opens.

SMILE, therefore, which is an ongoing project, includes plans to propose a roadmap in 2014 while simultaneously improving CNES’s competencies on mobile communication (test bench, simulation software, engineering models, and so on).

**Analysis: The Logic of Strange Projects—A Design Perspective**

To better understand the logic of exploratory projects, we dig deeper into the
FLIP project. After the first round of interviews, we organized a second interview with the project manager. Our goal was to clarify some technical questions and, in so doing, to reconstitute the design reasoning of the project. The interesting point about FLIP is that, as presented earlier, it started out as a “normal” project. Customer needs were identified and R&T had developed promising new technologies. The team was thus confident and, given the urgency, decided to start directly in the B-phase with the detailed design. However, as the project manager said, “We recognize that [short laugh] ... the solutions proposed by R&T were not competitive and, next, we decided to explore again the needs of the operators. Indeed, we needed to understand, beyond the concept of flexibility, what were the missions they were interested in. We wanted to identify all the potential missions with them. This proved to be a long and complex dialogue because they are reluctant to unveil their strategy. It took us one year and a half and we ended with 27 missions grouped in seven types. Hence, we realize that we know the need conceptually but we didn’t understand what it means operationally” (Interview with FLIP’s project manager, July 13, 2014). Starting from this new understanding, the project unfolded using a completely different logic. What the team actually did was a “kind of industrial partners.” (Interview with FLIP’s project manager, January 13, 2014)

Note that this type of reasoning is not limited to the transponder but is applied to all the components. Antennas, for example, are core elements of a telecom satellite that play a central role in its flexibility (e.g., the possibility to broadcast the signal in different geographical areas). Here is what FLIP’s project manager said about the design of the X-antenna mentioned earlier: “This is a textbook case of a decision that is not directly linked to the product. We know that the X-antenna is penalized in terms of performance: We lose 3 dB and it’s a bit expensive. But the benefit is that it is a technology driver for two-process technology that, until now, had been mastered only by the United States. Now European firms have also mastered these technologies. We’ve designed it in this perspective. And we’ve been to the engineering model. We’ve designed a prototype that demonstrates the feasibility and that can be tested. We didn’t want to limit ourselves to R&T. Look at it: It’s beautiful [showing the X-antenna on his computer]! We wanted to prove that we know how to build it, to force the industrial partner to build a working version. These process technologies are so interesting—for example, to save weight, we had to show that the main critical problems have been solved. But we know from the beginning that the X-antenna will not be chosen in the short run. That said, operators and other projects at CNES are beginning to look at it. And the way we designed it makes it compatible for different applications” (Interview with FLIP’s project manager, January 13, 2014).

Because this constitutes the heart of our argument, it could be useful to put these quotations in perspective. To do this, we rely on recent advances in design theory. This will help us show that what happens in this case is a fundamental shift in the logic of project management that, historically, has its roots in decision theory (Lenfle & Loch, 2010; Söderlund, 2011). However, as we suggested earlier, understanding innovation should lead us to abandon the rational, decision-based view of firms and projects. More precisely, we will rely on the C-K theory of design (Hatchuel & Weil, 2009; see also the Appendix) to analyze the design reasoning of the FLIP project, which, in our view, is typical of exploratory projects. What is fascinating here is that the first step in the design process is typical of the dominant model of project management: We begin with a description of the customers’ need from the strategic department and technical “off-the-shelf” solutions proposed by R&T. On
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this basis, given the urgency, the project quickly starts to develop two different solutions for the two main missions (see Figure 4). The hypothesis is that we have the concept and that the K-base is sufficient to start development.

However, what we see is that this logic does not hold for exploratory projects. Indeed, in exploratory projects case, one can neither make the assumption that the goal of the project is clearly defined beforehand, nor that the knowledge base is sufficient. Flexibility is actually a general concept that will be defined during the course of the project. Therefore, the logic of the project is fundamentally different from that of traditional project management. The concept of flexibility questions the very nature of the satellite and modifies the design rules in use, as illustrated by the FLIP antenna case. The project quickly becomes trapped in a dead end and adopts a logic of expansion (Hatchuel, 2002), which is typical of exploratory projects (Gillier et al., 2014; Lenfle, 2012). We summarize this expansive logic in three steps, shown in the gray sections of Figure 5.

• **Step 1**: This step involves the reopening of the initial mission concept that leads to the identification of 27 different missions grouped into seven families. Work takes place in parallel on four technical solutions that seem promising.

• **Step 2**: These solutions appear to be unsatisfying given the great variety of the different missions and the constraint of commonality. However, one of the solutions, called Ku/Ku, is developed as a first step to satisfy a customer’s short-term need. Meanwhile, the team explores the different solutions, which leads them to map the design space.

• **Step 3**: At the end of the project they develop three products to the EQM stage, build prototypes to demonstrate the feasibility of some of the technology, and enhance their competencies. This leads them to completely revise the design models of the payload to make it flexible.

What we observe here is a double expansion (see the gray parts of Figure 5) of both concept and knowledge that, we believe, constitutes a fundamental feature of exploratory projects (Lenfle, 2012). What makes the FLIP project an exemplary case is that it brings together many of the characteristics of exploratory projects (Lenfle, 2008):

- Difficulty in specifying the result ex ante;
- A questioning of the stage-gate process: What we see here is a constant back-and-forth between stages, sudden acceleration, and stage overlapping;
- Simultaneous management of different temporality—both short-run

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5 Note that the work with the operators to redefine the missions underlines the fundamental role of stakeholder management in projects (on this question, see Eskerod, Huemann, & Savage, 2015).
development and long-term exploration. This is a constant tension in exploratory projects:

- Development of new design rules instead of relying on existing rules, challenging the dominant design; and
- The fact that the “result” of the project is more complex than in a traditional product development project. Rather than a product, the result is generally one of the following:
  - qualified products (EQM)
  - prototypes that demonstrate the usefulness and feasibility of a solution
  - mapping of the design space defined by the concept of flexibility
  - new design models that can be reused for future projects
  - new competencies, as exemplified by the X-antenna.

We note that this analysis draws a picture of very altruistic projects. Fundamentally, these projects work to prepare for other, more development-oriented projects. They do the spadework that leads to lineages of future projects that builds on their exploration (Le Masson et al., 2010; Maniak, Midler, Lenfle, & Le Pellec-Dairon, 2014; Midler, 2013). Thus, as the project manager of FLIP explains: “Cross-fertilization is central here, including application outside of telecoms or flexibility. It’s a dimension we always try to take into account. It’s bizarre compared to traditional projects, which focus on the components they need, and that’s all. We try to break this logic that consists of strictly following the requirements.” He insists particularly on the importance of the development of new design models: “This is probably the major result of FLIP. ... Now that we’ve done this thinking, we keep it for future projects. For example, we find similar question on THD-Sat. They were quickly converging on a solution but they didn’t really understand why. So we stop the project and apply a FLIP-like logic to put the problem in perspective” (Interview with FLIP project manager, January 13, 2014). We see here how, in contrast to the rational approach, such projects help map an “unfamiliar landscapes” (McGrath, 2001) and build new competencies, instead of mainly using what already exists to reach a clearly defined goal. Therefore, the project mode seems to be an interesting way to structure exploration processes. We discuss this point in the next section.

**Discussion: Structuring Exploration Through Projects**

In the end, what we have here is a new type of project in terms of both logic and results. These exploratory projects respond to the growing and strategic role of innovation-based competition that has emerged during the past two decades. As we have seen, relying on projects to manage exploration assumes the development of specific management principles. These have already been identified in the literature (Loch et al., 2006; Lenfle, 2008; Davies, 2013; Dugan & Gabriel, 2013). This research goes one step further by making explicit the design reasoning that underlies their unfolding. This example demonstrates that their logic differs radically from that of the dominant model of project management: Goals are progressively defined during the project, new knowledge has to be developed, results are multiple, stages are overlapping, and temporality is complex. Based on all these differences, one might wonder if we can still talk about projects. Indeed, when compared with traditional projects, they really look like Bosch’s painting: bizarre, undefined, hard to understand, and without clear meaning. And during our interviews, project managers complained about the difficulty of managing these projects within CNES’s project management processes. As the project manager of the SMILE project said, “You can only be the dunce. Even building a work plan is complicated. I found myself at a kickoff meeting where I was asked to define budget requirements even though we were a bit in the dark on what we wanted to do. We try to present it in an acceptable form.” The problem is all the more complex because “we speak to people who are not from telecom and ignore what is at stake” (Interview, July 5, 2013). The head of the project department, who participates in all project reviews, confirmed this problem when he recognized that “SMILE is a fuzzy object; people outside the team have problems understanding what it is about” (Interview with Mr. FP, April 25, 2013). The risk, in this case, is that the blind application of the usual project management process leads the project into a dead end. As explained by the FLIP project manager, “There is an important risk of developing the wrong product because the schedule target is too stringent” (Interview with FLIP project manager, January 13, 2014). Until now, projects needed to circumvent the process mainly by putting on “makeup.” One of the project managers explained, “In order to survive, the only solution is to dress the project as it is expected to be, with a red nose if you need a red nose, white shoes, yellow tie and so on.”

This workaround strategy, frequently observed in innovation management, should, in our view, be a last resort. The challenge for firms, and for project management research, is to recognize the specificities of exploratory projects and to differentiate the management processes accordingly. Indeed, the CNES case and others in the literature demonstrate that the project form is relevant for managing exploration. Here again, the interviews with the project managers are precious. They point to the three fundamental contributions of the project form of organizing: its orientation toward practical goals, the time pacing of exploration, and the creation of a community.

**Orientation toward Practical Goals**

Concerning this first point, the project managers unanimously recognize that being organized as a project is fundamental and different from both R&T and development projects. As summarized...
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by Mr. FP, head of project department

“We are not exploring for the sake of exploring.” The project manager of FLIP refers to this idea as “being pragmatic.”

“We try to do something that works, to answer efficiently to the way we see the goal. We are not here to explore a lot of things, we want that things serve to do something tomorrow, whereas sometimes in R&T you search everywhere.

Here, we have constraints of cost, delay, and feasibility.” We find the same ideas when the SMILE project manager explains that these projects “are not like departments that put in place tools for themselves; we work for the future A- or B-phase. We always think globally. And we have to justify what we do at each project review” (Interview with the SMILE project manager, July 5, 2013). Indeed, these kinds of projects are not at all “floating,” as they might appear at first glance. They have to deal with the classical constraints of project management: cost, quality, and time.

Project reviews help discuss what happens, identify the relevant tracks to be explored, and define the next steps. This corresponds to the experimental learning process proposed by Loch et al. (2006). Of course, as we have seen, the requirements are more the result of the project than the beginning (see McLean, 1971), but this does not mean that exploratory projects are not projects, only that they are just that: exploratory. Moreover, as we explained in the previous section, we are now able to characterize more clearly these results, which could be products, prototypes, a mapping of the innovation field, new design models, or new competencies.

Pacing the Exploration

An important difficulty of exploration is its apparent endlessness. When is it finished? How can people give a rhythm to the exploration process? On these two questions, project-based organizing provides two important answers: project reviews and time limits. On the first point, the project managers we interviewed recognized the fundamental role of project review. The FLIP project manager explained: “Project reviews are a huge added value compared to individual action. The project has to be justified collectively to the outside world. It gives visibility, it gives deadlines, it gives meaning” (Interview with FLIP project manager, July 5, 2013). This demonstrates that these kinds of projects are not floating. They are carefully managed and the project review plays a central role in this management. Of course, these reviews differ from a traditional review. In the rational approach, reviews serve to check convergence toward the objective. In exploratory projects, they are an instance of sense-making (Loch et al., 2006; Lenthe, 2011), or a moment of reflection in action (Schön, 1983) during which results are collectively discussed and the course of action decided.

Moreover, projects are temporary. All projects have an end. However, that end is not necessarily the realization of an object, which means the end can be hard to identify. When is it time to stop exploration? From the cases we researched, we can identify three (non-exclusive) criteria:

- The budget is exhausted;
- The project has reached the end date;
- The innovation field has been sufficiently studied.

For example, we find a combination of these three criteria in the FLIP case. When asked when the project is finished, the project manager explained: “When we arrive at the end of the budget and the date. For FLIP, the end is planned for 2014: Budgets will be exhausted; EQM will be validated ... even if this does not prevent us to think about their evolution. But globally that’s it—either we haven’t any money, or we are out of ideas, or we are out of the scope and it’s forbidden. For example, in FLIP, the ground segment is out of the scope. The concept of a generic solution is also out of the scope, but will be studied in another project named GEICO. But today, on flexibility, we have what we need” (Interview, July 5, 2013). We think this statement is very important. It points to two criteria to evaluate, and therefore manage, in the unfolding of exploratory projects: (1) a kind of theoretical saturation (we have what we need), with the same meaning as used in grounded theory (Glaser & Strauss, 1967), and (2) “expandability”—the ability of the project to generate new explorations (Hatchuel, 2002; Gillier et al., 2014). There is no doubt that further research is needed in this area.

Building a Structured Community for Exploration

Our interviews reveal that the project perspective also plays a fundamental role in the structuring of the exploration process. Indeed, one of the risks of exploration is remaining spread out in different parts of the organization with only loose coordination, to say the least (this is a well-identified problem in innovation management—see, for example, Dougherty & Hardy, 1996). Setting up a project helps avoid this trap. The SMILE and FLIP project managers again converged on this question. For the SMILE project manager, “each department considered separately would not have any interest in exploring. Here, to combine our forces creates a critical mass. And people in the departments are happy with this; it creates contact, it creates competition, challenge. We are also linked by the news, our ability to listen to what happens in a world that changes very quickly. I found that we need to see each other; there are also human stakes, the feeling to get things moving together. It’s not an easy project. You need to have the faith. You need to balance it with something else. It’s good to be a team. We talk; we lift each other’s spirit” (Interview, July 5, 2013).
The FLIP project manager confirms this sentiment: “It creates coherence, an impressive dynamic. Instead of doing small R&T studies, the team knows that we are also going to build products; there is something of development; we consider the interfaces with the entire system” (Interview, July 5, 2013). These statements demonstrate the power of projects to create momentum and to build links between scattered people, links that underpin the success of the projects. This typical characteristic of projects (see, for example, Clark & Wheelwright, 1992; De Marco & Lister, 1999) is all the more important in highly uncertain contexts.

Conclusion

We started this article by noting the growing role of exploratory projects in today’s innovation-based competitive environment and the limitations of the dominant model of project management for managing such projects. This gave rise to a growing body of research on these highly uncertain projects. However, we pointed to our lack of knowledge on the practices of managers of exploration projects and the difficulty they encounter. Indeed, compared with the dominant model of project management, exploratory projects look strange because there are ambiguous goals and no requirements, the projects work on new concepts and not necessarily on no requirements, the projects work on new concepts and not necessarily on new knowledge. We are thus able to characterize how they unfold (double expansion in concept and knowledge), specify their results, and identify promising criteria (saturation and expandability) for their evaluation (see also Gillier et al., 2014). Third, we demonstrate that exploratory projects constitute a powerful tool for structuring the potentially very fuzzy processes of exploration. They are oriented toward goals, they help pace exploration, they provide opportunities for sensemaking, and they foster coordination between different disciplines that, otherwise, would remain scattered throughout an organization.

We believe that what is at stake here is important for the evolution of project management research and practice. Indeed, we have to reconsider the concept of the project itself that, for too long, has been equated with the rational model. This perspective has hindered our ability to think about other types of project logic. As a result, project managers of exploratory projects have considered themselves the “dunce” and their supervisors talk of “strange” projects. Given the role of innovation in today’s competitive environment, it is all the more important to formalize and circulate a relevant model of exploratory project management.

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Sylvain Lenfle is Senior Lecturer at the University of Cergy-Pontoise and Associate Researcher at the Management Research Center, École Polytechnique, France (I3-CRG, École Polytechnique, CNRS, Université Paris Saclay). Sylvain’s research deals with the links between innovation and project management in various industrial settings and in historical projects and he currently focuses on the management of exploratory projects. He can be contacted at slenfle@hotmail.com

## Appendix

### A Brief Introduction to C-K Theory of Design

The C-K theory of design describes design reasoning as the interaction between two spaces: the concept space C and the knowledge space K. Design begins with an initial concept, a proposition that is neither true nor false—that is, it is undecidable in the K space. The concept, let us say of a “flying boat,” cannot initially be said to be feasible or unfeasible, marketable or not.

The design process consists of refining and expanding the concept by adding attributes that come from the knowledge space (flying boats have sails or motors, hulls, foils, wings, and so forth). The process can also lead to the production of new knowledge that may be used in the design process—for example, as a result of an experiment conducted to understand the effect of foils on the boat’s behavior. The initial concept set is thus partitioned into several subsets.

The process unfolds until one refined concept is sufficiently specified to be considered true by the designer. At that point, the concept becomes a piece of knowledge (hence, the notion of a “C-K conjunction”). The generic structure of design reasoning is presented in Figure A1. For a complete presentation of C/K theory, its roots, and its applications, see Hatchuel and Weil (2009), Le Masson et al. (2010), and Agogué, Hooge, Arnoux, and Brown (2014).

![Figure A1](image_url)
The Challenge of Innovation in Highly Complex Projects: What Can We Learn from Boeing’s Dreamliner Experience?

Aaron J. Shenhar, Technological Leadership Institute, Verona, New Jersey, USA
Vered Holzmann, Tel Aviv University, Tel Aviv, Israel
Benjamin Melamed, Business School, Rutgers University, Newark, New Jersey, USA
Yao Zhao, Business School, Rutgers University, Newark, New Jersey, USA

ABSTRACT

Understanding the link between project complexity and innovation is highly pertinent. Yet, the challenge of innovative complex projects has received limited research attention and little theory development. This article provides a retrospective analysis of the difficulties experienced by Boeing during the development project of its highly innovative Dreamliner aircraft. Eventually successful, this project suffered extensive delays and cost overruns. The article analyzes the project’s complex nature of innovation, while using several frameworks to provide an integrative view of its challenges and suggesting possible alternative ways to address them. Insights for complex project teams and future research directions are offered.

KEYWORDS: aerospace; innovation; complexity; project management; complex project and program management; Boeing 787 Dreamliner

INTRODUCTION

Boeing Corporation, which was founded in 1916, has become one of the world’s largest manufacturers of commercial aircraft, ranking now 27th on the Fortune 500 list. On September 26, 2011, Boeing publicly announced the delivery of its first 787 Dreamliner transporter to its first customer, All Nippon Airways. That event took place almost 40 months later than originally planned, after a long series of unexpected delays. The actual development cost of the project was estimated at about US$40 billion and was “well more than twice the original estimate” (Mecham, 2011).

Adding to the difficulty was the discovery of a malfunction a year later in one of the aircraft’s lithium batteries, which caught fire after takeoff. These problems led to months of grounding, imposed by the FAA (Federal Aviation Administration), of the entire Dreamliner fleet already in service.

Boeing’s vision for the Dreamliner was to make it one of the most advanced commercial aircraft ever built and one of the most efficient to operate. However, its late delivery and early service problems were particularly troubling for a large corporation like Boeing, which is highly regarded as a leader in the aerospace industry and one of the world’s most experienced aircraft manufacturers. However, the Dreamliner’s late debut also provides an opportunity for the aerospace industry, and the research community at large, for retrospective in-depth learning.

In this article, we analyze the challenges that Boeing faced in this project and the lessons it learned while coping with them. By taking an innovation management perspective, our analysis offers ways to explain Boeing’s experience, and possible ways to avoid similar failures in the future.

Our conclusion is simple. Boeing’s delays and other problems could have been minimized, if not prevented. More important, a careful early analysis of the project’s innovation challenges and potential difficulties might have predicted many of the problems that followed, and perhaps avoided some of Boeing’s losses, including the resulting reputational damage.

After discussing our research method, the third section outlines the story of the Boeing 787 project. The case story section describes the project’s vision and the decisions made by the company through the project life cycle, then outlines the project’s challenges and describes the project’s development history, including the actions taken by the company in response to its delays. The next section, which is dedicated to innovation, includes a retrospective analysis of...
the project’s innovative challenges and a discussion on how these problems could have been avoided, or at least mitigated. We engage recent models of innovation and complexity, and point out where more theory development is needed. We conclude with a list of lessons that may be applied in future, large-scale strategic innovation projects, and suggest questions for future research.

Research Method

The Dreamliner project was one of the case studies in a multi-year study of the aerospace and defense (A&D) industry, which began in the 1990s (e.g., Tishler, Dvir, Shenhar, & Lipovetsky, 1996). In 2007, after Boeing announced its first 787 delay, we made the Dreamliner the focus of a dedicated in-depth longitudinal study. Between 2007 and 2013, we collected all publically available articles or posts about the Dreamliner project, as well as Boeing’s history and the project’s earlier decisions.2 We systematically coded all material into categories such as business, performance, strategy, technology, planning, control, testing, and so forth. We read and coded nearly 800 articles and posts, and interviewed eight non-Boeing aerospace executives and reporters who offered their non-classified perspectives. When it became clear that studying this project required more than traditional project and innovation expertise, we increased our team by adding experts in supply chain management and operations. We conducted regular research-team debates, dedicated to a specific category and its theory, and created discussion notes, which were then cross-analyzed to form the basis for our final analysis. Three independent scholars then reviewed our draft and offered comments and suggestions.

The Dreamliner Project

Initial Vision and Plan

The Dreamliner project was initiated in the early 2000s to take advantage of new technologies, including composite materials and electronic controls, with an effort to reduce fuel costs and noise levels and as a strategic preemptive move to compete with Airbus’ 380 program (Useem, 2006). The Dreamliner project was launched in April 2004 with a planned delivery date during the first quarter of 2008. In retrospect, it seems that this schedule was highly unrealistic. By 2008, however, Boeing had already collected a backlog of more than 850 orders, at an estimated value of US$140 billion, which made the Dreamliner the most successful launch of any aircraft in history. A final configuration was selected in September 2005 and the design of major subsystems began in June 2006. The project opened its assembly plant in Everett, Washington, USA, in May 2007; however, its first test flight took place in December 2009, almost 18 months later than expected, and as mentioned, the first delivery took place some 40 months later than planned.

Dreamliner’s Challenges

The Dreamliner was designed to be a revolutionary project in many respects: physical characteristics, technology, management style, financing, design and engineering management, quality assurance, and assembly processes. Many of these initiatives were intentionally taken on to benefit from new developments in aviation technology and to speed up design and development; however, as we will show, they posed unexpected challenges for both the company and the project team.

The first major challenge involved designing the aircraft’s body using lightweight composite materials (chemical compounds made of carbon). This change was necessary, since the Dreamliner was to provide long-haul transportation for 250 passengers for about a 20% lower fuel cost (Ye, Lu, Su, & Meng, 2005). Although composite materials were not totally new, they were never used to such an extent in a large civilian aircraft (Teresko, 2007). However, this decision created a challenge to the design of the big fuselage, which is a multi-sectional cylindrical barrel covering the seating area of the aircraft. The new technology required more sections than previously used for aluminum-based fuselages. The result was that initial prototypes failed during the testing stage, forcing Boeing to redesign the body structure by adding more sections and scheduling more prototype testing, which added significantly to the schedule (Holmes, 2006).

The second technological change involved new kinds of avionics and computing systems that had never been used before on large commercial aircraft. They included the largest ever-used displays on any commercial aircraft (Ye et al., 2005), as well as replacing previous mechanical controls with electronic signal controls—a technology known as “Fly by Wire.” Also new to commercial aircraft design, these technologies added to the project’s delays by extending its wiring, installation, and integration processes (Holmes, 2006).

Boeing also adopted a new organizational paradigm for the development of Dreamliner and decided to outsource an unprecedented portion of the design, engineering, manufacturing, and production to a global network of 700 local and foreign suppliers (MacPherson & Pritchard, 2005). With more than 70% foreign development content, this decision turned Boeing’s traditional supply chain into a development chain (Alt- feld, 2010; Tang, Zimmerman, Nelson, & James, 2009). Tier-1 suppliers became responsible for the detailed design and manufacturing of 11 major subassemblies, while Boeing would only do system integration and final assembly. Figure 1 describes the project’s major subassemblies and their tier-1 suppliers (Domke, 2008; Franck, Lewis, & Udids, 2009).

Furthermore, Boeing came up with a new risk and revenue sharing contract with its suppliers, called the “build-to-performance” model. According to the model, contract suppliers bear the non-recurring R&D cost up-front, own the intellectual property of their design, and get paid a share of the revenues from
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Comparing the Project’s Events to the Original Plan

The original plan of the 787 was to have all subassemblies completed and delivered by June 2007, have the maiden flight in August 2007, and make the first delivery by May 2008. On July 8, 2007, a rollout ceremony was held for the first Dreamliner (Norris & Wagner, 2009). However, the aircraft’s major systems had not yet been installed, and many parts were only attached with temporary fasteners (Trimble, 2007). It was the first of several delays prior to the first test flight, which took place nearly a year and a half later than planned (Cohan, 2009; Kotha & Srikanth, 2013). With more than 60 canceled orders, Boeing had to pay its customers nearly US$1 billion in penalties for late delivery because the first aircraft were not sellable. See Table 2 for a detailed sequence of events (The Seattle Times, 2009).

Project Development Difficulties

Design issues were not the only causes of delays. Boeing listed addi-
additional reasons such as weight control, fastener shortages, incorrect installation, extensive delays in suppliers’ work, and software development difficulties (McInnes, 2008). Following is a more detailed account of these reasons.

Fuselage design changes required altering joints between sections, as well as a strengthening wing design, resulting in an 8-ton increase in maximal takeoff weight. Boeing addressed this problem by additional and originally

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>December</td>
<td>Responding to airlines’ calls for more fuel efficiency rather than extra speed, Boeing drops its “Sonic Cruiser” concept. Much of the Sonic Cruiser’s composite materials, avionics, and engine technology will reappear in the 787</td>
</tr>
<tr>
<td>2003</td>
<td>December</td>
<td>Everett, Washington, USA is chosen as the first assembly plant</td>
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<td>2004</td>
<td>July</td>
<td>ANA places a 50-plane order</td>
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<td>2005</td>
<td>September</td>
<td>Main features of the 787 airplane design are complete and detailed design work is sent to Boeing’s global partners</td>
</tr>
<tr>
<td></td>
<td>December</td>
<td>286 orders by the end of 2005</td>
</tr>
<tr>
<td>2007</td>
<td>June</td>
<td>A 0.3-inch gap was found at the joint between the nose-cockpit section and fuselage section, made by different suppliers. Engineers fixed it by disconnecting and reconnecting internal parts</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>The first assembled 787 is rolled out at Everett, but unknown to the audience, it is a hollow shell</td>
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<td></td>
<td>September</td>
<td><strong>First delay:</strong> three months. Due to shortage of fasteners and incomplete software</td>
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<td></td>
<td>October</td>
<td><strong>Second delay:</strong> six months for first deliveries, three months for test flight. Due to unfinished work passed along by global partners and delays in finalizing the flight control software. Mike Bair, 787 program head, is replaced by Pat Shanahan</td>
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<td></td>
<td>December</td>
<td>346 orders by the end of 2007</td>
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<td>2008</td>
<td>January</td>
<td><strong>Third delay:</strong> three months for test flight. Due to unnamed suppliers and slow assembly progress at the Everett plant</td>
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<tr>
<td></td>
<td>April</td>
<td><strong>Fourth delay:</strong> six months, again for test flight; total of 15 months behind the original schedule for first deliveries. Due to continuing problems with unfinished work from suppliers</td>
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<tr>
<td></td>
<td>September</td>
<td>A second machinists’ strike begins at Boeing, lasting 57 days. The company struggles for a month afterward to get production back on track</td>
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<td></td>
<td>November</td>
<td>News emerges of a new, embarrassing and serious problem. About 3% of the fasteners put into the five test airplanes under construction in Everett were installed incorrectly and had to be removed and reinstalled</td>
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<tr>
<td></td>
<td>December</td>
<td><strong>Fifth delay:</strong> six months. Shanahan is put in charge of commercial-airplane programs, and Scott Fancher takes day-to-day operations lead on the 787 project. More than 900 orders by the end of 2008</td>
</tr>
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<td>2009</td>
<td>January–February</td>
<td>Middle East leasing company LCAL and Russian airline S7 group cancel 37 orders</td>
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<td></td>
<td>June</td>
<td><strong>Sixth delay:</strong> test flight is postponed indefinitely. Due to a structural flaw at the wing-body joint. Australian carrier Qantas cancels 15 orders</td>
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<td></td>
<td>July</td>
<td>Boeing writes off US$2.5 billion because the first three planes are unsellable and suitable only for flight tests</td>
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<td>October</td>
<td>Boeing announces that it will acquire the 787 rear fuselage assembly plant in Charleston, South Carolina, USA, buying out its partner Vought for about US$1 billion</td>
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<td>November</td>
<td>Additional 10 orders canceled. The total number of order reduces to 840</td>
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<td></td>
<td>October</td>
<td>Intensive talks between Boeing and the machinists’ union end in acrimonious failure. Boeing announces the choice of Charleston, South Carolina, USA, as the second final assembly plant</td>
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<tr>
<td></td>
<td>November</td>
<td>Boeing mechanics complete the wing-body joint fix. Engineers repeat the wing stress test, and the Dreamliner gets the green light to fly</td>
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<tr>
<td>2010</td>
<td>August</td>
<td><strong>Seventh delay:</strong> Boeing delays delivery of the first aircraft by three months due to engine failure and availability issues</td>
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<td></td>
<td>November</td>
<td>Boeing halts Dreamliner tests after an onboard fire</td>
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<tr>
<td></td>
<td>December</td>
<td><strong>Eighth delay:</strong> Boeing delays delivery indefinitely—no delivery date given</td>
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<tr>
<td>2011</td>
<td>September</td>
<td>First aircraft is delivered (40 months total delay)</td>
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<tr>
<td>2013</td>
<td>January</td>
<td>Entire 787 fleet in service is grounded for months by the FAA due to battery problems</td>
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unplanned redesign cycles, exploring multiple weight savings, which saved nearly 2 tons. (Domke, 2008).

In addition, the project repeatedly experienced insufficient supplies of basic components, such as fasteners, frames, clips, brackets, and floor beams. The body design changes required a different sleeve fastener design on wings, leading to the delay of the first test flight of August 2007. With 60 weeks of production lead time, the main fastener supplier, Alcoa Inc., was unable to meet demand on time (Lunsford & Glader, 2007). Furthermore, some fasteners were incorrectly installed (Gates, 2008).

But perhaps the most troubling issue in the Dreamliner project was the inability of Boeing’s suppliers to meet the project’s demands. This resulted in “traveled work,” where suppliers’ work was passed along back to Boeing’s Final Assembly Line (FAL). As Pat Shanahan, the second project director, put it: “We designed our factory to be a lean operation. And the tools and the processes, the flow of materials, the skills of personnel are all tailored to perform last-stage high-level integration, check out and test. We thought we could modify that production system and accommodate the traveled work from our suppliers, and we were wrong” (Komonews.com, 2015).

How Did Boeing Deal With Its Unexpected Challenges and Delays?

Faced with major delays due to redesigns, part shortages, incorrect installations, software delays, and even a union strike, Boeing initiated several bold actions to deal with these issues. Such actions eventually led to the introduction of what proved later to be a highly desired aircraft.

• In December 2008, Boeing opened a Production Operation Center in its Everett plant to better coordinate with its tier-1, as well as tier-2 and tier-3 suppliers. The Center’s mission was to “monitor global production among suppliers, solve problems quickly and keep the program advancing” (James, 2009).

• Dreamliner’s components and modules began testing right away at the original manufacturer’s site before being shipped out to the next assembler. This way, Boeing was able to identify and solve problems when they occurred, rather than later, when their impact was detected.

• Since Vought turned out to be one of its least reliable suppliers, in 2009 Boeing decided to acquire Vought’s interest in Global Aeronautica, and its operations in South Carolina for US$580 million. An Innovation and Contingency Perspective on Complex Projects

A retrospective look at the project’s challenges, suggests that most of them were rooted in the company’s decisions to engage new (or innovative) techniques and practices often used for the first time. While strategically justified, it seems that the company needed better adaptation of organizational and development practices to the innovation introduced by these decisions.

Innovation can be viewed as the “application of better solutions that meet new requirements, in-articulated needs, or existing market needs” (Frankelius, 2009). The Organisation for Economic Co-operation and Development (OECD) (2005) defines innovation from an overall broad perspective as “the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations” (OECD, 2005, p. 46). Complexity, in turn, in most studies is related to a large number of distinct and independent elements (Williams, 1999). Following these definitions, it is conceivable that Boeing’s challenges were a result of a combination of multiple innovations in its Dreamliner development project. Thus, in the following discussion we describe the relevant literature on innovation and project management, which will be used for analyzing Boeing’s experience and explaining the challenge of innovation posed by this project. We then use this analysis to depict possible alternative ways to manage such kinds of highly complex innovations.

As the Theory Suggests, One Size Does Not Fit All Innovations

One of the early studies of innovation conducted by Marquis (1969) was dedicated to exploring the differences between two types of innovation: incremental (a small change in an existing product) and radical innovation (a change based on a completely new idea). This distinction appears often in many studies (e.g., Baker & Sinkula, 2007; Balachandra & Friar, 1997; Chao & Kavadias, 2008; Gemünden, Salomo, & Hößle, 2007; Germain, 1996; Kock, Gemünden, Salomo, & Schultz, 2011; Leifer et al., 2000). Marquis (1969) also mentioned a third type, system innovation, which relates to large complex efforts (systems) that combine many new and/or improved ideas in one big system development project, such as aircraft, communication networks, or space programs; however, he did not investigate this kind of innovation in detail in his study. The concepts of exploitation versus exploration emerged later (March, 1991), essentially distinguishing between two types of learning: improvements or modifications of existing ideas and introduction of fundamentally new ideas (Benner & Tushman, 2003; Danneels, 2002; Gatignon, Tushman, Smith, & Anderson, 2002). Innovation studies have also expanded in additional directions, such as new product development (Chen, 2015; Salomo, Weise, & Gemünden, 2007), open innovation (Chesbrough, 2006; Gemünden et al., 2007), portfolio management (Beringer, Jonas, & Gemünden, 2012; Kock, Heising, & Gemünden, 2014; Unger, Rank, & Gemünden, 2014), or other industries such as automotive (Lenfle & Midler, 2009).

Another well-established and relevant concept is structural organizational
contingency theory, which suggests that organizations must find the right fit between problem and context and must adapt their structure, processes, and practices to the unique environment of their task. This idea implies that different kinds of organizations functioning in distinct environments must be structured and managed in different ways (Benner & Tushman, 2003; Burns & Stalker, 1961; De Brentani & Klein, 2015; Drazin & Van de Ven, 1985; Hanisch & Wald, 2012; Howell, Windahl, & Seidel, 2010; O’Connor, 2008; Pennings, 1992; Ritter & Gemünden, 2003). Scholars have often suggested that organizations that perform more innovative tasks would be different from organizations which develop more routine products (e.g., Abernathy & Utterback, 1978; Burgelman, 1983; Dewar & Dutton, 1986; Drazin & Van de Ven, 1985; Galbraith, 1982; Perrow, 1967; Thompson, 1967).

Correlations between structural and environmental attributes have been well studied when the organization is the unit of analysis. However, they have only entered the realm of project management in the last two decades. The argument was that projects can be seen as “temporary organizations within organizations” and thus may exhibit variations in structure based on context and environment (Lenfle, 2008; Lundin & Söderholm, 1995; O’Connor & Rice, 2013; Payne & Turner, 1999; Shenhar, 2001).

The evolution of project management contingency theory and its relation to innovation was characterized by the introduction of specific context factors, which would distinguish projects by different dimensions, leading to specific contingency decisions (Hanisch & Wald, 2012). For example, Henderson and Clark (1990) have used a 2 × 2 matrix to distinguish between the components of a product and the ways they are integrated. Wheelwright and Clark (1992) have classified projects based on product and process types; Turner and Cochrane (1993) have grouped projects based on how well their goals and their means are defined; Youker (2002) has grouped projects based on product type; and Pich, Loch, and De Meyer (2002) have used a project’s information adequacy (or level of uncertainty) to distinguish between three strategies: instructionism, learning, and selectionism. Shenhar and Dvir (2004, 2007) have used four dimensions to distinguish among projects: novelty, technology, complexity, and pace, and have shown how this categorization can be applied to innovation as well. It is interesting to note that the connection between projects and innovation is getting more and more attention recently, as demonstrated first in the 2007 IRNOP conference dedicated to this link (Brady & Söderlund, 2008). Consecutive articles discuss various aspects of innovation and project portfolio management. For example, Killen, Hunt, and Klein-schmidt (2008) studied Australian companies and found that project portfolio management practices are very similar for new service and tangible product development project portfolios. Biedenbach and Müller (2012) studied the relationship of innovative capabilities and long-term project success, whereas Sicotte, Drouin, and Delerue (2014) suggested a set of six critical capabilities for innovative companies managing successful projects. Unger et al., (2014) reported that corporate innovation culture and national-level culture are related to dimensions of project portfolio success, and Meifort (2015) reviewed the current research on innovation portfolio management and categorized it into four perspectives: optimization, strategy, decision making, and organization. The topics of complexity and uncertainty in projects have been often used interchangeably. For example, Gerald, Maylor, and Williams (2011), when analyzing 25 notable papers, have referred to “complexity in projects” versus “complexity of projects” by suggesting an umbrella typology of five different dimensions of complexity: structural, uncertainty, dynamics, pace, and socio-political. In contrast, Howell et al. (2010) have presented uncertainty as the most common theme in the study of project contingency theory (PCT), followed by complexity, team empowerment, criticality, and urgency, whereas Bosch-Rekveldt, Jongkind, Mooi, Bakker, and Verbraeck (2011) have demonstrated the elements that contributed to project complexity by introducing the technical, organizational, and environmental (TOE) framework of complexities.

Based on these and other studies, four current conclusions about the state of knowledge of PCT emerge. First, just as for sustained organizations, “there is no one best way” for projects as well, and “one size does not fit all.” Second, no generally accepted framework has emerged thus far to support the analysis of highly complex and innovative projects. Third, most emergent frameworks are theoretical or literature-based, with only a few grounded by empirical evidence. Fourth, research often offers limited prescriptive ideas on actually managing innovations. However, as claimed, “for practitioners a project’s complexities can be used as a starting point for a reflection on the challenges a project faces, or will face, and the development of strategies to cope with them” (Geraldi et al., 2011, p. 983).

Analysis

Could Contingency Methods Help Prepare Boeing for Its Challenges?

As we have seen, Boeing’s difficulties were a result of the following major challenges: The use of newly developed technologies, outsourcing a large extent of design to numerous, less experienced subcontractors (and creating a development chain), a new business model of revenue sharing, and a new assembly model. As claimed earlier, these strategies probably helped retaining Boeing’s competitive positioning by taking advantage of modern technologies, and practices, but their execution was less than optimal.

In reviewing the current state of knowledge, no single available...
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framework seems comprehensive enough for analyzing the spectrum of innovation challenges in a highly complex project such as the Dreamliner. To enrich the analysis, and complement possible limitations in any single model, we combined three frameworks offered by different authors: Pich et al. (2002), Shenhar and Dvir (2004, 2007), and Geraldi et al. (2011), thus creating a broader perspective. We selected these frameworks based on the following criteria: the framework must offer practical implications for project innovation teams; it was based on empirical evidence, not just theory; or it adds a factor that is not covered by other models. The following section describes each model in detail and its accompanying discussion outlines the lessons that could be derived for Boeing’s project. In a later section we combine all these lessons into one integrated overview.

Pich et al.’s Categories of Project Learning

Pich et al. (2002) characterize projects based on the degree of information available upfront to the project teams. Each of their recommended three types of projects requires a different project management strategy as described below:

- **Instructionist project** is a project where most of the information needed for planning is available, and the project team has a good understanding of the “best policy” that has to be implemented. Planning an instructionist project mainly involves optimization that is focused on the critical path and risk management. The instructionist project primarily exploits known information and does not need to deal with high levels of uncertainty.

- **Selectionist project** is a project where there is not enough information to define an optimal policy; the project team is faced with a higher level of uncertainty, and it cannot accurately anticipate the results of its actions. Rather than exploit existing knowledge, the team is encouraged to explore; plan multiple trials and prototypes, while executing them simultaneously; and then select the best performing solution. From this point on, the project could be managed as an instructionist project.

- **Learning project** is a project susceptible to unforeseen events that might influence its course. In this environment, there is little benefit in detailed planning of the entire project, because the unforeseen might alter its course and force the team to learn and continuously readjust the plan. While each project needs a clear vision, its detailed planning can only be done for the nearest tasks and must be updated with progress.

In the Boeing case, the technologies of composite materials and “fly by wire” were new to this family of company products and this required an upfront analysis of the level of uncertainty and the allocation of sufficient time for testing and redesign. Similarly, the extensive outsourcing of design for the first time, as well as the new business model, required a slower pace of adaptation and learning of the new practices by all factors. However, Boeing employed what looks like an instructionist strategy (Pich et al., 2002), which is based on a low level of upfront uncertainty, such as construction, where activities, time, and cost are essentially predictable, and no surprises are expected. It does seem, however, that this project would require a selectionist style of project management. Such a style would ensure that the project is ready to acknowledge its upfront level of uncertainty and allocate sufficient resources for repetitive designs, prototype building, and testing before the final design is selected. It would also ensure enough time for training and certifying the project’s subcontractors as well as adjusting the newly implemented business model.

Shenhar and Dvir’s Diamond of Innovation

The Dreamliner’s project innovative challenges could also be analyzed by using the “Diamond of Innovation” model. Based on a study of over 600 projects, the “Diamond of Innovation” provides a framework for project classification (Shenhar & Dvir, 2004, 2007). Each one of its dimensions of novelty, technology, complexity, and pace consists of four possible project categories, and by selecting a category in each dimension, one creates a specific diamond-shaped view for each project, which serves as a project classifier. Once a classification is selected, the model helps identify the unique impact of each dimension, and provides recommendations for a preferred style of management. The Diamond of Innovation implies that the Dreamliner project could be classified as outlined below. (We then discuss the fit between the actual management and the required style based on this classification):

- **Novelty**: From its customers’ perspective, the Dreamliner was a generational change in an existing line of previous commercial aircraft built by Boeing. That would place it at the **Platform** level of novelty, which really did not create a unique challenge to the company that made all the strategic decisions needed for a new platform. However, there was another challenging aspect of novelty. The new “build-to-performance” business model, however, was unfamiliar to the company and its subcontractors. As major stakeholders, they can be considered as “users,” and for them it was an unknown experience. That challenge would move the novelty to a **new-to-the-market** level, which suggests that the implementation of the new model would require pilot testing and repetitive model modifications until the final version was established and fully understood.

- **Technology**: The technology of composite materials was new to the commercial aircraft industry, and no prior experience existed on how to design...
Novelty: Market Innovation—how new is the product to the market, users, and customers. Novelty level impacts market-related activities and the time and effort needed to define and freeze requirements (a higher novelty would delay this freeze).

Technology: Technological Innovation—how much new technology is used. It impacts product design, development, testing, and the requisite technical skills (a higher technology level requires additional design cycles and results in a later design freeze).

Complexity: Level of System Innovation—represented by the complexity of the product or the organization. Complexity impacts the degree of formality and coordination needed to effectively manage the project.

Pace: Urgency of the Innovation—How critical is your time frame. It impacts the time management and autonomy of the project management team.

Table 3: Diamond of Innovation: definitions, dimensions, and project types.

<table>
<thead>
<tr>
<th>Novelty</th>
<th>Technology</th>
<th>Complexity</th>
<th>Pace</th>
</tr>
</thead>
<tbody>
<tr>
<td>New-to-the-world</td>
<td>High-tech</td>
<td>Low-tech</td>
<td>Regular</td>
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<tr>
<td>New-to-the-market</td>
<td>Medium-tech</td>
<td>Low-tech</td>
<td>Fast-competitive</td>
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<td>Derivative</td>
<td>Medium-tech</td>
<td>Medium-tech</td>
<td>Time-critical</td>
</tr>
<tr>
<td>High-tech</td>
<td>Low-tech</td>
<td>High-tech</td>
<td>Blitz</td>
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</table>

Table 3: Diamond of Innovation: definitions, dimensions, and project types.

and integrate it into a large wide body such as the 787. Similarly, the technologies of electronic controls (“fly by wire”) were also new in the commercial aircraft sector. The innovative use of these technologies placed the Dreamliner in the high-tech category of innovation. In contrast, previous commercial aircraft such as the 777, which had used traditional aluminum body materials, would be classified as medium-tech. The ramifications of such innovative technologies suggest that this project required a different approach than that used in Boeing’s previous generations. The immature technologies required additional time, more testing, and additional design-build-test cycles, as well as more prototyping. Such additional work was not planned in advance, requiring elaborate decision-making processes, and additional design resources (which were later added to the program).

• Complexity: Typically, most aircraft-building efforts can be considered systems on the dimension of complexity.

The Dreamliner project, however, added a significant amount of complexity to the effort. Management’s decision to outsource an unprecedented amount of design and development work to hundreds of subcontractors worldwide required an enormous amount of coordination and clear rules in work procedures as well as documentation. We propose that such complexity pushed the program from the system level to the array category, which requires extensive coordination and formality. The ramifications for the project were significant. What appears to be missing in this case was a detailed and elaborate system of vendor education, training, and verification that these vendors can actually do the job. In addition, Boeing had to invest in a highly formal and strict policy for vendor behavior, standards of work, and coordination. Preparing these formal rules and procedures required an extensive investment of time for building the complex management and control system. Array projects are often conducted across national borders and cultures, requiring them to find specific ways to overcome language and cultural differences. It seems that Dreamliner needed to implement more of these efforts upfront.

• Pace: The Dreamliner project was expected to be in the market in time to face and benefit from the growing demand. That would rank this project at the fast competitive level. Indeed, Boeing intended to treat the project as fast competitive, but faced with unexpected delays, the pace often seemed even faster.

Based on these observations, we classify the Dreamliner project as a platform/new-to-the-market, high-tech, array, and fast competitive, leading to a specific style of management for this classification. However, a careful analysis of the program’s actual style was different along the dimensions of technology and complexity. Specifically, the actual approach chosen for managing novelty was closer to platform, instead...
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of new-to-the-market, medium-tech approach, instead of high-tech, and the one chosen to manage complexity was closer to the category of system rather than array. Figure 2 is a visual depiction of the gaps between the required management style (bold diamond) and its actual counterpart (dashed).

Geraldi et al.’s Typology of Complexity

Based on an extensive literature survey, Geraldi et al. (2011) have adopted a broad perspective to the idea of complexity, and thus identified five dimensions of a project’s complexity: structural complexity, uncertainty, dynamics, pace, and socio-political complexity. Two of them—dynamics and socio-political complexity—were not covered by the frameworks used earlier and may add new insights to the analysis.

- **Structural complexity**: Structural complexity relates to a large number of distinct and interdependent elements. It is impacted by size, variety, and interdependence of the elements.
- **Uncertainty**: Uncertainty represents the gaps between the amount of information required to make a decision and what is available. Uncertainty has an intrinsic relationship with risks, but as the literature suggests, there may be different kinds of uncertainty, such as uncertainty of goals and uncertainty of methods (Turner & Cochrane, 1993).
- **Dynamics**: Dynamics refers to changes in factors as goals or specifications. When changes are not well communicated or assimilated by the team, such changes may lead to high levels of disorder, rework, or inefficiency. Projects may not only change “outside-in” but also “inside-out,” where teams may change their constitution or motivation, or internal politics may take over.
- **Pace**: Pace relates to the temporal aspects of a project. It represents the urgency and criticality of time goals. Pace essentially refers to the rate or speed at which produces should be delivered.
- **Socio-political complexity**: This kind of complexity relates to the problems involved when managing stakeholders, such as lack of commitment, or problematic relationships between stakeholders, as well as those related to the team. Issues that are often mentioned in this category include “complexity of interaction” between people and organizations, and differences of languages, cultures, and disciplines. It also refers to the complexity of the problem situation itself and the complexity of the human and/or group factor. Overall, this factor emerges as a combination of the political aspects and emotional aspects involved in projects.

Geraldi et al. (2011) do not discuss specific impacts of each complexity dimension on project management, but rather, indicate that the assessment of project complexity could affect such items as the choices of competitive priorities, different project management methodologies and tools, managerial capacity development, or identifying problems in troubled projects. Furthermore, they note that the assessment of the type of complexity in projects is often subjective and will be influenced by the project manager.

Perhaps the most significant contribution of Geraldi et al.’s work (2011) is the proposition that complexity dimensions are frequently interdependent. For example, they indicate that high uncertainty may increase the level of dynamic complexity, which will bring increased structural complexity. Similarly, high structural complexity may lead to increased socio-political complexity, and high socio-political complexity may lead to increased levels of change and uncertainty. These interdependencies are clearly noticeable in the case of Dreamliner, and are outlined in the following discussion.

Geraldi et al.’s model (2011) may offer further insights into the analysis of Boeing’s Dreamliner challenges, particularly with regard to the dynamics and socio-political complexity dimensions. The significant number of changes that were required in order to get the project back on track increased the degree of
the dynamics compared to the original intentions. These dynamics required continuous adjustments of the project’s organizational structure, design, and testing processes, additional resources and modified processes, not to speak of the added resources. They also caused several changes in leadership during the development period. Once again, one may claim that, had the company originally assessed the degree of innovation in technology and complexity, the original plan might have been more realistic and thus may have avoided much of the unplanned dynamics.

The last dimension of socio-political complexity is also meaningful. Boeing’s intentions of outsourcing design to a large network of subcontractors and the new “build-to-performance” incentives model created a high level of additional complexity. Subcontractors had difficulties adjusting to Boeing’s advanced design requirements, which were augmented by geographical distances, language, and cultural differences. In retrospect, analysis of Geraldi et al.’s model suggests that the project should have been better prepared for these kinds of complexities, which resulted from its business-related decisions. Such preparations would require an intense process of subcontractors’ education about Boeing’s requirements and design standards, followed by a tight system of coaching, reviewing, controlling, and ongoing communication with its subcontractors.

**Combined Lessons from the Three Models**

As we have seen, analyzing the Dreamliner project using different innovation models may help explain the company’s difficulties and suggest alternative ways that could have prevented some or all of these delays. Overall, a careful upfront analysis of the project during the planning process would look for all the new practices that distinguish this project from its predecessors, and select the mitigation techniques that would deal with these challenges upfront. Table 4 summarizes the combined lesson that we derived from our analysis, along with possible alternative activities that might have prevented the difficulties.

A combined analysis using all three models offers a more in-depth understanding of the project’s challenges than using one model alone. Specifically, we discuss these combined insights using the two major perspectives of uncertainty and complexity, as well as their interdependencies. First, Pich’s et al. (2002) model shows that the project adopted an instructionist strategy, which is based on relatively low levels of uncertainty, instead of the selectionist strategy that is typically required in cases that involve a higher level of uncertainty. Shenhar and Dvir’s model (2007) analysis confirms this observation, by making a distinction between two types of uncertainty—novelty and technology. In terms of novelty, Boeing treated the uncertainty faced by its stakeholders (subcontractors) as “platform,” where in most cases the experience of a previous generation was new and its novelty in our opinion should be considered as “new-to-the-market.” Similarly, by introducing several key new technologies, Boeing has apparently lifted technological uncertainty from a “medium-tech” to a “high-tech” level; its managerial practices, however, were in our judgment, more typical of a “medium-tech” level.

From the complexity standpoint, we may conclude that the project’s complexity was higher than it was in Boeing’s previous generations due to the decision to share the design work with an extensive number of subcontractors. Shenhar and Dvir’s (2007) model would suggest that this project should thus be seen as an “array”; however, our observation suggests that its actual management practices fit better with the “system” level, where everything is done in one location and in one organization. In reality, we believe that the integration and communication needed for this extensive worldwide effort suggests that this project should have been treated as an “array.” Geraldi et al.’s two dimensions of complexity dynamics and socio-political complexity only strengthen this analysis (2011). Based on our observation, Boeing treated the project as having a low level of dynamics and socio-political complexity, as if things are quite stable and the cultural environment is mostly homogeneous. However, the need to make an extensive number of changes during the development and communicate them with a large collection of subcontractors around the world, have increased, in our view, both the dynamics and the socio-political complexities from low to high.

Finally, Geraldi et al.’s interdependencies of dimensions are also seen in the other two models. When an instructionist strategy (Pich et al., 2002) is replaced by a selectionistic strategy, or when novelty or technology shift from platform and medium-tech to new-to-the-market and high-tech, both the dynamic and socio-political uncertainties advance from the low to the high levels. A similar argument holds true for the shift from system to array in Shenhar and Dvir’s model (2007). In sum, as one can see, each model offers a slightly different analytical perspective, but collectively, we believe, the multi-model analysis indeed enriches our understanding of the project’s challenges and potential lessons.

**Discussion**

Boeing’s confidence in its past experience and record of success perhaps led project leaders to believe that the new project would be as successful as before. Based on the above analysis, however, we demonstrated that the challenges and scope of innovation were probably underestimated. The level of new practices required to manage design subcontractors and the extent of technological innovation were much higher than in its previous commercial aircraft projects. The effort involved in integrating new technologies required a much...
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<table>
<thead>
<tr>
<th>Model Used for Analysis</th>
<th>Variable</th>
<th>Actually Used</th>
<th>Recommended</th>
<th>Implications and Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pich et al. (2002)</td>
<td>Project management learning strategy</td>
<td>Instructionist strategy is used for a project where most of the information for planning exists and there is a low level of uncertainty</td>
<td>Selectionist strategy is used where there is insufficient information for planning, due to high level of uncertainty</td>
<td>Faced with extensive levels of uncertainty, the project had to create a master plan with additional prototypes and tests before final decisions could be made. This would probably extend the original schedule, but eventually produce a more realistic plan that would reduce the final cost.</td>
</tr>
<tr>
<td>Shenhar and Dvir (2007)</td>
<td>Novelty: Market or User (Stakeholder) Uncertainty</td>
<td>Platform—A next generation in an existing line of products</td>
<td>Platform and New to the Market—To customers, the product was indeed a Platform. But for subcontractors, Boeing’s design and incentives model were “New to the Market”</td>
<td>The company had to train and coach subcontractors in its design methods as they learned to address new design and development practices. In addition, the new incentives model was rarely used in the industry and was new to Boeing’s overseas partners. The model had to be carefully implemented with small pilots where both sides experience it and gradually learn how to work effectively with it.</td>
</tr>
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<td></td>
<td>Technology: Extent of using new technology—level of technological uncertainty</td>
<td>Medium-tech—where most technologies are well known with a small number of changes</td>
<td>High-tech—the project is using new technology that was recently developed and rarely used before in such kinds of projects</td>
<td>The high-tech level required planning at least three to five design cycles, and an increased number of prototypes that would enable testing the new technologies design and integrate it with the entire aircraft.</td>
</tr>
<tr>
<td></td>
<td>Complexity: How complex is the product and/or the organization that is creating it</td>
<td>System—a collection of subsystems that is creating a multifunctional product</td>
<td>Array (System of Systems)—a large collection of systems or organizations, working together for a common mission, often widely dispersed geographically</td>
<td>Boeing’s development chain created an array of companies around the world that was engaged in design and development. To succeed, such an array must be carefully coordinated with clear rules, standards, and common forms of documentation, reporting, and communication. These elements are typically prepared before the array is launched worldwide.</td>
</tr>
<tr>
<td>Geraldi et al. (2011)</td>
<td>Dynamics—Extent of changes</td>
<td>Low Dynamics—not too many changes are expected and the process is executed as planned</td>
<td>High Dynamics—where many changes are common and continuous adjustments are needed</td>
<td>The high levels of uncertainty led to numerous changes, which increased the dynamics level of the project.</td>
</tr>
<tr>
<td></td>
<td>Socio-political Complexity—Complexity due to sociological differences and political influences</td>
<td>Low level of socio-political complexity, as in previous projects where most of the work was done inside</td>
<td>High level of socio-political complexity, which resulted from the need to coordinate the large collection of different cultures and languages</td>
<td>The resulting high socio-political complexity required extensive attention to the cultural and languages differences. The company had to prepare an extensive training program to make all managers aware of these differences and teach them strategies to cope with them.</td>
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Table 4: Dreamliner’s innovation challenges analysis.

higher allocation of time and other resources than originally planned. Lacking an established framework for such allocations, planners found out later that they needed to add more design cycles to the original plan, build more prototypes, and conduct additional testing. Later corrective actions led to delays and higher cost, which may have been avoided had these challenges been addressed in advance.

In addition, from an organizational standpoint, the development effort of the Dreamliner was more complex than in previous projects due to the innovation involved in outsourcing much of the design and development, as well as a new incentives model. The project lacked sufficient organizational support systems for managing the new and highly complex network of inexperienced suppliers. Here, too, such systems were eventually put in place, but at a much higher cost than if implemented at inception. The interface between technological innovation and organizational complexity was also significant. The time required for integration and for redesign iterations across multiple firms was underestimated. Boeing originally allocated only two months for system integration before scheduling the first flight. In retrospect, that time was much lower than needed.
Similarly, from a strategic standpoint, we believe that the company was not fully ready to manage the innovative business model of Build-to-Performance. Such innovation required the burden of fully controlling strategic outsourcing, supplier selection, contracting, monitoring, testing, and quality control, as well as addressing the cultural and distance differences; however, only a few of these activities were completed before the project was launched. Our analysis indicates that the company should have selected suppliers more carefully based on their R&D capabilities, level of commitment, and financial strength. Furthermore, drawing from the analysis, we believe that the company would have greatly benefited by initiating an extensive training program for its subcontractors, making sure they were ready to take on the challenge before they could commit to undertaking the design and development work.

Tactically, Boeing found it difficult to resolve the incentive issues underlying traveled work by linking suppliers' performance to suppliers' gain. The models may indicate that Boeing should have revised the risk-revenue sharing contract to provide mid-course financial incentives for suppliers to work faster and better, while penalizing them for delays and unnecessary traveled work. In addition, open communication and well-planned monitoring and controlling suppliers' processes could have effectively reduced traveled work, ensuring only properly completed work would pass on to the next stage, while helping detect problems early on.

What Can Companies and Researchers Learn From Boeing's Experience?

Innovation is clearly one of the major drivers of economic growth; yet, it is risky and often ends up in disappointing results or failure. For example, Tepic, Kemp, Omta, and Fortuin (2013) reported 16 failures out of 38 innovation projects conducted by European industry companies and Baron, Esteban, Xue, Esteve, and Malbert (2015) discussed the cooperation between processes related to system development and project management in developing new products. Empirical innovation studies have often focused on small- or medium-sized projects that built tools, appliances, cars, or software; yet, as mentioned, highly innovative and complex projects have received less attention. Complex projects involve a substantial degree of difficulty due to a large number of components and technologies, involvement of numerous organizations, extensive communication and coordination requirements, and widely dispersed teams. When it comes to innovation, the challenge is even greater, leading to higher risk, which often requires adapting specific management processes during the development project. As Gann and Salter (2000), Hobday and Rush (1999), and Davies and Mackenzie (2012) indicated, the management of complex projects, which involve an integration of multiple components, calls for understanding and implementation of practices derived from the company strategy, management practices, and organizational processes. While the management of innovation in highly complex projects is still not fully investigated, most traditional project and program management tools rarely deal with planning and managing the project's innovation. Such models tend to assume that projects mostly are linear, certain, and predictable, and pretty much, "one size fits all." Well-established traditional risk management tools are aimed at protecting a project when things might fail, hence providing a preconceived remedy (or mitigation) when things are going wrong. Based on our assessment, we suggest that innovation management, however, is not about "what can go wrong?" It is about figuring out "how long will it take to get it right?"

Conclusions

Our analysis has shown that highly complex and innovative projects may benefit from adopting a contingency approach for their planning and execution processes. One of the main lessons of this and similar contingency studies is that "one size does not fit all innovations." Companies as well as researchers may explore more ways to understand the differences among projects and among different innovations. The three models for the analysis used in this article have demonstrated possible ways to identify such differences and adapt optimal management strategies. Pich et al.'s (2002) model shows how different levels of upfront information impact the project management strategy; for a best fit, they recommended selecting between the instructionist, selectionist, and learning strategies. The Diamond of Innovation (Shenhar & Dvir, 2004, 2007) provides a possible framework for analyzing innovation at the project level by integrating project management and innovation management. Classifying a project using the Diamond of Innovation dimensions, leads to specific decisions based on each dimension. For example, the model suggests that a high-tech project must include at least three cycles of design, build, and test. It also suggests that such projects need to allocate about 30% of the time and budget as contingent resources beyond a typical traditional plan. Similarly, an array program must prepare clear guidelines and coordinating mechanisms to make sure all components and participating companies are using the same terminology and standards, are similarly trained, and are effectively communicating. Gerald et al.’s (2011) model specifically addresses five kinds of complexity, adding the dynamics and socio-political dimensions to previously existing models. Low or high levels in these dimensions require specific attention to their impact.

These models however, may not be the only ways to deal with innovation. For example, as early as 1984, Saren (1984) suggested classifying existing models of innovation according to five types: departmental-stage models, activity-stage models, decision-stage
models, conversion process models, and response models. More recently, Garcia and Calantone (2002) identified the constructs that are related to marketing and technological perspectives, at the macro and micro levels of a project. They presented a comprehensive list of constructs based on radicalness, newness, uniqueness, and complexity. Undoubtedly, additional models of innovation may be developed and applied to the fast-changing world of innovation.

A second clear conclusion we derived from our analysis is that there is currently no single comprehensive model to understand and analyze the entire spectrum of innovation challenges in highly complex projects such as the Dreamliner. After accepting the reality that one size does not fit all, practicing companies may still need to rely on a combination of models to understand the extent of innovation in a project and find the optimal ways of managing them. Furthermore, using several models of analysis may shed different lights on understanding the challenges of a complex project. Contingency aspects could be multifaceted and interactive, and no single or best model provides an overall direction or conclusive recommendations at this time. Different models may also be complementary to each other, and if used together, they may compensate for weaknesses or limitations of any single model alone.

This study may also offer new directions for future research. As we mentioned, research communities have typically focused on smaller scale projects. The more complex projects have received less attention thus far. There is clearly a need to develop comprehensive models of innovation in highly complex projects. Such models will establish a new basis for understanding the links between complexity, uncertainty, and innovation. We contend that future researchers may find ample opportunities for studying this important and intriguing field.

One of the main directions for future research is seeking additional and perhaps more refined models to distinguish among projects. Such distinctions may be of two kinds: First, identifying the major dimensions that characterize typical qualities of projects. For example, future researchers may find additional types of uncertainties and complexities in projects. The challenge would be to identify what really characterizes contingencies and how to avoid overlaps and contradictions. The second kind of investigation may be aimed at finding different scales or ranks for each dimension. Classical low-high distinctions seem to have been replaced in recent years by more refined frameworks involving three, four or more levels of distinction.

Once new dimensions and types are offered, another main direction for future studies is identifying managerial implications for different kinds of projects on each dimension. Such implications may relate to the organizational issues of complex projects. For example, should highly innovative projects be organized differently from lower innovative efforts? Differences may also be found in planning, monitoring, team selections, managerial qualities, subcontracting, stakeholder management, and many others.

Finally, this study is not free of limitations. First, using one case study is clearly insufficient to offer a comprehensive view of the industry or other complex innovative projects. Second, our research method, which relied on open sources, has a potential limitation of missing an in-depth better understanding of the project’s internal dynamics and managerial processes taken by Boeing. Third, in this kind of study, one can only analyze the difficulties encountered during the project. It is impossible, however, to predict what may have happened if Boeing had taken a different approach. Thus, all potential remedies suggested at this stage can only be seen as possible options without a clear guarantee for better success. Finally, the lack of one comprehensive acceptable theory and the need to rely on a collection of models might have made this study prone to the specific choices of the researchers. Nevertheless, this study can be seen as a step forward toward a better understanding of the nature of innovation combined with complexity. From a research and theory perspective, this study has shown how theoretical models could offer real guidance to practicing organizations in addressing complex problems, particularly when using a combination of theories, rather than one model individually. More studies in the future may use this route to strengthen the link between theory and practice.

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Aaron J. Shenhar, PMI Fellow, is a Professor of Project Management and Leadership at Tel-Aviv University, Israel, and the CEO of SPL, an education and consulting organization dedicated to aligning projects and business. Until 2008 he was Institute Professor of Management and the founder of the project management program at Stevens Institute of Technology. Previously he held various positions at the Universities of Minnesota and Rutgers Business School. He holds five academic degrees in engineering and management from Stanford University and the Technion in Haifa, Israel. He was the first recipient of the Project Management Institute Research Achievement Award, recipient of the IEEE Engineering Manager of the Year Award and was recently awarded as PMI Fellow as well as the IMPA Research Achievement Award.

With over 80 refereed research articles, his research was published in journals such as Strategic Management Journal, Management Science, Sloan Management Review, Research Policy, and IEEE Transactions on Engineering Management. He also served as consultant to major companies such as Intel, 3M, Honeywell, NASA, and IAI, as well as the aerospace industry in its Program Excellence Award. He can be contacted at aaron.shenhar@gmail.com

Vered Holzmann earned her PhD degree in management from Tel-Aviv University for her dissertation on “A Model for Risk Management Based on Content and Clustering Analyses.” She has graduated with honors from the Department of Philosophy (BA) and graduated from the School of Business, Tel-Aviv University, with a thesis on the subject of communications effectiveness in projects (MBA). Vered is a seasoned project manager (PMP, SCM) with a distinguished record of accomplishment in managing international projects in higher education, leading software development teams, and supervising quality assurance and control of fast track projects. Serving as the VP for research and academic affairs in the PMI Israel Chapter, Vered is responsible for initiation and organization of academic conferences, awarding scholarships, and managing the academic forum. Vered serves as a lecturer in the faculty of management in Tel-Aviv University, and her research interests include communications and knowledge management, internationalization, project risk management, and entrepreneurship and innovation in the context of leadership and management. She can be contacted at veredhol@post .tau.ac.il

Benjamin Melamed is a Distinguished Professor in the Department of Supply Chain Management, Rutgers Business School—Newark and New Brunswick, Rutgers University, New Jersey, USA. He has a PhD and MSc in Computer and Communications Sciences, from University of Michigan, Ann Arbor, and a BSc, in Mathematics and Statistics, from Tel-Aviv University, Israel. Before joining Rutgers he was a department head at NEC USA Inc., and a member of the technical staff at AT&T Bell Labs. Melamed’s research interests include supply/service chain operational and financial management (including modeling, analysis, simulation and optimization), systems modeling and performance evaluation, stochastic processes, traditional and hybrid simulation (discrete-event and fluid-flow paradigms), and decision support tools. He authored or co-authored over 100 papers and co-authored two books, and has published in a broad range of scientific journals, including Operations Research, Mathematics of Operations Research, Management Science, J. of Applied Probability, Advances in Applied Probability, J. of Stochastic Processes and their Applications, IEEE Trans. on Automatic Control, Annals of Operations Research, Stochastic Models, Journal of Business Logistics, Performance Evaluation, J. of Optimization Theory
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and Applications, Nonlinear Analysis, JACM and QUESTA. He performed studies for NJ-DOT, DHS, NSF, and DARPA. Melamed was awarded an AT&T Fellow in 1988 and an IEEE Fellow in 1994. He can be contacted at melamed@rutgers.edu

Yao Zhao is a Professor in the Department of Supply Chain Management, Rutgers Business School—Newark and New Brunswick, Rutgers University, New Jersey. He holds a PhD degree in Industrial Engineering and Management Sciences from Northwestern University, Evanston, Illinois, USA. He is the co-director of the Rutgers Supply Chain Analytics Laboratory and a faculty fellow at the Lerner Center for Pharmaceutical Management Studies at Rutgers. He was a visiting scholar at Duke Fuqua School of Business and MIT Operations Research Center. His research interests lie in supply chain management, project management, and healthcare services management. He has published in leading operations research and management journals such as Operations Research, Manufacturing & Service Operations Management (M&SOM), Production and Operations Management, and serves as an associate editor for Operations Research. He is the recipient of an honorable mention in the M&SOM student paper competition in 2001, the National Science Foundation Career Award in Manufacturing Enterprise Systems in 2008, the Dean's Award for Meritorious Research in 2011, and the first prize in the INFORM case writing competition in 2014. He can be contacted at yaozhao@andromeda.rutgers.edu
ABSTRACT

Although concurrency between project development stages is an effective approach to speeding up project progress, previous research recommends concurrent engineering primarily for less complex, incremental projects. As such, in complex radical aircraft development projects, managers opt for less concurrency; however, by using system dynamics modeling, this study shows that less concurrency can contribute to overall project delays, rather than preventing them. The time lost by rework due to early starts of project stages is more than compensated by the time gained by early feedback and faster learning, with positive effects on project completion and subsequent sales.

KEYWORDS: concurrent engineering; human error; decision making; system dynamics

INTRODUCTION

Although large, complex new product development (NPD) projects that finish on time and within budget clearly must exist we rarely read about them. Instead, the regular and prominent mentions in the popular press focus on large projects that run out of time, money, and control. In the aerospace industry, in particular, multi-year schedule overruns of new product development projects seem to be the rule rather than the exception. The Airbus A380 suffered a two-year project delay and US$10 billion in lost orders. Although the Boeing Dreamliner has fewer lost orders, it was delayed more than the Airbus A380. Recently, it has become apparent that Lockheed Martin’s Joint Strike Fighter program is also experiencing major delays. Again, cost increases range in the billions of dollars, and delays are likely to be years rather than months. How can such frequent massive delays be possible?

Scholars have offered a number of explanations, ranging from the technological to the psychological (e.g., the four sublimes stated by Flyvbjerg, 2014). On the technological side, aerospace projects are highly complex technical undertakings, mirrored by equally complex organizational structures. The incessant increase in technological complexity, not just in the machines, software, or airplanes being built but also in the projects in which they are designed, appears overwhelming for humans (Perrow, 1999). On the psychological side, human factors play a significant role in complex technical environments in which important judgments and decisions must be made (e.g., Kahneman & Tversky, 1979; Meyer, 2014). To take an aerospace example, according to recent estimates, more than one half of flight accidents are attributable to “pilot errors” (Saada, Meng, & Huang, 2014). Could the management of major aircraft development programs be liable for similar “pilot errors” in their judgment and decision making?

The more complex a project becomes, and as such, the riskier it is, the more managers develop a bias against actions that appear risky, even if these actions would produce better long-run outcomes than other alternatives that seem effective initially (Denrell & March, 2001). The iterations between up- and downstream stages that result from concurrent development create delays and extra costs in the present, and the benefits of increased product quality or faster time to market are far removed. In addition, there is always the fear that iterations between project stages turn into never-ending, problem-solving oscillations (Mihm, Loch, & Huchzermeier, 2003). As a result, new product development project managers may find concurrent engineering practices too risky because the costs are evident and for the short term, whereas the benefits are distant and long term (Graebner & Eisenhardt, 2004;
Pilot Error?

March, 2006). As one manager, working on new aircraft development projects, revealed to us: When you lose trust in the project because of mistakes and delays, everything changes. Then you don’t get the capacity [budget, engineers] in the beginning of the next project to find out how we can learn as much as possible to try to prevent these mistakes.

As managers become more risk adverse, they prefer first-time-right goals and full completion of one project stage (i.e., strict gates or high quality gates) before the next begins. Sequential engineering is viewed as a strategy to mitigate disruptions in the development process that are caused by mistakes and rework in downstream stages that are associated with a concurrent approach (Liker & Morgan, 2006; Savci & Kayis, 2006). Or, in the words of the manager cited earlier: When production fails because of design issues, the quality systems are even more strictly used next time around to make sure that we don’t make any mistakes. Instead of getting to the cause of these mistakes, we tend to be more strict in approving designs and products, so we throw away half of what we produce. This leads to more delays, and more strict quality systems, and then we are stuck in a vicious loop.

Project managers thus face a trade-off between risk mitigation and learning with regard to concurrency: They may opt for strict stage or quality gates to try to mitigate disruptions in the development process, but strict gates could hinder learning from design iterations that are caused by concurrency. When gate review criteria are more strict and objective, the team experiences less motivation to acquire new information from teams working in downstream stages or re-examine existing information. Gates can then increase learning failure, reduce flexibility, and affect the market performance of new products (Pich, Loch, & De Meyer, 2002; Sethi & Iqbal, 2008). Therefore, in the aircraft development programs that so frequently are delayed, managers may have opted for less concurrency than was desirable, and this poor choice could have contributed to the disruptions of or delays in deliveries. We therefore adopt this question as our formal research objective: In new aircraft development programs, what is the impact of opting for less concurrency between development stages to mitigate disruptions in these programs on overall project duration and costs?

We have developed a system dynamics simulation model of a four-stage aircraft development program, based on the Boeing Dreamliner setting. To enable evaluation of the long-term effects of concurrency, our modeled aircraft supply chain includes both the non-recurring phase (aircraft development) and the recurring phase (production). The recurring phase includes an endogenous customer demand to simulate customer responses to delivery delays.

We conduct scenario analyses with this model, in which we hone in on issues of concurrent versus sequential engineering, from basic design to detail design, to tooling, to ramp-up and full production. Our findings challenge existing theory, which claims that concurrency between development stages is primarily beneficial when uncertainty and complexity are low, to prevent expensive design iterations. We suggest that a greater degree of concurrency leads to earlier starts of the learning curve trajectories in every stage, as well as earlier feedback across downstream through upstream stages. As such, sequential engineering as a strategy to mitigate risks leads to longer delivery delays with major effects on subsequent aircraft sales. However, limits exist, beyond which increasing the degree of concurrency no longer increases project performance, because the number of mistakes that accompany high levels of concurrency increase.

Literature Review

The most obvious psychological candidate for project delays is the planning fallacy (Kahneman & Tversky, 1979), a form of optimistic bias by which people underestimate the time it will take to complete an upcoming task, even though they realize that similar tasks have taken longer in the past. Optimism bias will also negatively influence project or sub-project termination decisions (Meyer, 2014). To protect project managers against this planning fallacy, improve project management, and reduce project delays, new approaches to the management of product development have emerged. Over the years, decision making in new product development has become professionalized, including the development of tools and procedures for guiding organizations toward desired outcomes (March, 2006). Barczak, Griffin, and Kahn (2009) found that between 1990 and 2004, the use of formal processes, methods, and techniques to improve product development increased from 54% to 69%. The best-performing firms in their sample used more formal processes, tools, and techniques than the rest. A recent study shows that when the level of innovativeness increases, the amount of formal controls that are imposed on the development team also increases, while flexibility decreases (Holahan, Sullivan, & Markham, 2014). When the difficulty of the problem exceeds the decision maker’s competency, the decision maker makes mistakes (Summers & Scherper-eel, 2008). In new product development, mistakes can be expensive, so decision makers focus on controlling them by either mitigating their size and impact or eliminating them.

Risk mitigation is an important element of the stage gate method (Cooper, 2008). Stage gate, a popular system for managing risk in product development, offers a map that guides the process of moving from a product idea to a successful new product. Stage gate consists of a set of information-gathering stages, followed by “go kill” decision gates (Cooper, 2008). In each subsequent stage, uncertainty and risks diminish and costs increase, which creates an effective mechanism for managing
risk. By constraining investments when uncertainty is high, the system lowers the costs of mistakes—that is, of investing in the “wrong” project (Summers & Scherpereel, 2008). However, two objections have been raised about the suitability of this stage gate method in complex new product development projects (van Oorschot, Sengupta, Akkermans, & van Wassenhove, 2010). First, the more complex and novel a product is, the more crucial learning is for the team (Brown & Eisenhardt, 1995; Sethi & Iqbal, 2008). Gates can potentially adversely affect learning in the project: When gate review criteria are stricter and more objective, the team’s motivation to acquire new information or re-examine the existing information declines. Gates thus can increase learning failure, reduce flexibility, and affect new product market performance (Pich et al., 2002; Sethi & Iqbal, 2008). Second, complex new product development projects are typically characterized by unknown unknowns, or the inability to recognize and articulate relevant variables and their functional relationships (Sommer & Loch, 2004; Tatikonda & Rosenthal, 2000). In these contexts, the early definition of specifications can lock a firm into an incorrect definition. Better results may follow from remaining flexible in the beginning. For example, the timing of gates could be made more flexible to allow the team more time when it realizes that the gate deliverables cannot be provided timely enough (Cooper, 2008). Another option is to have resource flexibility (i.e., being able to reallocate personnel, financial, and equipment resources) during the execution of project stages (Tatikonda & Rosenthal, 2000). Additionally, task completion flexibility (i.e., the use of conditional or “fuzzy” gates that allow the project to pass gates although not all requested tasks are completed) can support projects with high levels of uncertainty (Biazzo, 2009; Cooper, 1994). Also, the concept of spiral or agile development has been built into the stage gate approach to allow the team to move rapidly to finalize product design through a series of “build-test-feedback-and-revise” iterations (Cooper, 2008).

Some research has focused on the benefits of investing in parallel paths or overdesigning a product (Childs & Triantis, 1999; Krishnan & Bhattacharya, 2002; Lenfle & Loch, 2010), or front-loading (Thomke & Fujimoto, 2000). Finally, stages can be arranged to overlap to speed up the knowledge development or learning process within the new product development project—which is also known as simultaneous or concurrent engineering (Cooper, 2008; Ford & Sterman, 2003; Karlsson & Åhlström, 1996; Lin, Chai, Wong, & Brombacher, 2008; Loch & Terwiesch, 1998; Terwiesch, Loch, & De Meyer, 2002; Tyagi, Yang, & Verma, 2013).

In concurrent engineering, the information-absorbing downstream development phase (e.g., detail design) starts before the information-supplying upstream phase is completed (e.g., basic design), thereby potentially reducing the overall cycle time (Clark & Fujimoto, 1991; Terwiesch et al., 2002). The main drawback of concurrent engineering is the risk of creating additional engineering rework (Mihm et al., 2003; Mitchell & Nault, 2007; Savci & Kayis, 2006). This happens when changes are made in the upstream phase after the preliminary start of the downstream phase. In sequential engineering, the downstream phase can only start when the upstream phase is finalized, thereby reducing the risk of rework.

As mentioned previously, new product development project managers typically find concurrent engineering practices too risky. To prevent never-ending, problem-solving oscillations, previous research has recommended that specific settings use concurrent engineering (Cantamessa & Villa, 2000; Krishnan, Eppinger, & Whitney, 1997; Loch & Terwiesch, 2005; Terwiesch & Loch, 1999). The success of overlapping development stages depends on upstream evolution (refinement of the upstream-generated information, from its preliminary form to a final value) and downstream sensitivity (relationship between the duration of downstream iteration and the magnitude of the change in the upstream information value) (Krishnan et al., 1997). Concurrent engineering is recommended only in situations in which the downstream task is insensitive to changes in the upstream task. When the downstream task is sensitive, overlapping is possible only if the upstream task evolves quickly, such that its information can be frozen before being transferred to the downstream task. When the downstream task is sensitive and the upstream task evolves slowly, overlapping is not recommended (Cantamessa & Villa, 2000; Krishnan et al., 1997). In turn, many new product development project managers continue to employ sequential engineering to avoid the risk of time-consuming iterations in situations in which information evolves slowly and is sensitive.

As such, the benefits of either sequential or concurrent engineering depend on the strength of the feedback effects from downstream to upstream stages, and how many flaws transfer from upstream to downstream stages when downstream stages begin with preliminary designs. These feedback effects between stages are not static, however. The sensitivity of downstream tasks or the evolution of upstream tasks is not consistently low or high throughout the entire project as suggested by previous research. For example, upstream evolution can be low until the downstream stage gets involved, in which the evolution of the upstream stage suddenly speeds up. Therefore, feedback effects between stages are dynamic: their strength and influence on project performance change over time. These effects create such dynamic complexities, that perhaps it is not so surprising that even world-class companies such as Boeing, Airbus, and Lockheed Martin find it difficult to assess them correctly. Therefore, we propose a research design to examine the effects of different levels...
of concurrency on the performance of a new aircraft development program in which we include dynamic feedback effects between stages.

**Research Design and Model Description**

System dynamics is employed as the theoretical lens through which new product development processes are analyzed. System dynamics is eminently suited to investigate these processes because it is equally as nonlinear, feedback oriented, and delay sensitive as the new product development environment; thus, it can effectively capture the complexity of this environment. Not surprisingly, a considerable body of system dynamics knowledge exists related to dynamic behavior in new product development projects (e.g., Abdel-Hamid, 2010; Abdel-Hamid, Sengupta, & Swett, 1999; Ford & Sterman, 1998; Lin et al., 2008; Rahmandad & Weiss, 2009; Reddi & Moon, 2013; Repenning, 2001). In 2007, Lyneis and Ford wrote a review paper on project management applications of system dynamics. To categorize the literature, the authors divide project models into four categories, based on their primary focus: (1) project features (development processes, resources, decision making); (2) rework; (3) control (reducing deviations between planned and actual project performance); and (4) ripple and knock-on effects (side-effects of control efforts). The authors conclude that more research is required on how ripple and knock-on effects might differ throughout different project stages and how these effects may change when different processes or tools are used (Lyneis & Ford, 2007). This is precisely the objective of our model in which we focus on the side effects of sequential versus concurrent processes. In addition, we do not only focus on the performance of the project itself (in terms of time, quality, and costs), but also on how this performance influences the production process and the behavior of (potential) customers in the long-term. Existing project models often do not include customer demand, or at best, treat demand as a constant; that is: not influenced by project performance. We know that this is not true in most situations, for example, in the aerospace industry; therefore, we should include customer demand as an endogenous variable in our model (Sterman, 2000).

Data for our model were gathered through several interviews with five important stakeholders of a leading global aerospace supplier that developed and manufactured highly engineered aircraft systems for the Airbus A380: the program manager, the manufacturing manager, the research and development manager, the director strategy, and the interim manager of business development. Because aircraft development projects typically take almost a decade to complete, the interviews took place between 2003 and 2013. Furthermore, our model uses insights from other well-documented system dynamics models (Abdel-Hamid & Madnick, 1991; Smets, van Oorschot, & Langerak, 2013; Sterman, 2000; van Oorschot, Langerak, & Sengupta, 2011; van Oorschot et al., 2010; Warren, 2008). Finally, the model was used as a management game in a workshop with the research and development manager and his team of engineers. For the team, this was a way to play with different concurrency scenarios. In addition to using previous models as building blocks, this management game was a way to validate the model (Do the scenarios and their results make sense to the engineers?).

Our simulation model includes four major stages that apply to any aircraft development program: (1) basic design, (2) detail design, (3) tooling development, and (4) production (including an initial stage of proto-production). Furthermore, the model contains customer dynamics (effects of delays on customer orders). As such, our model simulates the entire aircraft supply chain from the non-recurring development phase to the recurring production phase, including endogenous customer demand. We have included all these major stages in the model for two reasons: first, these stages represent common industry practices, and second, since we are interested in the interactions between the upstream, current, and downstream development stages, we should at least include three development stages. A full description of the model, following the guidelines provided by Rahmandad and Sterman (2012), is provided in Appendix A. The system dynamics model itself is available on request. In this section, we provide a high-level overview of the most important stocks and flows, including descriptions of the key feedback loops in the model.

**Stocks and Flows Structure of Aircraft Development Stages**

Figure 1 presents a high-level overview of the model we developed. Note, that for reasons of clarity and readability, not all variables and relationships are included in this figure. The figure is divided into four parts. The largest part in the middle represents the stocks and flows used to model an aircraft development stage. The parts on the left- and right-hand sides reflect, respectively, the previous (upstream) and subsequent (downstream) development stage. These up- and downstream stages are modeled similarly to the stage in the middle. Therefore, in Figure 1, we do not duplicate all the variables and relationships of all stages, but only the variables that link the up- or downstream stage to the stage in the middle. The lowest part in Figure 1 reflects the proto, and normal production stages, including sales and delivery to customers.

At the top of Figure 1, the core process of any development stage is depicted: the development of designs (basic designs in stage 1; detail designs in stage 2; or tooling designs in stage 3). A stage may begin as soon as the upstream stage is sufficiently completed (completeness of design of stage $i-1 >$ required completeness of
design of stage \( i-1 \). (Note that in a pure sequential approach, the previous stage has to be 100% finished before the next stage can start.). This means that designs flow from the stock "Designs to Be Developed" to the stock "Designs Remaining." When designs are completed, they flow into the stock of "Designs Completed." The design
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Completion rate is influenced by design capacity, in other words, the number of engineers (not shown in Figure 1, but this capacity depends on the number of designs remaining and the detected design flaws) and the productivity of these engineers. Productivity is influenced by the design quality of both the previous and current stages. The lower the design quality in either stage the lower the productivity, and hence the design completion rate. (It takes longer to determine how to design a certain part of an aircraft if all the previous designs used for input are of low quality.) Design quality can be viewed as a proxy for upstream evolution, discussed by Krishnan et al. (1997): When upstream evolution is low (low quality of the previous stage), it will have a negative impact (reduced productivity) on the next stage. We define “design quality” as the ratio of flaws corrected to the total flaws in a certain design stage.

Design flaws have their own stocks and flows, as depicted in Figure 1. When there are flaws in the design, they are initially gathered in the stock of "Undetected Design Flaws." Although design flaws in a given stage are typically generated during the development of that particular stage, they also can be inherited or transferred from the previous stage. In other words, when a flaw exists in the basic design, it might contaminate all detail designs that use information from it. The lower the level of concurrency between design stages (i.e., less overlapping), the lower the probability of contamination. This is because most of the flaws in the previous stage will be detected and corrected before the next stage begins, which means that most flaws that could have contaminated this next stage will be detected in time (before this stage starts) and as such flow into the stock of “Prevented Design Flaws.” The higher the level of concurrency, the lower the probability that upstream flaws are detected on time, which leads to a lower level of prevented design flaws, and more flaws that eventually must be fixed. The detection of flaws before the start of a stage can be viewed as a proxy for downstream sensitivity, discussed by Krishnan et al. (1997): Downstream sensitivity is high when most flaws incurred in the previous stage have not been detected before the start of this downstream stage because of the high level of concurrency. This will increase the time and effort required in this downstream stage.

The detection rate of flaws depends on the completeness of both the current stage and the next stage: The higher the level of completeness, the more flaws will be detected. Designers can detect flaw not only in their own work but also the work of their predecessors; for example, when detail designers begin working out the details of a basic design, they can detect flaws in this basic design and provide feedback to the basic designers. The fix rate of flaws detected depends on the available design capacity and engineers’ productivity; flaws that are fixed flow into the stock of “Corrected Design Flaws.” The completeness of a design stage is determined by the ratio of work that is already done and the total known workload (normal design work and rework of flaws).

To explain the learning process within and between different stages, we need to look at three key feedback loops that our model contains. First, the learning within a stage is described by loop R1 (pieces of the puzzle). This reinforcing loop describes how, initially, design work proceeds slowly but picks up speed gradually as more design work is done. As the design stage nears completion more of the overall picture becomes clear and it becomes easier to detect remaining design flaws. Furthermore, with better design quality, the remaining blank spots can be filled in more quickly. Learning between stages is described by loops R2 and R3. Loop R2 (downstream feedback), also a reinforcing loop, describes the positive side effects of concurrent engineering. Design flaws in the current stage can also be identified by engineers working in the downstream stage. Thus, the sooner the downstream stage can begin (i.e., higher degree of concurrency), the sooner this downstream information feedback helps to detect flaws in the current stage, thereby boosting the design quality of this stage and the productivity of its engineers. Loop R3 (upstream contamination), another reinforcing loop, describes the negative side effect of concurrent engineering. When there is a high level of concurrency between these two stages, there is a greater likelihood that flaws in the upstream design have not been detected yet and thus will be inherited by the downstream design. In other words, upstream design flaws contaminate the design of the current stage, thereby reducing its quality and hence the productivity of engineers during this stage. In sum, learning is not modeled by one variable; it is a combination of variables in different stages (flaws, design quality, and productivity).

In addition to the three design stages in our model (basic, detail, and tooling), we have modeled the production and sales process as well. The design quality of all the previous design stages will influence the production process. For example, if all three previous stages have a 90% quality rating, the feasible production rate will be just 73% \(0.9 \times 0.9 \times 0.9\) of the potential (gross) production rate. This scenario prompts the realistic behavior of gradually increasing production rates, especially for the first units (learning curve). The production completion rate is also influenced by the number of customer orders in the backlog. The higher the backlog, the higher the production capacity (not in Figure 1) and the higher the production completion rate. Order backlog and production capacity are positively related, because high backlogs usually lead to long delivery delays. Long delivery delays have a negative impact on market attractiveness, which will be described in the next paragraph. When customer orders are fulfilled, these orders flow into the stock.
“Aircrafts Delivered.” The balancing loop B1 (order depletion) prescribes that the higher the customer order backlog is, the higher the production completion rate will be, and as such the more orders will be fulfilled, and the faster the order backlog is reduced again.

When production cannot keep up with the new order rate, delivery delays go up. The longer these delays the lower the market attractiveness of these units. Market attractiveness influences customers in two ways: when attractiveness drops, first, existing customers may start canceling their orders; and second, potential customers may refrain from placing a new order. Both will have a negative effect on the customer order backlog, which will reduce delivery delays again. Hence, this behavior is also described by a balancing loop (B2: order cancellation).

Finally, Figure 1 contains some variables that we use to compare different scenarios: the cumulative number of person-years invested in development and production, and the total number of person-years per unit.

Model Analysis

Base Case Behavior

Figure 2(a–d) shows typical behavior in the base case, which reflects the current managerial practices in this industry. Specifically, the base case simulates the behavior of a new aircraft development program where there is relatively low concurrency between Stages 1 and 2 (basic and detail design), moderate concurrency between Stages 2 and 3 (detail design and tooling development), and low concurrency between Stages 3 and 4 (tooling development and proto-production). This level of concurrency is defined by the required level of completeness of the previous design stage, or rcpdi, where i can be 1, 2, or 3, representing Stage 1, 2, or 3. The interviews we conducted indicated that the following completeness levels are used: rcpd1 = 0.9, rcpd2 = 0.5, and rcpd3 = 0.9. One of the managers we interviewed described the base case behavior as follows: In the beginning, we lose a lot of time in getting it right, and at a certain point there is no time left to getting it right. Then we have to get to the industrialization [detail and tooling] stage and finally, the production has to be done in one day. That is what is happening continuously. And nobody is really rearranging the way we should work. Concurrent engineering is a term that is used a lot in this industry, but it is not done only in the basic design stage, but not between stages. So, it is still cascading of designs, with a hand-over delivery to the next stage. The integration of stages is still a long way behind. Figure 2 presents the results for these completeness levels.

As loop R2 in Figure 1 demonstrates, evaluating increased concurrency between Stages 3 and 4 (tooling development and proto-production) increases the required level of concurrency of the detail design stage, as illustrated by the graph for the undeveloped flaws at this stage, which shows two large waves and one smaller one. This smaller wave reflects the number of flaws that actually arose during the tooling development stage.

Figure 2(d) shows the behavior of (potential) customers in the base case. While the aircraft is being developed, customer order backlog increases. In the base case, the first delivery of the new aircraft was scheduled for month 82 (mid-2007). Because the development stage had not been completed at that time (many flaws are still remaining and proto-production has not even started yet), some customers canceled their orders. This cancellation process continues until the production rate is up to speed, and the customer order backlog is steadily declining. Finally, we note some key performance indicators for this base case: In 200 months (end of 2017), 260 aircrafts will be produced, which will take 5.83 development and 39.27 production person-years per unit (total = 45.20 person-years per unit), respectively.

Evaluating Increased Concurrency between Stages

As loop R2 in Figure 1 demonstrates, high levels of concurrency can accelerate development by increasing feedback from downstream stages. However, higher concurrency can also lead to more contamination from upstream stages, which decelerates development (loop R3). To address this apparent trade-off, we performed scenario analyses to determine which loop (downstream feedback or upstream contamination) is more powerful and at which levels of concurrency. We ran 11 scenarios, with the required completeness of the previous design stage (rcpd(i)), ranging from 0.05 to 0.975. In
Figure 3(a,b), we first show some behavior over time for scenarios with low ($rcpd_i = 0.9$), mid-range ($rcpd_i = 0.5$), and high ($rcpd_i = 0.1$) levels of concurrency. Figure 4 depicts the normalized financial performance of all 11 scenarios. The norm is a sequential design in which the required completeness of all stages is 0.975 (note that this norm is different; that is, more sequential than our base case).

The simulation results in Figures 3 and 4 provide two insights. First, increasing the levels of concurrency between development stages increases development performance (total person-years per unit is decreased), but only to a certain point. Beyond this point, increasing the levels of concurrency further decreases performance. The best result arrives when the required completeness
between stages is 0.4 (large black dot in Figure 4, with normalized total person-years per unit = 83.42 and normalized number of aircraft produced = 184). In other words, when 40% of the upstream stage is finished, the downstream stage can begin. Accordingly, there is a 60% overlap between stages. Compared with the completely sequential design, the total number of person-years per unit decreases by almost 17%, and output increases by 84% (the base case would have resulted in normalized total person-years per unit = 90.60 and normalized aircraft produced = 142). Moving toward a more sequential design means that the downstream feedback loop becomes less effective. In addition, although the number of inherited flaws from upstream stages also diminishes (Figure 3b), the loss of downstream feedback decreases development speed to the extent that many customer orders are canceled. As a result, development costs per unit increase quickly (because there are fewer units produced). At the other extreme, the development stages evolve quickly but at the high cost of correcting flaws. Figure 3(a), shows that although the required concurrency between stages is slightly more or less than 0.4, development is more or less the same. For example, the required completeness of 0.3, 0.5, and 0.6 lead to, respectively, 85.91, 83.56, and 85.13 total normalized person-years per unit. As shown by the curves in Figure 4, the flatness of the U-shaped curve is primarily caused by the production costs per unit if managers only consider the

Sequential Design ($rcpd = 0.9$)  
Mixed Design ($rcpd = 0.5$)  
Concurrent Design ($rcpd = 0.1$)

Figure 3: Simulation results for low ($rcpd = 0.9$), moderate ($rcpd = 0.5$), and high ($rcpd = 0.1$) levels of concurrency. (a) Completeness of tooling stage, (b) corrected tooling flaws, (c) aircrafts produced, and (d) customer order backlog.
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Figure 4: Financial performance of scenarios with different levels of concurrency.

Discussion

This research began with our amazement that so many major new aircraft development programs finish much later and with much higher costs than originally planned. In most complex systems, human errors—not technical flaws—account for most major incidents. It therefore seems reasonable to assume that psychological limitations provide potential explanations for the project delays in aerospace new product development.

This research focuses on one such psychological limitation or managerial decision trap: managers’ tendency to strive for full completion of one project stage before allowing the next stage to start, particularly in high-risk settings. What if the managers involved had acted differently—would things have been better? As the manufacturing manager indicated in hindsight, when the project was finished: When we started this development project we had a “first-time-right” strategy, meaning that nothing was supposed to leave the basic design phase until it was 100% finished. We thought that this would prevent expensive problem-solving iterations and rework between the basic and detail design phases, which eventually lead to budget and schedule overruns we all know so well in new aircraft development programs. But, we have discovered that this approach reduces learning between phases to such an extent that it is causing schedule overruns instead of preventing them.

We developed a simulation model of a major new aircraft development program, based on input from the industry and a body of pre-existing, well-tested, new product development simulation models. The analysis suggests that major improvements occur when more concurrency is allowed, because in projects of such complexity, team learning is crucial (Brown & Eisenhardt, 1995; Sethi & Iqbal, 2008), and more concurrency feeds learning in two major ways, even when it also results in rework or throwing away previous work based on outdated assumptions. First, downstream stages can begin learning sooner, albeit at a slower pace, such that they are ready to “hit the ground running” when the definitive outputs arrive from the preceding stage. Second, learning in the downstream stages results in valuable upstream feedback, which addresses the unknown unknowns so pervasive in complex new development projects (Sommer & Loch, 2004).

Finishing aircraft development programs sooner not only saves time and money; it also results in fewer order cancellations and more sales. High concurrency across all project stages leads to significantly higher sales. However, because high concurrency also leads to higher design costs due to the increase of flaws, these high concurrency levels are not recommended, from the perspective of total person-years per unit. High concurrency levels increase the possibility that downstream engineers unknowingly inherit flaws by upstream
The main advantage of using simulation as a research method is that it enables what-if analyses, a process that by definition is impossible empirically or outside laboratory settings. Thus we gain insights into how much concurrency would have been beneficial and why. We suggest that the use of simulation modeling to generate new insights in this manner deserves wider usage, certainly when combined with empirical research methods (Davis, Eisenhardt, & Bingham, 2007). The finding that increased levels of concurrency between development phases speeds up product development is not new. Many researchers have advocated this approach, but primarily for product development projects with low uncertainty and complexity (Eisenhardt & Tabrizi, 1995; Krishnan et al., 1997; Smith & Eppinger, 1997; Terwiesch et al., 2002). Others have focused on the concurrent engineering of different software releases (Rahmandad & Weiss, 2009), where the development and market introduction of different releases overlap and therefore influence each other; as such, these authors have modeled a multi-project environment. New aircraft development is, because of its nature, often not introduced to the market in short iterative, agile, releases. The delays within and between projects are much longer, which influences the dynamic behavior of the system, and may lead to different best practices. When a development team knows what to develop or how to define different releases of the product, it is easier to decide how and which activities can be overlapped and which cannot. However, with our simulation we have challenged this idea and tested what could happen if managers take the risk to overlap development phases even in the most uncertain and complex environments, such as new aircraft development. Future research could analyze how other uncertain and complex environments (e.g., the semiconductor industry, telecom industry) respond to overlapping and whether or not a U-shaped relationship between overlapping and performance exists. Furthermore, it would be interesting to examine this U-shape in less uncertain and complex projects. Salomo, Weise, and Gemünden (2007) found that projects with high levels of innovativeness may be negatively influenced by too strict processes (as in strict gates between stages). This may imply that projects with low levels of innovativeness could potentially benefit more from strict gates and have a different U-shaped relationship between overlapping and performance.

Our contributions to the literature are threefold. First, our work answers to the call for more research on how side effects of different project approaches might differ throughout different project stages and how these effects may change when different processes or tools are used (Lyneis & Ford, 2007). Second, we find that although concurrency leads to more design flaws and hence more rework cycles feared by managers, the time lost by these rework cycles is in the end more than compensated for by the time gained by faster learning and therefore higher productivity in the later stages of the project. As such, complex projects with downstream development stages that are sensitive to changes in upstream stages can also benefit from a concurrent approach, which is a finding that extends the results of previous research (Cantamessa & Villa, 2000; Krishnan et al., 1997; Loch & Terwiesch, 2005; Terwiesch & Loch, 1999). Third, our results show that by including production and sales processes (with endogenous customer demand), the conclusion about what levels of concurrency work best changes. That is, if we only look at the non-recurring stages (the development project), lower levels of concurrency perform best, which is in line with the risk-aversive behavior of most managers in this industry. When we only look at the recurring stages (production and sales), higher levels of concurrency perform best. However, when we look at
the entire system of non-recurring and recurring stages, medium levels of concurrency are recommended. Although our findings do not imply that small pieces of aircraft are delivered to customers in iterative cycles, as would be the case in pure agile development, it does imply that production engineers are involved earlier in the process or that prototypes are built as soon as possible to speed up learning. This probably leads to a more expensive development project, but also a less expensive production process; a finding that could only be discovered by focusing on the entire system. As Sterman (2002) point out: almost nothing is exogenous. "The failure to recognize the feedback in which we are embedded, only intensifies our problem. One of the goals of system dynamics is to lengthen the time horizon we consider so we can see the patterns of behavior created by the underlying feedback structure, not only the most recent events" (Sterman, 2002, p. 511). Our results support this: protecting the system from time-consuming rework cycles only leads to more delays in the long run.

Managerial Limitations and Contributions

For practicing managers, the simulations do not “prove” anything about the programs; rather, they cast reasonable and beneficial doubts on the effectiveness of established approaches to managing major, complex projects. If programs are repeatedly late and over budget, something is systematically being overlooked or done wrong. There must be a “blind spot” in how management regards these projects and then how they are handled. The degree of concurrency allowed in such projects is one such blind spot. Our goal is to prompt managers to consider our findings, which indicate that the benefits of more concurrency in complex projects (early feedback from downstream stages) outweigh the drawbacks (more flaws due to contamination from upstream stages). To paraphrase the reaction of one of the interviewed managers to our research results: Basic design is difficult, but the detail and tooling stage should start almost at the same moment. In the thinking process, people should be actively thinking about the doing: what the design does to the production process, what it does to the maintenance process, what it does to the quality systems. Normally we tend to take these with us in projects as risks instead of actions. […] The mindset should be: How can I create learning loops early in the process instead of mitigating risks. That is a different way of thinking which has not yet landed and which is something that we are trying to get into place in our company.

References


Henk Akkermans is Professor of Supply Network Dynamics at Tilburg University, The Netherlands. He holds a PhD in Industrial Engineering from Eindhoven University of Technology. His current research interests are in behavioral decision-making dynamics in decentralized organizational networks, ranging from decision-making issues in new service/product development via ramp-ups to maintenance/asset management. He can be contacted at ha@uvt.nl

Kim E. van Oorschot is an Associate Professor of Project Management and System Dynamics at BI Norwegian Business School, Norway. She received her PhD in Industrial Engineering from Eindhoven University of Technology. Her research interests include decision making, trade-offs, and tipping points in dynamically complex settings, such as new product development projects. She can be contacted at kim.v.oorschot@bi.no
Appendix A: Model Documentation

This model documentation gives a full description of equations used in the system dynamics model (Table A1). Next, we give a list of symbols used and explain what the symbol stands for (Table A2); if the symbol reflects an exogenous variable (a constant in the model), we include the value of this constant, and we provide the source. Note that the simulation model is available on request to readers of the Project Management Journal.

### Formulations and Comments: Generic Simulation and Scenario Parameters

<table>
<thead>
<tr>
<th>i = 1, 2, 3; 1 = Basic design; 2 = Detail design; 3 = Tooling development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subscript i is used to indicate the project stage.</td>
</tr>
<tr>
<td>Initial time = 0 Months</td>
</tr>
<tr>
<td>Final time = 200 Months</td>
</tr>
<tr>
<td>Time step = 0.25 Months</td>
</tr>
<tr>
<td>The following units of measures are used as equivalents in the model: documents, tools, flaws.</td>
</tr>
</tbody>
</table>

### Formulations and Comments: Basic Design, Detail Design, and Tooling Development

<table>
<thead>
<tr>
<th>Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>$DD_i(t) = DD_i(0) + \int_0^t (-dsr_i(s))ds; DD_0(0) = 0; DD_2(0) = TDR_2; DD_3(0) = TDR_3$</td>
</tr>
<tr>
<td>$dsr_i(t) = 0$</td>
</tr>
<tr>
<td>$dsr_2,3(t) = \text{IF THEN ELSE } (cd_1,2(t) &gt; rcpd_1,2, DD_2,3(t)/td, 0)$</td>
</tr>
<tr>
<td>$DR_i(t) = DR_i(0) + \int_0^t (dsr_i(s) - dcr_i(s))ds; DR_i(0) = 0$</td>
</tr>
<tr>
<td>$dcr_i(t) = \text{MIN}(DR_i(t) / ddd, \text{prod}<em>{i}(t) \cdot \text{cad}</em>{i}(t))$</td>
</tr>
<tr>
<td>$DC_i(t) = DC_i(0) + \int_0^t (dcr_i(s))ds$</td>
</tr>
<tr>
<td>The rate at which designs are completed ($dcr$) depends on the number of designs that are still remaining ($DR$), the minimum time required to complete a design ($ddd$), the design capacity available ($cad$) and the productivity of engineers ($prod$). Designs that are completed are gathered in the stock Designs Completed ($DC$). (cad and prod will be defined later).</td>
</tr>
<tr>
<td>$cd_i(t) = \text{DIM}(DC_i(t) + CDF_i(t)) / (TDR + DDF_i(t) + CDF_i(t))$</td>
</tr>
<tr>
<td>The completeness of any design stage is determined by the ratio of work that has been done (designs completed ($DC$) and flaws corrected ($CDF$)) and the total amount of work that needs to be done (total designs required ($TDR$), detected design flaws ($DDF$) and $CDF$). $DDF$ and $CDF$ will be explained later.</td>
</tr>
<tr>
<td>$DCap_i(t) = DCap_i(0) + \int_0^t (cdc_i(s))ds; DCap_1(0) = 10; DCap_2,3(0) = 0$</td>
</tr>
<tr>
<td>$cdc_i(t) = (DR_i(t) - DCap_i(t))/\text{dcad}$</td>
</tr>
</tbody>
</table>

(Continued)
Pilot Error?

Formulations and Comments: Basic Design, Detail Design, and Tooling Development

<table>
<thead>
<tr>
<th>Formulations</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_C(t) = \min(D_C(t) + D_D(t) / (1 + D_C(t) / D_D(t)))$</td>
<td>Documents/month</td>
</tr>
<tr>
<td>The actual design capacity ($D_C$) for each stage adapts to the required capacity ($D_R$) with a certain design capacity adjustment delay ($D_D$). The required capacity depends on the number of documents that are still remaining ($D_C(t)$), the number of flaws that are detected ($D_D(t)$), and rework time ($D_D(t)$). Furthermore, the required capacity is constrained by a maximum capacity ($maxD_C(t)$), i.e., the maximum number of engineers that are allowed to work on the project.</td>
<td></td>
</tr>
</tbody>
</table>

$$caff(t) = D_C(t)$$

$$cad(t) = D_C(t) - frf(t)$$

Engineers have to divide their time between fixing flaws and doing normal work. We assume that engineers will always prioritize fixing flaws over their normal design work. As such, the capacity available for fixing flaws ($caff$) is equal to the design capacity. Hence, the fix rate of design flaws ($frf$) is influenced by $caff$, which will be explained later. If there is any capacity remaining after fixing flaws, this capacity is allocated to the normal design work ($cad$).

Formulations and Comments: Design Quality and Flaws

<table>
<thead>
<tr>
<th>Formulations</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$UDF_i(t) = UDF_i(0) + \int_0^t { grf_i(s) + trfps_i(s) - drfbs_i(s) - drf_i(s) } ds; UDF_i(0) = 0$</td>
<td>Flaws</td>
</tr>
<tr>
<td>$grf_i(t) = d_{d_1}(t) - df - dcr_i(t)$</td>
<td>Flaws/month</td>
</tr>
<tr>
<td>$trfps_i(t) = 0$</td>
<td>Flaws/month</td>
</tr>
<tr>
<td>$drfbs_i(t) = grf_i(t)$</td>
<td>Flaws/month</td>
</tr>
</tbody>
</table>

Design flaws are described by four stocks. First, flaws that are made, flow into the stock of Undetected Design Flaws ($UDF$). Flaws can be generated during a stage (generation rate of flaws, $grf$), while designs are made. This generation rate of flaws depends on the design completion rate (the higher the design completion rate, the more mistakes are made) and on the quality of the design ($d_{d_1}$). Furthermore, this generation rate is influenced by a constant error factor ($ef$) that defines how many flaws one document can have. Flaws can also be inherited from a previous design stage, in which case these flaws are transferred from one stage to the next (transfer rate of flaws from previous stage, $trfps$). This means that in theory, a downstream stage can already have undetected flaws before this stage has even started. For example, if a basic design has undetected flaws, it is very likely that these flaws are inherited by or transferred to the detail design. In this case the detail engineers start their work with the wrong designs without knowing this.

$$PDF_i(t) = PDF_i(0) + \int_0^t [drfbs_i(s)] ds; PDF_i(0) = 0$$

$$CDF_i(t) = CDF_i(0) + \int_0^t [drf_i(s)] ds; CDF_i(0) = 0$$

$$DDF_i(t) = DDF_i(0) + \int_0^t [drf_i(s) - frf_i(s)] ds; DDF_i(0) = 0$$

If undetected flaws in, for example, the basic design stage are detected before the detail design stage has started, the inheritance of flaws by the detail design stage is prevented and flaws flow from the stock of Undetected Design Flaws into the stock of Prevented Design Flaws ($PDF$) (defined by the detection rate of flaws before start of stage, $drfbs$). The detection rate of flaws ($drf$) describes the number of flaws that are detected during a particular design stage per time unit. Once detected, the flaws flow into the stock of Detected Design Flaws ($CDF$). When these flaws are fixed ($frf$), they flow into the stock of Corrected Design Flaws ($DDF$).
**Formulations and Comments: Design Quality and Flaws**

The detection rate of flaws in a particular stage is influenced by the level of completeness of the stage (the higher the completeness, the more flaws are detected), but also by the completeness of the next stage. In highly complex development projects, flaws are often detected by downstream phases. The earlier these downstream engineers are involved in the project, the higher the detection rate of flaws, and the faster engineers are able to learn and improve the quality of the design. As such, we assume that there is a certain percentage of undetected flaws that can be discovered by the current stage and by the next stage (percentage of flaw discovery, \(f_{dS}\)). Furthermore, the detection rate is constrained by the level of undetected design flaws and the minimum time required to detect a flaw (detection delay, \(d_{fS}\)). Finally, the detection rate is also influenced by the flaws that are detected by the previous stage (\(f_{dS}\)). This can happen when for example detail engineers are working out the details of a basic design that is flawed.

When basic engineers discover the flaw in the basic design, the flaws that are inherited from the upstream stage but are detected before the start of the current stage just in time, that is, just before the current stage starts working on the "infected" design. The higher the level of completeness of the previous stage (\(C_{dS}\)) and the minimum time required to detect a flaw (detection delay, \(d_{fS}\)), the lower the rate of flaws before the start of the stage.

Flaws in a stage can be detected by engineers in the upstream (previous) stage. Sometimes this detection is just in time, or before the engineers in the stage have started working on the flawed designs. In this case, flaws are detected but prevented (\(f_{dS}\)). When engineers have started working on the flawed designs already, the flaws need to be corrected (\(f_{cS}\)). To calculate the number of faults that are detected during the stage but that are nevertheless prevented or detected just in time, we first need to determine the percentage of designs that are possibly infected by flaws from the previous design (\(p_{i}\)). This \(p_{i}\) is the ratio of the sum of designs remaining and designs completed, and the total number of designs required (\(TDR\)). Note that before the start of the stage (\(SD = 0\)), all defined design flaws in upstream stages will prevent flaws in downstream stages. This start time is a dummy variable that is 0 when the stage has not started yet and 1 when the stage has started.

\[
\begin{align*}
    f_{dS}(t) &= \text{IF THEN ELSE}(SD_{S})(t = 1, drf_{S}(t)(1 - p_{i})(t)(0), 0) \\
    f_{dS}(t) &= 0 \\
    f_{dS}(t) &= \text{IF THEN ELSE}(SD_{S})(t = 1, drf_{S}(t)(1 - p_{i})(t)(0), 0) \\
    f_{dS}(t) &= 0 \\
    SD_{S}(t) &= \text{IF THEN ELSE}(SD_{S})(t > rcd_{S}, (-SD_{S} + 1)/\text{timestep}, 0) \\
    C_{dS}(t) &= \text{MIN}(\text{caff}(t) - \text{prod}(t), DDF(t)/d_{fS}) \\
    \text{prod}(t) &= \text{MAX}(\text{minp}, d_{q}(t)) \\
    \text{prod}(t) &= \text{MAX}(\text{minp}, d_{q}(t)) - d_{q}(t) \\
    \text{prod}(t) &= \text{MAX}(\text{minp}, d_{q}(t)) - d_{q}(t) \\
    d_{q}(t) &= \text{CDF}(t)/\text{t}(t) = \text{CDF}(t)/\text{t}(t) + DDF(t) + CDF(0) \\
\end{align*}
\]

The fix rate of flaws is determined by the available capacity, the productivity of engineers (\(\text{prod}\)) and the minimum time required to fix a flaw, the fix delay (\(d_{fS}\)). The productivity of engineers in a particular stage is influenced by the design quality of that stage, but also by the design quality of the previous stages. It is assumed that when engineers have to use input from a previous stage that has low quality, their productivity will be negatively influenced. The same holds for the quality of their own design work in their own stage. Furthermore, the productivity is constrained by a lower bound, the minimum productivity (\(\text{minp}\)). The design quality (\(d_{q}\)) is the ratio of corrected design flaws (\(\text{CDP}\)) and the total design flaws (\(t_{df}\)) which is the sum of all flaws that can potentially damage the design.

(Continued)
Pilot Error?

Formulations and Comments: Production Process

\[
WIP(t) = WIP(0) + \int_0^t pc(t) \, ds; \quad WIP(0) = 0
\]

\[
AP(t) = AP(0) + \int_0^t pc(t) \, ds; \quad AP(0) = 0
\]

The production process is modeled by two stocks: work in process (WIP) and aircrafts produced (AP). WIP is defined by the production start rate (psr) and the production completion rate (pcr). The stock of aircrafts produced (AP) is the accumulation of pcr.

\[
psr(t) = \text{IF THEN ELSE}(cd(t) > rcpd, COB(t)/pct(0))
\]

\[
pcr(t) = \text{MIN}(WIP(t)/\text{minpt}, FPC(t))
\]

The production start rate begins when the completeness of the tooling stage (cd) is higher than the required level of completeness of the tooling stage (rcpd). If this is true, the production start rate is equal to the customer order backlog (COB) divided by the target production cycle time (pct). If this is untrue, the production stage is not allowed to start and psr is equal to 0. The production completion rate is determined by the minimum of the WIP divided by the minimum production time (minpt) and the feasible production capacity (FPC). COB will be explained later.

\[
FPC(t) = FPC(0) + \int_0^t cFPC(s) \, ds; \quad FPC(0) = 0
\]

\[
cFPC(t) = 1 - FPC(t)/\text{POC(t)/PCad}
\]

The feasible production capacity (FPC) is determined by the gross production capacity (GPC) and the design quality of the previous three design stages. If all three are at 90%, the feasible production capacity will be just 0.9 × 0.9 × 0.9 = 0.73% of the gross production capacity. This creates the realistic behavior of a gradually increasing production rate for especially the first units. FPC is modeled as an adaptive expectation with an adjustment time equal to the target production cycle time (it is assumed that after each production cycle, engineers will learn and are able to adjust their production rate).

\[
GPC(t) = GPC(0) + \int_0^t cGPC(s) \, ds; \quad GPC(0) = 0
\]

\[
cGPC(t) = 1 - GPC(t)/\text{POC(t)/PCad}
\]

\[
POC(t) = \text{IF THEN ELSE}(\text{time < sfd} - \text{PCad} 0, \text{MIN}(WIP(t)/pct, \text{maxPC}))
\]

GPC is modeled as an adaptive expectation of the required production capacity (POC) over a certain production capacity adjustment delay (PCad). One problem with production capacity is that you cannot order it out of the blue. Factory buildings and production lines have to be developed, employees have to be trained, and all this has to happen well ahead of delivery time. So, when calculating the POC, we need to take into account the point in time when the first deliveries should take place, offset that back in time to account for the target production cycle time and then calculate the required capacity based on the WIP and pct (constrained by a certain maximum level of production capacity, maxPC).

\[
CPP(t) = \text{MIN} (1, \text{AR(t)/spp})
\]

Dimensionless

During the production of the first 40 units, a stage that is called proto-production, invariably aspects of the design come up in production that are not smart or just plain wrong. Through the downstream feedback loop the quality of the detailed and tooling design can still be improved during this proto-production phase. This quality is influenced by the completeness of the proto stage (cpp), which is defined as the ratio of AP and the size of the proto-production (spp). This cpp is used to calculate the detection rate of flaws (dfr) in the detailed and tooling design stages.

Formulations and Comments: Customer Demand

\[
PM(t) = PM(0) + \int_0^t npr(s) \, ds; \quad PM(0) = 300
\]

\[
npr(t) = PM(t)/pd
\]

Units

Units/month

(Continued)
### Formulations and Comments: Customer Demand

<table>
<thead>
<tr>
<th>Formula</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>[P(t) = P(0) + \int_0^t \left( npr(s) - nor(s) \right) ds; \quad P(0) = 0]</td>
<td>Units</td>
</tr>
<tr>
<td>[nor(t) = ma(t) \cdot P(t)/csd]</td>
<td>Units/month</td>
</tr>
<tr>
<td>[COB(t) = COB(0) + \int_0^t \left( nor(s) - ofr(s) \right) ds; \quad COB(0) = 0]</td>
<td>Units</td>
</tr>
</tbody>
</table>

Customer orders come out of the stock of Potential Market (PM). After a prospecting delay (pd) potential customers become prospects (P). This is defined by the new prospect rate (npr). Prospects can place a customer order (nor) after a commercial sales delay (csd), depending on the market attractiveness (ma) of the product. The new customer orders are accumulated in the Customer Order Backlog (COB).

\[ofr(t) = ma(t) \cdot \min(COB(t)/ma(t), pct(t))\]  
\[ocr(t) = (1 - ma(t)) \cdot COB(t)/cld\]  
\[AD(t) = AD(0) + \int_0^t ofr(s) ds; \quad AD(0) = 0\]  
\[CC(t) = CC(0) + \int_0^t ocr(s) ds; \quad CC(0) = 0\]

The longer customers have to wait for their product, the more customers will cancel their order. As such, the order cancellation rate (ocr) is determined by COB, the market attractiveness of the product (ma), and a cancellation delay (cld). The order fill rate (ofr) is defined by COB, ma, and the minimum time required to fill an order (minort). The order fill rate is accumulated in the stock of Aircrafts Delivered (AD). The order cancellation rate is accumulated in the stock of Customer Orders Canceled (CC).

\[ma(t) = \frac{pct}{PDD(t)}\]  
\[PDD(t) = PDD(0) + \int_0^t cPDD(s) ds; \quad PDD(0) = \frac{pc}{t}\]  
\[cPDD(t) = \frac{-PDD(t) + aPDD(t)}{cpd}\]  
\[aPDD(t) = \text{IF THEN ELSE}(time < sfd, pct, COB(t)/maxPC)\]

The market attractiveness is defined as the ratio of the target production cycle time and the perceived delivery delay (PDD) by customers. The longer the delivery delay the lower the market attractiveness. PDD is modeled as an adaptive expectation. It adapts slowly to the actual perceived delivery delay (aPDD) during a customer perception delay (cpd). It is important to note about aPDD that customers cannot start perceiving it until the scheduled first delivery (sfd) has passed, so there is a conditional statement in the equation of aPDD that makes sure that until the scheduled first delivery (sfd), customers do not take delays into account. Furthermore, customers assume that deliveries will be according to the nominal capacity (maxPC) of the company, instead of the much lower feasible production capacity (FPD). Feasible capacity is lower because of the many quality issues during ramp-up, which mostly remain hidden from customers.

### Formulations and Comments: Financial Indicators

<table>
<thead>
<tr>
<th>Formula</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>[CDPY_i(t) = CDPY_i(0) + \int_0^t adPY_i(s) ds; \quad CDPY_i(0) = 0]</td>
<td>Person-years</td>
</tr>
<tr>
<td>[adPY_i(t) = DCap_i(t) \cdot dpr]</td>
<td>Person-years/month</td>
</tr>
<tr>
<td>[CDevPY(t) = CDPY_i(t) + CDPY_j(t) + CDPY_k(t)]</td>
<td>Person-years</td>
</tr>
<tr>
<td>[CPPY(t) = CPPY(t) + \int_0^t apPY(s) ds; \quad CPPY(0) = 0]</td>
<td>Person-years</td>
</tr>
</tbody>
</table>

(Continued)
Pilot Error?

Formulations and Comments: Financial Indicators

<table>
<thead>
<tr>
<th>Formula</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$apPY(t) = GFC(t) \cdot ppr$</td>
<td>Person-years/month</td>
</tr>
<tr>
<td>$devPYu(t) = CDevPY(t)/AP(t)$</td>
<td>Person-years/unit</td>
</tr>
<tr>
<td>$proPYu(t) = CPPY(t)/AP(t)$</td>
<td>Person-years/unit</td>
</tr>
<tr>
<td>$tPYu(t) = devPYu(t) + proPYu(t)$</td>
<td>Person-years/unit</td>
</tr>
</tbody>
</table>

We simply cumulate the hours in each of the three design stages into the stock of Cumulative Design Person-Years ($CDPY$). To transfer design capacity ($DCap$) to person-years, we use the design productivity ($dpr$). Then the cumulative development person-years ($CDdevPM$) is calculated as the sum of the cumulative person-years of the three design stages. Likewise, we cumulate the hours in the production phase into the stock of Cumulative Production Person-Years ($CPPY$). To transfer gross production capacity ($GPC$) into person-years, we use the production productivity ($ppr$). By dividing both these person-year-numbers by total units produced, we get the development ($devPYu$), production ($proPYu$), and total person-years per unit ($tPYu$). Note that although we do not have actual hourly rates or profit numbers, we can say something about hours spent and about cumulative sales, which is a good proxy for comparing different policy options.

Table A1: Formulation and comments.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Variable Name</th>
<th>Value</th>
<th>Units</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD</td>
<td>Aircrafts delivered</td>
<td></td>
<td>Units</td>
<td>a</td>
</tr>
<tr>
<td>adPY</td>
<td>Add design person-years</td>
<td></td>
<td>Person-years/month</td>
<td>b</td>
</tr>
<tr>
<td>AP</td>
<td>Aircrafts produced</td>
<td></td>
<td>Units</td>
<td>a</td>
</tr>
<tr>
<td>aPDD</td>
<td>Actual perceived delivery delay</td>
<td></td>
<td>Months</td>
<td>a</td>
</tr>
<tr>
<td>apPY</td>
<td>Add production person-years</td>
<td></td>
<td>Person-years/month</td>
<td>b</td>
</tr>
<tr>
<td>cad_i</td>
<td>Capacity available for design</td>
<td></td>
<td>Documents/month</td>
<td>c,d</td>
</tr>
<tr>
<td>cafil_i</td>
<td>Capacity available for fixing flaws</td>
<td></td>
<td>Flaws/month</td>
<td>c,d</td>
</tr>
<tr>
<td>CC</td>
<td>Customer orders canceled</td>
<td></td>
<td>Units</td>
<td>e</td>
</tr>
<tr>
<td>cdc_i</td>
<td>Change of design capacity</td>
<td></td>
<td>Documents/month/month</td>
<td>a</td>
</tr>
<tr>
<td>CDevPY</td>
<td>Cumulative development person-years</td>
<td></td>
<td>Person-years</td>
<td>b</td>
</tr>
<tr>
<td>cDF_i</td>
<td>Corrected design flaws</td>
<td></td>
<td>Flaws</td>
<td>b</td>
</tr>
<tr>
<td>cd_i</td>
<td>Completeness of design</td>
<td></td>
<td>Dimensionless</td>
<td>b</td>
</tr>
<tr>
<td>CDPIY_i</td>
<td>Cumulative design person-years</td>
<td></td>
<td>Person-years</td>
<td>b</td>
</tr>
<tr>
<td>cFPC</td>
<td>Change of feasible production capacity</td>
<td></td>
<td>Units/month/month</td>
<td>f</td>
</tr>
<tr>
<td>cld</td>
<td>Cancellation delay</td>
<td>60</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>COB</td>
<td>Customer order backlog</td>
<td></td>
<td>Units</td>
<td>a</td>
</tr>
<tr>
<td>cpd</td>
<td>Customer perception delay</td>
<td>12</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>cPDD</td>
<td>Change of perceived delivery delay</td>
<td></td>
<td>Months/month</td>
<td>a</td>
</tr>
<tr>
<td>cPGC</td>
<td>Change of gross production capacity</td>
<td></td>
<td>Units/month/month</td>
<td>a</td>
</tr>
<tr>
<td>CPPY</td>
<td>Cumulative production person-years</td>
<td></td>
<td>Person-years</td>
<td>b</td>
</tr>
<tr>
<td>cpp</td>
<td>Completeness of proto stage</td>
<td></td>
<td>Dimensionless</td>
<td>b</td>
</tr>
<tr>
<td>cspd</td>
<td>Commercial sales delay</td>
<td>60</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>dcad</td>
<td>Design capacity adjustment delay</td>
<td>6</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>DC</td>
<td>Designs completed</td>
<td></td>
<td>Documents</td>
<td>e</td>
</tr>
<tr>
<td>DCap</td>
<td>Design capacity</td>
<td></td>
<td>Documents/month</td>
<td>a</td>
</tr>
<tr>
<td>DCR</td>
<td>Design capacity required</td>
<td></td>
<td>Documents/month</td>
<td>a</td>
</tr>
<tr>
<td>dcr</td>
<td>Design completion rate</td>
<td></td>
<td>Documents/month</td>
<td>e</td>
</tr>
<tr>
<td>dd</td>
<td>Detection delay</td>
<td>6</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>ddd_i</td>
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<td>Months</td>
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</tr>
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<td>Flaws</td>
<td>c,d</td>
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<td>DD</td>
<td>Designs to be developed</td>
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<td>Documents</td>
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</tr>
<tr>
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<td>Person-years/unit</td>
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</tr>
<tr>
<td>dpr</td>
<td>Design productivity</td>
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</tr>
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<td>Design quality</td>
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<td>Dimensionless</td>
<td>d,g</td>
</tr>
<tr>
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<td>Detection rate of flaws before start of stage</td>
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<td>Flaws/month</td>
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<td>Detection rate of flaws</td>
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<td>Flaws/month</td>
<td>c,d</td>
</tr>
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<td>DR</td>
<td>Designs remaining</td>
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<td>Documents</td>
<td>e</td>
</tr>
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<td>Design start rate</td>
<td></td>
<td>Documents/month</td>
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<td>ef</td>
<td>Error factor</td>
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<tr>
<td>fd</td>
<td>Fix delay</td>
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<td>Month</td>
<td>f</td>
</tr>
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<td>fdfs_i</td>
<td>Flaws detected before start of stage</td>
<td></td>
<td>Flaws/month</td>
<td>f</td>
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(Continued)
### Abbreviation Variable Name Value Units Source

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<th>Value</th>
<th>Units</th>
<th>Source</th>
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<td>Flaws detected during the stage</td>
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<tr>
<td>fdspl</td>
<td>Flaws detected during the stage but prevented</td>
<td></td>
<td>Flaws/month</td>
<td>f</td>
</tr>
<tr>
<td>FPC</td>
<td>Feasible production capacity</td>
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<td>Units/month</td>
<td>f</td>
</tr>
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<td>frf</td>
<td>Fix rate of flaws</td>
<td></td>
<td>Flaws/month</td>
<td>c,d</td>
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<tr>
<td>GPC</td>
<td>Gross production capacity</td>
<td></td>
<td>Units/month</td>
<td>a</td>
</tr>
<tr>
<td>grf</td>
<td>Generation rate of flaws</td>
<td></td>
<td>Flaws/month</td>
<td>c,d</td>
</tr>
<tr>
<td>ma</td>
<td>Market attractiveness</td>
<td></td>
<td>Dimensionless</td>
<td>h</td>
</tr>
<tr>
<td>maxDCap</td>
<td>Maximum design capacity</td>
<td>20; 200; 100</td>
<td>Documents/month</td>
<td>f</td>
</tr>
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<td>maxPC</td>
<td>Maximum production capacity</td>
<td>4</td>
<td>Units/month</td>
<td>f</td>
</tr>
<tr>
<td>minoft</td>
<td>Minimum order fill time</td>
<td>1</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>minp</td>
<td>Minimum productivity</td>
<td>0.2</td>
<td>Dimensionless</td>
<td>f</td>
</tr>
<tr>
<td>minpt</td>
<td>Minimum production time</td>
<td>1</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>nor</td>
<td>New order rate</td>
<td></td>
<td>Units/month</td>
<td>i</td>
</tr>
<tr>
<td>npr</td>
<td>New prospect rate</td>
<td></td>
<td>Units/month</td>
<td>i</td>
</tr>
<tr>
<td>ocr</td>
<td>Order cancellation rate</td>
<td></td>
<td>Units/month</td>
<td>e</td>
</tr>
<tr>
<td>afr</td>
<td>Order fill rate</td>
<td></td>
<td>Units/month</td>
<td>a,e</td>
</tr>
<tr>
<td>p</td>
<td>Prospects</td>
<td></td>
<td>Units</td>
<td>i</td>
</tr>
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<td>PCad</td>
<td>Production capacity adjustment delay</td>
<td>12</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>pcr</td>
<td>Production completion rate</td>
<td></td>
<td>Units/month</td>
<td>a</td>
</tr>
<tr>
<td>pct</td>
<td>Target production cycle time</td>
<td>24</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>pd</td>
<td>Prospecting delay</td>
<td></td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>PDD</td>
<td>Perceived delivery delay</td>
<td></td>
<td>Months</td>
<td>a</td>
</tr>
<tr>
<td>PDFi</td>
<td>Prevented design flaws</td>
<td></td>
<td>Flaws</td>
<td>f</td>
</tr>
<tr>
<td>pfdi</td>
<td>Percentage of flaw discovery</td>
<td>0.7; 0.3; 0.2</td>
<td>Dimensionless</td>
<td>f</td>
</tr>
<tr>
<td>pfdpl</td>
<td>Percentage of flaw discovery during proto</td>
<td>0.1</td>
<td>Dimensionless</td>
<td>f</td>
</tr>
<tr>
<td>pi</td>
<td>Percentage of designs possibly infected</td>
<td>0.1</td>
<td>Dimensionless</td>
<td>f</td>
</tr>
<tr>
<td>PM</td>
<td>Potential market</td>
<td></td>
<td>Units</td>
<td>i</td>
</tr>
<tr>
<td>ppr</td>
<td>Production productivity</td>
<td>30</td>
<td>Person-years/unit</td>
<td>f</td>
</tr>
<tr>
<td>prod</td>
<td>Productivity</td>
<td></td>
<td>Dimensionless</td>
<td>f</td>
</tr>
<tr>
<td>prodPu</td>
<td>Production person-years per unit</td>
<td></td>
<td>Person-years/unit</td>
<td>b</td>
</tr>
<tr>
<td>psr</td>
<td>Production start rate</td>
<td></td>
<td>Units/month</td>
<td>a</td>
</tr>
<tr>
<td>rcpd</td>
<td>Required completeness of previous stage</td>
<td>0.9; 0.5; 0.9</td>
<td>Dimensionless</td>
<td>j</td>
</tr>
<tr>
<td>rPC</td>
<td>Required production capacity</td>
<td></td>
<td>Units/month</td>
<td>a</td>
</tr>
<tr>
<td>SD</td>
<td>Start of design stage</td>
<td></td>
<td>Month</td>
<td>b</td>
</tr>
<tr>
<td>std</td>
<td>Scheduled first delivery</td>
<td>72</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>spp</td>
<td>Size of proto-production</td>
<td>40</td>
<td>Units</td>
<td>f</td>
</tr>
<tr>
<td>td</td>
<td>Transfer delay</td>
<td>3</td>
<td>Months</td>
<td>f</td>
</tr>
<tr>
<td>tdfi</td>
<td>Total design flaws</td>
<td></td>
<td>Flaws</td>
<td>b</td>
</tr>
<tr>
<td>TDRi</td>
<td>Total number of designs required</td>
<td>100; 1,000; 1,000</td>
<td>Documents</td>
<td>f</td>
</tr>
<tr>
<td>tPu</td>
<td>Total person-years per unit</td>
<td></td>
<td>Person-years/unit</td>
<td>b</td>
</tr>
<tr>
<td>trfpsi</td>
<td>Transfer rate of flaws from previous stage</td>
<td></td>
<td>Flaws/month</td>
<td>f</td>
</tr>
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<td>Abbreviation</td>
<td>Variable Name</td>
<td>Value</td>
<td>Units</td>
<td>Source</td>
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</tr>
<tr>
<td>UDF</td>
<td>Undetected design flaws</td>
<td>Flaws</td>
<td></td>
<td>c,d</td>
</tr>
<tr>
<td>WIP</td>
<td>Work in process</td>
<td>Units</td>
<td></td>
<td>a</td>
</tr>
</tbody>
</table>

Note that variables without a value are not exogenous, their equation is given in Table A1.

a Sterman (2000).
b Common modeling choice.
c Smets et al. (2013).
d Van Gorschot et al. (2010).
e Van Gorschot et al. (2011).
f Value or equation that is based on interviews with stakeholders.
g Adapted from Abdel-Hamid and Madnick (1991). Design quality has been modeled before by using the number of undetected flaws in the design (see also Van Gorschot et al., 2010). In our article, we have also used this number of undetected flaws, but we modeled quality as the ratio of flaws that are already corrected and the total number of design flaws (including the number of undetected flaws). Using a ratio makes it easier to use design quality in other equations.
h Adapted from Van Gorschot et al. (2011). Delays in development and production have a negative effect on the number of customer orders. In the paper by Van Gorschot et al., all potential customer orders will be lost when delays are longer than expected. In our article this is modeled more gradually: the longer the delay is compared to expected, the more orders will be canceled or not even placed at all.
j Scenario choice.

Table A2: Alphabetical list of model variables.
Appendix B: Optimized Case

To analyze whether performance can be improved further by allowing different levels of concurrency across different development stages, we simulated an optimized case. We approximated the setting with the lowest total person-years per unit ($tPYu$) as a function of different required completeness of previous design stages ($rcpd_i$). In addition, we adopted an efficient hill-climbing algorithm to search through the parameter space for the lowest total person-years per unit after 200 months (Kaufman, 1993). The hill-climbing algorithm is suitable, because our goal is to simulate search behavior in managerial decision making (Sommer & Loch, 2004). The optimization function is as follows:

$$\min_{rcpd_i} tPYu(200)$$

The parameter space is defined by possible values of $rcpd_i$: $0.05 \leq rcpd_i \leq 0.95$. Next, we find optimal performance (normalized total person-years per unit = 82.44) for $rcpd_1 = 0.58$, $rcpd_2 = 0.64$, and $rcpd_3$, leading to a 1% improvement over the scenario in which $rcpd_i = 0.4$ for all $i$. Figure B1 shows these optimized values for $rcpd_i$, including their 99% confidence bounds.

Note that this optimized case involves high overlap between tooling development and proto-production. It is not an easy policy to implement. Typically, tooling equipment in aerospace manufacturing promises to last several decades, because product life cycles tend to be several decades long as well. In contrast, this policy suggests a sort of “dispensable tooling”—tooling that suffices for the first few years of production ramp-up, when most of the “teething problems” are overcome. Then, when designs and production prescriptions have become firmly fixed, the dispensable tools can be replaced with long-lasting tools.

<table>
<thead>
<tr>
<th>Required completeness of Basic Design $rcpd_1$</th>
<th>Required completeness of Detailed Design $rcpd_2$</th>
<th>Required completeness of Tooling $rcpd_3$</th>
</tr>
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<tbody>
<tr>
<td>0.38</td>
<td>0.42</td>
<td>0.38</td>
</tr>
<tr>
<td>0.72</td>
<td>0.64</td>
<td>0.27</td>
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<tr>
<td>0.16</td>
<td></td>
<td></td>
</tr>
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</table>

Figure B1: Ninety-nine percent confidence intervals for required completeness between stages to minimize total person-years per unit.
The Innovation Journey and the Skipper of the Raft: About the Role of Narratives in Innovation Project Leadership

Tanja Enninga, HU University of Applied Sciences Utrecht, the Netherlands
Remko van der Lugt, HU University of Applied Sciences Utrecht, the Netherlands

ABSTRACT

Innovation project leaders have the challenging role of guiding their team by managing four intertwined processes: developing content, meeting project constraints, stimulating creativity, and guiding group dynamics. This article investigates the role narratives play in leading an innovation project and how an innovation project leader uses stories in practice. We found a variety of stories that relate to all four processes. We argue that the roles of stories can be divided into three different aspects: the story, the storytelling, and the storymaking. Together, these aspects of stories can support managing the four intertwined processes to deliver innovation.

KEYWORDS: innovation; narrative; project leadership; storytelling; storymaking

INTRODUCTION

The need for innovation in organizations is hardly questioned, although in practice it appears to be difficult to accomplish, as many innovation projects fail. Although an innovation project is quite distinct, it still meets the definition of a project: “a temporary endeavor undertaken to create a unique product, service or result” (Project Management Institute, 2008, p. 5). The biggest difference between innovation projects and other types of projects is the innovation project’s exploratory character (Lenfle, 2008; March, 1991). This makes the project less structured, less predictable, and more complex. van de Ven, Polley, Garud, and Venkataraman (2008) use the word journey as a metaphor to describe this exploratory process. The cover of their book shows six men paddling a raft through whitewater rapids, suggesting an expedition off the beaten track: rough from time to time, but exciting.

According to the literature, innovation leadership can refer to two distinct groups. Taking the strategic perspective, innovation leadership can refer to the top executives of an organization, or, at the operational project level, it can refer to the individual project manager. The strategic level is about doing the right projects, whereas the project level is about doing the project right (Cooper, 1996; Lundin et al., 2015). In this article, we take the second perspective, that of the innovation project leader who has to get the project right. The role of the project leader is essential to the project’s success (Aronson, Shenhar, & Patanakul, 2013; Sarin & O’Connor, 2009; Yang, Huang, & Wu, 2011). The innovation project leader is the skipper of the project, who has the challenging job of steering the raft through the rapids.

In recent years, the use of stories and storytelling has gained attention as a tool for managing complex organizational processes. This article explores the role stories could play in an innovation project and the ways an innovation project leader might use stories in his or her daily practice to manage the multidimensional challenges of an innovation project, with its sometimes paradoxical or contradictory demands. The article is based on a case study of the development of the first Heineken BeerTender. With this article, we contribute to the project management literature, specifically regarding the roles that stories could play in managing the sometimes competing aspects that an innovation project leader must manage. This study offers innovation project leaders information about the role and use of narratives in leading an innovation project. The stories described in this article may offer innovation project leaders inspiration and learnings from another project, just as the innovation project leader in this case study also learned from another project.
### About the Role of Narratives in Innovation Project Leadership

#### Literature Review

**Project Management and the Innovation Project**

Project management is often seen as accomplishing a predefined goal within given time, budgetary, and quality constraints, and as a structured process of logically grouped activities (PMI, 2008). The goals of innovation projects, on the other hand, are less predefined. The process is less structured and the activities are not necessarily as logically grouped (Ahern, Leavy, & Byrne, 2014; Lenfe & Loch, 2010). Especially at the beginning, the innovation process is nonlinear and fuzzy (Brentani & Reid, 2011; Khurana & Rosenthal, 1997; Kim & Wilemon, 2002; Koen et al., 2001; Reid & de Brentani, 2004). There are roadblocks, U-turns, and dead ends (Garud, Gehman, & Kumaraswamy, 2011; van de Ven et al., 2008). Because various participants from multiple disciplines are involved, a variety of outcomes is possible (Deuten & Rip, 2000; Garud et al., 2011), not to mention the unexpected events that can occur, as Laufer, Hoffman, Russell, and Cameron (2015) point out. Despite all these obstacles, in the end, the project team has to deliver the new product, service, or process. Meeting project constraints requires multidimensional leadership activities: The innovation project leader needs to be creative and analytical, focused and explorative, supportive and trust building, providing discipline and pushing boundaries (Amabile & Khaire, 2008; Bartlett & Ghoshal, 1995; Hohn, 1999; van de Ven et al., 2008). Though these activities can sometimes have competing values, they are all essential factors of effective management (Bel, 2010). Thus, an important role of the project leader who is “steering the raft” is to manage those contradictions (Arto, Kivik, Poskela, & Turkulainen, 2011; Hunter & Cushenbery, 2011; Sari & O’Connor, 2009; Smith, 2009; Stenmark, Shipman, & Mumford, 2011), and to lead in an integrative way, paying attention to the processes as well as their interconnectedness, all while maintaining an overview of the progress of the innovation journey as a whole.

**Developing content.** The primary goal of innovating is the delivery of the content, the actual innovation. Therefore, the primary role of the innovation project leader is to manage the development of this content through different stages (Buijs, 2012; Cooper, 1990, 2014). This is a challenge because neither the goal nor the methods to achieve it are well defined (Turner & Cochrane, 1993). And unless the project is a start-up, the innovation will be part of a larger context, and the new product needs to fit within the existing organization (Bledow, Frese, & Mueller, 2011; Rosing, Frese, & Bausch, 2011).

**Meeting project constraints.** Although relatively little attention has been paid to this aspect, the innovation leader also has to deliver the product within the “iron triangle” (Atkinson, 1999) of time, cost, and quality, just as with in any other project, despite all the additional difficulties an innovation project might face (Lenfe, 2008).

**Stimulating creativity.** Creative problem solving during the innovation process is both a diverging and converging process, and an essential clustering in between (Buijs, 2012; Tassoul & Buijs, 2007). As Rittel and Webber (1973) said, problems can be ill-defined and “wicked,” and the innovation team has to make sense of these problems before they can be solved (Weick, Sutcliffe, & Obstfeld, 2005). To understand and formulate these kinds of “wicked” problems, and to guide the diverging and converging process toward possible solutions, the team needs both creative and analytical and find solutions off the beaten track (Grint, 2008; Kolko, 2009). Therefore, the innovation project leader must inspire the team to diverge and stimulate creativity to find new solutions, as well as lead the team toward converging choices (Oliver, Heracleous, & Jacobs, 2014).

**Guiding group dynamics.** The innovation project involves a variety of interactions with different stakeholders (Eskerod, Huemann, & Righhofer, 2015): with the outside world, with partner stakeholders, between the team and the larger organization, and between multidisciplinary team members (Kleinsmann, Buijs, & Valkenburg, 2010). These interactions often take place between different “systems” and have to cross boundaries. Because of this, we will adopt the term interfaces from Kleinsmann et al. (2010) to describe such boundaries between groups and systems. The project leader needs to guide the group dynamics through all the complexities and ambiguities, in all the different interfaces. In particular, when the stakes are high and tension increases, the innovation project leader has an essential role in mediating group dynamics (Drach-Zahavy & Somech, 2001; Nijstad & De Dreu, 2002; Taylor & Greve, 2006).

This complicated set of processes requires multidimensional leadership activities: The innovation project leader needs to be creative and analytical, focused and explorative, supportive and trust building, providing discipline and pushing boundaries (Amabile & Khaire, 2008; Bartlett & Ghoshal, 1995; Hohn, 1999; van de Ven et al., 2008). Though these activities can sometimes have competing values, they are all essential factors of effective management (Bel, 2010). Thus, an important role of the project leader who is “steering the raft” is to manage those contradictions (Arto, Kivik, Poskela, & Turkulainen, 2011; Hunter & Cushenbery, 2011; Sari & O’Connor, 2009; Smith, 2009; Stenmark, Shipman, & Mumford, 2011), and to lead in an integrative way, paying attention to the processes as well as their interconnectedness, all while maintaining an overview of the progress of the innovation journey as a whole.

**Organizational Narratives**

For centuries, storytelling has been a way to inform and influence people and communicate ideas. In recent decades, increasing attention has been paid to...
the use of stories in organizations (Czarniawska, 2014; Denning, 2010). No wonder: Stories entertain, explain, inspire, educate, convince, generate and sustain meaning (or undermine and destroy it), stimulate imagination, offer reassurance, justify, inform, advise, and warn (Gabriel, 2000).

The terms story and narrative are both used in this perspective, and, although there is some ambiguity in the literature, we follow Denning (2005a) and use the two terms as synonyms. Narratives can be structured, with a beginning, middle, and end, and with events recorded in a structured manner and the solution to the problem presented in a plot. Other narratives might be provisional, without this beginning-middle-end structure, and even without a plot (Bartel & Garud, 2009).

Several things distinguish narrative from a non-narrative description of events. A narrative presents actors dealing with a series of events that have an underlying pattern; it is told from a certain point of view and is presented in a coherent sequence (Fenton & Langley, 2011; Pentland, 1999). A description aspires to factual objectivity, while stories add meaning to the facts and therefore also aspire to an emotional effect (Gabriel, 2000). Telling stories is the art of weaving these components together: “a product of intimate knowledge,” as Gabriel (2000, p. 1) calls it.

Narratives to Lead

Czarniawska (2014) points out that organizational storytelling entered the scene from a corporate culture perspective as a communication tool and from knowledge management as a repository for knowledge. Organizational stories can transfer all kinds of information and help people understand or take action (Denning, 2005a, 2011; Schank, 1990; Swap, Leonard, Shields, & Abrahams, 2001). Stories can serve as a repository of knowledge in various ways, correlating with the four intertwined processes that are associated with the innovation project. Stories can be a way to understand complex processes (Brown, Gabriel, & Gherardi, 2009; Browning & Boudès, 2005; Kurtz & Snowden, 2007). Stories can play a role in sensemaking (Czarniawska, 2005; Tsoukas & Hatch, 2001), in solving problems (Brown & Duguid, 1991), as well as in the decision making and guiding actions that follow (Havermans, Dorst, & Den Hartog, 2015). Stories can combine knowledge and translate it into ideas (Bartel & Garud, 2009), and they can play a role in the creative process by developing personas and scenarios (Madsen & Nielsen, 2010). Stories can help establish a space where ideas can flourish and knowledge can be exchanged (Buckler & Zien, 1996), and in this way they can help build trust within an organization (Denning, 2005b). Stories can also be used to transfer knowledge and ideas to others outside the innovation project (Connell, Klein, & Meyer, 2004).

Narratives to Lead the Innovation Project

Despite the abundance of literature on storytelling in organizations and on innovation projects, little attention has been paid to the use of narratives during the innovation project. We have seen an increase in research about innovations, innovative companies, their products, and their leaders (see, for instance, Kets de Vries, 1998; Marshall & Bresnen, 2013; von Post, 2011; Sharma & Grant, 2011; Ungerleider, 2014), but few studies have considered the role of stories in innovation projects. One study that does take this perspective is Buckler and Zien (1996), who report stories from participants in new product development (NPD) processes in various organizations. These narratives are about “what happened,” how innovative ideas were born and innovations started, and how these stories were used inside organizations to keep the innovative culture alive and to foster new innovations. Similarly, in an in-depth study, Deuten and Rip (2000) describe how an innovation project leader used stories about earlier events to motivate and persuade team members. The authors state that master stories can emerge from this “mosaic of stories.” Finally, Bartel and Garud (2009) argue that innovation narratives can overcome the challenges of interacting and communicating with different parties. Innovation narratives, which portray events in a structured manner and offer a particular point of view on a situation through the use of a plot, can serve as boundary objects, helping to bridge the differences between people with different knowledge. Provisional narratives, on the other hand, capture fragments of activity without a clear plot. Because these narratives portray observations, they can generate multiple interpretations. Bartel and Garud (2009) point out that these provisional narratives could be particularly useful for real-time problem solving within and across different domains.

Knowledge Gap

From the literature, we do know that innovation project leaders have to combine different roles to lead their teams, as well as establish interfaces with the world outside the team. We also know that stories can play a role in helping organizations communicate and solve problems. However, we do not know what role stories can play in leading an innovation project and how stories are actually used in practice by innovation project leaders.

The Case Study

The case we studied involved the development of a new product: the first Heineken BeerTender. We studied the work of the innovation project leader and the team during the development phase of this project. The BeerTender is a draught beer system aimed at the consumer market. After the idea to develop such a system was accepted by the executive board, a multidisciplinary core team was put together to develop the product. Each team member was
About the Role of Narratives in Innovation Project Leadership

responsible for a specific part of the project—for example, the appliance, the beer in the keg, and the marketing. Depending on the issues that arose, the core team hired specific expertise. The team came together regularly in so-called interface meetings to update one another about their progress and to discuss issues. The innovation project leader was an experienced line manager from within the Heineken organization, with a solid network in the company and a thorough understanding of both the product and the market. The leader and the team worked together for three years. During that time, the project suffered several severe setbacks and unexpected incidents, but despite this, the innovation was successfully introduced to the market. The BeerTender consists of two components: a home appliance that is marketed by Krups and Heineken beer packaged in a small keg. At the time of the product’s introduction, it was an innovation in all respects: It was a new product, a new experience for consumers, a new supply chain, and it had patented technology and new production methods for the Heineken organization.

Research Design
This case study explores the specific role that narratives play in innovation projects. The research design focuses on the human side (Müller, 2015), addressing the specific role of the innovation project leader. We took a “project-as-practice” approach (Blomquist, Hällgren, Nilsson, & Söderholm, 2010) to better understand how narratives worked in the daily practice of an innovation project leader in situ. We studied one case for a three-year period.

Data Collection
The exploratory fieldwork was set up to collect data for a “thick description” (Geertz, 1973) of this innovation process. Following Czarniawska (2004), who shows different ways to collect stories, we recorded spontaneous incidents as well as elicited stories. The fieldwork was performed by the first author in two steps. First, she did research and collected data as a participating observer during the three years the project leader managed the project. She participated and was present in various meetings and workshops of the project team, and had access to relevant reports and memos during this phase. Shortly before the market introduction of the BeerTender, the project leader left the project. A few months later, the first author interviewed the project leader in a retrospective interview to complete the fieldwork.

The interview was conducted on three different occasions, within a period of three weeks. The setting was an open dialogue between researcher and project leader in which they discussed all the major events over the past three years of the project. The interview was recorded in Dutch, the native tongue of both project leader and researcher. During this dialogue, the project leader was not informed that the focus of this research was to explore how narratives were used during the innovation project. The 10 hours of conversation were recorded on video, and later transcribed and coded.

Extracting the Stories
Together with a documentary film director, we identified relevant fragments within the 10 hours of videotape. This material was then organized into sectors and characterized by keywords. Based on the footage of the retrospective interview and the narratives that were heard and observed during the project, we extracted 15 stories of one to four minutes each. All the 15 narratives that were identified emerged during the study of the project, and they also reappeared in the filmed interview, although not all narratives were told in a clear and concise way. Therefore, the footage of the interview was edited into coherent video clips. The chosen narratives illustrate the richness of the project’s journey, although we did have to make choices—for example, where to “cut” each story line to retain the richness without making it too complicated. Authoring a story, as Rhodes and Brown (2005) state, is a creative act. The choices we made in authoring, as well as the choices we made in cutting, are obviously subjective. However, to reduce the risk of subjectivity, we checked the stories with different participants during the innovation project. We showed the edited video clips of the stories to the project leader and four people directly involved, and they all recognized the stories as coherent with the narratives and the experiences they remembered from their time working on the project.

Analyzing the Use of the Narratives
To understand how the narratives affected leadership in the innovation journey, we used our notes, memos, and presentations from our years as participant observers, as well as the transcription of the interview. These served as raw data to analyze how the narratives were developed, enriched, and shared, and how they were used to manage the innovation project. Where necessary, we used the time codes to go back from transcripts to the original videotaped material for contextual or nonverbal information.

Findings
The Stories
We found a variety of narratives with different subjects, different forms, and different functions. The richness of these stories would make a fiction writer jealous.

Deuten and Rip (2000) talked about finding a “mosaic of stories” in the project they studied. The same can be said here. Out of these 15 stories, we found four fiction and 11 nonfiction stories, using metaphors and analogies. We found ten retrospective stories about “what happened” and five stories that depicted the future and “what could be.”

Some narratives were rich and colorful and had a clear plot, while others were provisional. Some changed form in the telling: For instance, the story...
about sailing to New York started as a provisional story without a plot, but in the end it became a structured story, continuing with a second episode, “Flinging a Whale.”

The narratives in this study have a great amount of variety. Just as with other case studies about the use of narratives in organizational settings, we also found fictional characters being used to imagine and understand a problem at hand, or to depict a possible way toward a solution (Madsen & Nielsen, 2010).

Because we cannot describe in this article all the narratives we found, we chose four stories. These four can serve as examples of how stories were used in each of the four intertwined processes of managing the innovation project. Moreover, these four examples illustrate the mix of “what happened” and “what could be,” how fact and fiction are combined, how narratives are used for various purposes, and how the function of the narrative can change during the project.

Developing Content

Of the 15 extracted stories, more than half dealt with the content of the innovation project: what happened during consumer research, what type of solution the team was trying to find for the appliance, and how the innovation was breaking the rules of existing organizations. This is one of those stories from the innovation project leader:

**STORY: FLING ‘M IN, GRAN!**

The appliance had to be without hassle—“idiot proof,” as we called it. To illustrate this, we created in the team the following story: Imagine an old man (Grandpa) who has a BeerTender. He is going to watch the soccer match on TV. He pours himself a beer and gets comfortable in his big armchair. The game is on. He wants to have a second beer, but cannot leave the TV, because the match is too exciting. So he shouts for his wife. When she tries to pour him a glass, she finds out the keg is empty. “How do I put the new beer in, hon?” she asks the old man. He shouts back: “Come on, just fling ‘m in, Gran!” That shout became proverbial. Putting in a new keg should be so easy, so idiot proof, that even Grandma would have no difficulties whatsoever putting a new one into the appliance.

When we evaluate the content-related stories we found according to the functions proposed by Czarniawska (2014), six of them fit on the “knowledge” side, arising from the need to understand, to make sense, and to combine different areas of knowledge, and guide into action. The other two stories were about the strategic intent and used to share with others. Therefore, we classified these two stories about strategic intent as having primarily a communication function.

Meeting Project Constraints

We only found two stories that dealt with meeting project constraints and the triangle of time-cost-quality. “Time as a Trump” is one.

**STORY: TIME AS A TRUMP: INVITING THE QUEEN**

How can you finish your project on time? That’s one of the biggest issues in projects like this. And, as the project leader said, “those ‘Gyro Gearloose’ [world-famous Disney inventor] people are never ready; the appliance will never be 100 percent finished. There is always room for improvement.” The project leader learned to steer on the aspect of “time.” Here’s his story:

Nobody is the master of time. In a complex project like this BeerTender project, one person holds the purse strings. Another one manages the manpower. And then there’s a boss who deals with the idea development itself. In this kind of innovation project, there isn’t one person who is the boss of time—not in a large company, not even when you’re doing it on your own. Nobody can say: “I’m the boss of time, and today this or that has to happen.”

I talked to the co-director of the building project of the Amsterdam Arena, the soccer stadium of the Dutch AJAX-team. That was a very innovative building concept, with a stadium roof that could open and close. And this guy had construction supervisors who ran into problems when one job turned out to be very difficult. They kept buying time, wanting to move the completion date further and further away. So then the manager said: “Guys, tomorrow I’m sending the invitation to Her Majesty the Queen to open the Arena building.” And he really did.

Someone could also say: “We’ll have a presentation with the board of directors. We have to do it well and it’s next week.” But then there’s a safety margin. You don’t show everything, or not yet. Or you can add something the next day. But inviting H.M. the Queen for the opening … that’s when your boat arrives in New York. There’s no way out. But be careful! You can only play a trump card like that once! And if you fail in the eyes of the Queen, you fail big-time.

This story about inviting Her Majesty the Queen was told by an external project leader, who was invited, because the team had to gain knowledge about speeding up and concluding such a complicated project, one that is never actually 100% finished.

The other story was about what happened when the CEO came to see the progress of the project and test the prototype of the draught beer system. Team members told this story to others to share this exciting moment and their anxiety that something might go wrong with an “all’s well that ends well” plot.

Stimulating Creativity

We classified two stories as dealing mainly with stimulating creativity—both of them were about trying to find solutions off the beaten track.

**STORY: REVVING WHILE BRAKING**

Krups, the partner making the appliance, has a different business model from a brewer’s. A hardware appliance is often produced in quantities at one time, and sold only once every few years to a consumer. Heineken, on the other hand, is a
“fast mover” with a business model based on selling over and over. The production of the beer kegs is not fixed and can be augmented depending on the demand. Traditionally, household appliances and fast-moving consumer goods are sold in different stores. And in some countries, hardware stores are not allowed to sell beer. So how do you align those two different models in the supply chain? To understand the nature of the problem, the team decided to illustrate the case with the story of a father—Suppose a young man in the Netherlands buys an appliance for his father—let’s say for his 50th birthday. However, the father happens to live on Schiermonnikoog, a small island in the very north of the Netherlands. When he gets this appliance as a gift, he needs to buy the beer as well. His son isn’t going to bring a keg every week, is he? So, the only grocery store on the island has to sell the beer kegs. Otherwise, this birthday present is useless to the father. And the shop will only sell beer if it has a certain amount of turnover—it won’t order a particular kind just for one father with one appliance! If you make the appliance available all over the country, as you would with any standard appliance, you will encounter this kind of problem.

The story led to a discussion of how to approach the market, with scenarios for the father (where to buy appliance and beer) and scenarios for the various retailers as well. The solution was found in a different business model than usual, and in selective distribution. We named it “Revving While Braking.” Both the character—a father from Schier—and the term revving while braking became common expressions that the team used to address this complex issue.

Both of the stories we classified as dealing with stimulating creativity originated in a problem that had to be solved in the content area. It could be argued that these stories might be classified as part of the content development process. However, because the raison d’être of these two stories is the “wick-edness” of the problem, we classified them under the category of stimulating creativity.

Guiding Group Dynamics

We classified three stories under the category of guiding group dynamics. One story is a “what happened” story that the project leader shared to explain why and how he worked on the group dynamics of the team. The stories that we describe here are not really two different stories; rather, they can be seen as two episodes within the same storyline. These two episodes together span almost the entire three years of the BeerTender project. The first episode of the story was initially developed within the team, at the instigation of the innovation project leader.

STORY: AS WE SAIL TO NEW YORK

Early after the project leader started the project and had put his team together, he had his team members share their individual ambitions with one another, as a means to get to know each other better and to understand one another’s ambitions. “New York” symbolized their collective end goal: finding new land, being ambitious and daring. The project leader started with this story: “We all felt, since each of us had a subproject to work on, that we’d better regard the interface meeting as a holy institution. Otherwise, because everyone was responsible for a part of the problem … we’d be pulled apart. I used the metaphor of a boat. We are sailing to New York, but don’t ask me how. The wind will take us somewhere. We’re all in that little boat. There’s no way you can get out halfway. Just make sure that the rudder, the sails, and the galley all operate. Then there’s a chance that all of us will arrive there one day.”

EXTENDED DYNAMICS

At a certain moment during the project, everything was going smoothly. Everything was doing its job—the spinnaker, the mainsail, and the people too, from the helmsman to the cook, and as long as you have the right winds, strong and in the correct direction; then the boat goes very fast. In this kind of situation, with all the right elements in place, it would be strange if you didn’t reach New York—unless you hit a whale.

So we never expected the unexpected. We were sailing at full speed. And then, all of a sudden, there was that mad Friday morning when the telephone rang. I was at home and my colleague from Switzerland rang to say he had heard that the CEO of Moulinex had just applied for a suspension of payment. Moulinex-Brandt was the mother company of our hardware partner Krups. That was like crashing into a whale, full speed! Then it’s all hands on deck. Suddenly, there are a whole lot of other things happening. And don’t adjust the sails when you’re stuck on a whale. There’s no point. For two months I had the feeling: Guys, this ship is going down! I was so afraid that all the other smaller partners would leave, too. But as a result of enormous efforts, we got all the partners in the project aligned and were able to carry on.

I said to my wife: “We made it. We’ve reached the Hudson!” We hadn’t made it yet, of course. It took a lot more time and money after that. But basically, we had passed this point of no return.

Intertwined Processes

Although each of the stories above was categorized under a single process, we could argue that many of the narratives actually affected more than one process. The stories dealing with stimulating creativity, for instance, also dealt with developing content. Many of the stories we found were shared in the project team and later with others, both inside and outside the organization, and therefore, they had an influence on group dynamics. In the team, stories were shared to enhance mutual understanding, and later they were shared with new team members to bring them to the same level of understanding and common language as the rest of the team.

Stories were used to communicate at the different interfaces identified by Kleinsmann et al. (2010). In the interface with the outside world, we found stories about prospective users and their behavior. In the interface with the organization, we found narratives such as “Revving While Braking” to explain
the difficulty of different business models and dealing with the supply chain, although this story has aspects that involve interfaces with the outside world as well. Most of the stories worked at the interface within the development team. The story about sailing to New York is not only a story about shared ambition (reaching New York), but also a story about the regular knowledge exchange within the team (being in the same boat). The team even called their regular meetings “interface meetings.”

In the second episode of that story, when the going got tough and “the boat hit the whale,” the interface changed from inside to outside the team. Kleinsmann et al. (2010) also note two different roles in the interface with the outside world: the outside world as supplier of knowledge (giving information), and the outside world as consumer of knowledge. We found this distinction in the “inbound” or “outbound” direction of the narratives. For instance, in the narrative “Fling ‘m in, Gran!” knowledge from the outside world—information about consumer behavior—was adopted by the team and built into a story. In the story “Half a Case,” dealing with the shelf life of the beer in the keg, the information from the project is meant to inform the outside world. (“Half a Case” is not used in this article as one of the story examples.)

In some cases, we also found a change in the interface, and therefore, a change in the direction of the narrative. The “Revving While Braking” story originated within the interface of the team. The story was, however, also used at a later stage of the project to communicate with others outside the team, in the interface with the organization, and to some extent, even with the outside world; it became an outbound story. A similar shift in interface and the direction of information happened with the narrative “Inviting the Queen.” The story came from an outside expert, but it became part of the team’s knowledge. At a later stage, the project leader shared the story with others in the organization to explain why it was important to force the product launch.

**Learning from Others**

Nearly all the narratives in this case study originated from events and problems encountered during the Beer-Tender project, except the story about the Queen. The team had meetings on several occasions with innovation project leaders from other organizations. Only in the case of the time management and “Inviting the Queen” did this lead to a vivid story. And although time wasn’t on their side and external factors (see “Hitting a Whale”) meant that it took much longer before they could finally invite their queen, the “Inviting the Queen” story still has a special meaning for most of the former team members.

**Accidental Narratives**

The narratives we found emerged during the innovation process. “It just happened,” the project leader told us. Neither storytelling nor storymaking was deliberately used as a management tool. The construction of a narrative was a way to make sense of a problem at hand, or a way to reframe or redefine a problem or situation. Often, this happened during so-called interface meetings, where the multidisciplinary teams updated one another about their progress in developing the NPD content and project deliverables, and where problems and issues were discussed. The “Revving While Braking” story, for instance, emerged during a group discussion between the two partners Heineken and Krups, in which their different business models and approaches to the supply chain became obvious. The discussion was tense at some moments, with people having differences of opinion and trying to convince one another. The discussion was also rich and evocative. It went on and on, without any clear perspective on a solution. Someone tried to explain his point of view (once again) by using a basic storyline. And then another person added a line. Step by step, the narrative about a father living on a tiny Dutch island was born. This led to a discussion of how to approach the market, with scenarios for the father (where he could buy the appliance and beer) and scenarios for the various retailers. The solution was found in a different business model than usual, and in selective distribution. The team named this approach “Revving While Braking.”

**Discussion**

The objective of this study was to explore what specific role stories can play in leading an innovation project and how innovation project leaders use these stories in practice. Based on the findings of this study, we divided the role stories can play into three categories: the role of stories, the role of storytelling, and the role of storymaking.

**Role of Stories**

When studying the role of narratives in organizations, many authors have emphasized the role of stories as objects, artifacts that can be told, shared, transmitted, and used (Bartel & Garud, 2009; Brown et al., 2009; Buckler & Zien, 1996; Czarniawska, 2005; Dening, 2005a; Swap et al., 2001). However, in our study, some stories did not have a direct role as the object. These stories served as scaffolding for a specific step in the process, such as problem definition, reframing, or sensemaking. The story itself, the object, happened to be the output, but the core purpose was to improve the process, in which the story construct was subservient.

**Role of Storytelling**

van der Lugt (2005) investigated the role of sketching in the NPD-process. He distinguishes “thinking sketches,” “talking sketches,” and “storing sketches” in the earlier phases of NPD. Thinking sketches are individual sketches to focus and guide nonverbal thinking; talking sketches share a common graphical setting for the idea being debated; and
storing sketches archive design ideas. We propose an analogical grouping for the narratives in this case study: thinking narratives, talking narratives, and storing narratives. We did not observe individual thinking narratives, although one could argue that thinking narratives must exist as a prelude to shared talking narratives. In our case study, the storing narratives are those narratives that “stayed alive” after their initial (talking) use, and were used as a source of reference and to share with others. For “storing narratives,” the narrative as such, the “thing,” is more important than the process of making it.

Our study supports the view that narratives could serve as translation devices in various interfaces (Bartel & Garud, 2009), although we found a less strict division between narrative forms and respective functions. For instance, the narrative the “REVving While Braking” originated as a way for the members of the developing team to reframe a complex problem. It was not intended to explain the problem outside of the team or to explain a chosen solution. However, after it helped the team, the same narrative became a boundary object (Carlile, 2002; Star & Griesemer, 1989) that was used to explain the problem and approach to stakeholders outside the core team. This means that the function of the narrative changed over time, from a “talking narrative” to a “storing narrative.”

Role of Storymaking

The participants would probably have called the making of a narrative explaining, reframing, or solving a problem or issue. In the “REVving While Braking” story, for instance, the team members were not deliberately creating a narrative. However, the making of this narrative positively affected the process of problem understanding or problem solving, helping divergent thinking or convergent thinking, and having an overall positive impact on the group process. We will refer to this activity as storymaking as opposed to storytelling. Based on the case study, we can identify three different roles that storymaking played in leading this innovation project.

The genesis of a new story is an act of sensemaking produced by the team together (Weick et al., 2005). In an uncertain situation, sensemaking is an important role for the leader. It can be seen as an act of cartography: “Where are we now?” and “Where are we going?” In this process of observation, discussion, and inquiry, the making of the narrative maps new terrain. As Ancona, Malone, Orlikowski, and Senge (2007) pointed out, sensemaking is more an act of creativity than analysis, and that is certainly the case during the making of a narrative.

The multidisciplinary team considered in this case study consisted of people from different backgrounds and different education. We observed differences in “thinking styles” (Leonard & Straus, 1997). Some of the team members were more rational thinkers, who were at ease with an Excel spreadsheet, whereas others were quite comfortable presenting their ideas in memos and reports; that kind of rational thinking is often considered a “left brain” activity. The industrial designers in the team, on the other hand, were more “right-brainers,” trained to think creatively and visually. Storymaking—developing characters in a series of events—could serve as a link between rational and creative thoughts (Rasmussen, 2005) and bridge differences in thinking styles (Wood & Anderson, 2001).

By developing a story, as in the “REVving While Braking,” the participants were also able to develop their conversation. During the first problemsolving attempts, before the story “REVving While Braking” was developed, the debate was tense and participants argued, trying to convince one another about the merits of their own viewpoints. By building a storyline with a character and events, team members were able to suspend their own beliefs and mental models and “perceive” the images of their team members via the fictional narrative elements.

In this perspective, developing the story seemed to follow Scharmer’s (2001) four fields of conversation. Scharmer illustrates this model with an example from a workshop that included people from various backgrounds. At first, the participants were talking nicely with one another. At a certain moment, however, the conversation became a discussion, a debate. The talking hardened and participants stressed their own point of view and the legitimacy of that view. “We clearly were in tough debate, and I was witnessing a vivid and forceful clash of mental models or views of the world” (Scharmer, 2009, p. 274). When talking later about a piece of art each participant had created, Scharmer noticed a different type of conversation that included appreciative inquiring about different views, and the closing conversation at the end of the workshop showed a collectively felt presence. These observations resulted in a model of the four fields of conversation (Figure 1).

This storytelling process was an intervention that moved the participants from a tense situation where they stated their own beliefs and opposing points of view toward a more reflective dialogue where there was room for inquiry.

So, the storytelling not only served as a sensemaking tool and a tool to bridge differences in thinking styles, it also stimulated participants to find a way to solve a content problem and to develop a new, coherent outcome together. Therefore, the act of storymaking was beneficial in supporting the four intertwined processes.

Implications

Theoretical Implications and Future Research

We know that the innovation project leader has to combine and intertwine different roles to lead the team, as well as establish interfaces with the world.
Innovation narratives could serve as translation devices at these various interfaces with different types of knowledge integration. It would be interesting to understand how different forms of innovation narratives might enhance the transition of ideas and help translate and integrate knowledge.

Finally, future research should investigate how different narratives work best and in what situations. As Bartel and Garud (2009) said, we need a “repertoire of multiple narratives from which individuals can draw upon ... to generate a rationale and script their behaviors that otherwise may be dismissed as being irrational or inappropriate” (p. 114). Do narratives from outside the organization, even from a different context, like “Inviting the Queen,” offer the innovation project leader more (or less) rationale, and do they help legitimize his or her behavior? Or would it be more effective to build such a repertoire exclusively from narratives from innovation projects in which the organization has been involved?

**Practical Implications**

As we focused on the role of the innovation project leader and the use of narratives, we noted practical implications of this study that address daily practices by innovation project leaders.

The use of stories, both storytelling and storymaking, could support innovation project leaders in their daily practice as tools to combine and intertwine the different roles that are involved in leading an innovation project. The stories described in this case study could be used by other innovation project leaders to tell, to inspire, to help find solutions, to learn from, and to keep going. The story “Inviting the Queen,” for example, might inspire project leaders to act accordingly and play the same card in order to force a product launch.

Innovation project leaders could also actively use the telling of their own team stories to bridge gaps between their team and the larger organization. The innovation project leader could use the making of stories within the team to serve a variety of goals, including framing (and reframing) problems and creating space for solutions, while at the same time postponing strong opinions in order to bridge team differences and tensions. Innovation project leaders can introduce a provisional story as a tool to encourage team members to build upon, reflect, and focus on the goals and challenges of the project. Making such a story doesn’t require any specific tools or settings. Storymaking can be practiced whenever and wherever needed. The shared activity of constructing a story also offers innovation project leaders an understanding of the personal views within the team as well as group dynamics. This could enhance leadership of the innovation project and make it more effective.

By grouping narratives into thinking, talking, and storing narratives, the innovation project leader can decide whether the final narrative should be preserved and stored, or whether its usefulness was as a talking scaffold in the intertwined processes of the innovation journey.

All these aspects of the roles of narratives in leading the innovation journey are tools that the innovation project leader can use to manage the intertwined processes effectively. This case study is by no means a map, as the

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Figure 1: Four fields of conversation (Scharmer, 2001).
wildwater world of the journey is not predictable and can be rough from time to time. But it is also exciting.

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About the Role of Narratives in Innovation Project Leadership


Tanja Enninga, MSc, is Senior Researcher and PhD candidate at Hogeschool Utrecht’s University of Applied Sciences, The Netherlands. Her research focuses on the human side of innovation. Her PhD topic is about how innovation project leaders could learn vicariously from the experiences of others via narratives. In addition to her work at the university, she is a management consultant and supervisory board member in healthcare. She received a master’s degree in marketing from the University of Glamorgan, United Kingdom. She can be contacted at tanja.enninga@hu.nl

Remko van der Lugt, PhD, is Professor of Co-design at Hogeschool Utrecht’s University of Applied Sciences, The Netherlands. His research focuses on involving users as experts of their experiences throughout the design process. Current research topics include systemic design, service design, and sustainability by design. In addition to his work in Utrecht, Remko is a researcher at Delft University of Technology and facilitator of creative processes at FinguinXL. He received his PhD in industrial design engineering (on sketching in design idea generation meetings) from the Delft University of Technology (2001) and his master’s degree in naval architecture (1993) from the same university. He received a master’s certificate in creative studies from the Center for Studies in Creativity at Buffalo State College, State University of New York (1991). He can be contacted at remko.vanderlugt@hu.nl
A Contingency Approach on the Impact of Front-End Success on Project Portfolio Success

Alexander Kock, Technology and Innovation Management, Technische Universität Darmstadt, Darmstadt, Germany
Wilderich Heising, Boston Consulting Group, Frankfurt, Germany
Hans Georg Gemünden, BI Norwegian Business School, Oslo, Norway

ABSTRACT

The pre-project or ideation phase is often disregarded in project portfolio management. Senior managers put more emphasis on later project stages, and researchers predominantly investigate the front end from a single project perspective. This study investigates how and under which circumstances the performance of the front end affects project portfolio success. Using a sample of 175 firms, we confirm a strong positive relationship between front-end success and project portfolio success. Results show that this effect becomes stronger for larger project portfolios, for portfolios with more interdependency between projects and, finally, for firms that have a strategic orientation toward riskiness.

KEYWORDS: front-end success; project portfolio success; turbulence; riskiness; complexity; project portfolio management

INTRODUCTION

A major trend in today’s business environment is “projectification”—the tendency to carry out more and more tasks in project-organized undertakings (Maylor, Brady, Cooke-Davies, & Hodgson, 2006; Midler, 1995; Packendorff & Lindgren, 2014). Projects and project portfolios gain in importance in the upper echelon agenda. A holistic view of the multitude of projects becomes one of the major topics for organizations striving for competitive advantage, and successful project portfolio management increasingly determines sustainable business success (Meskendahl, 2010).

Although project portfolio success and eventually company success have many antecedents (Kester, Hultink, & Griffin, 2014; Martinsuo, 2013; Meifort, 2015), one of the major sources for success is a company’s ability to innovate (Eisenhardt & Martin, 2000; Wheelwright & Clark, 1992). Not surprisingly, new product development success has been elaborated in depth in the last decades (Evanschitzky, Eisend, Calantone, & Jiang, 2012; Kock, Gemünden, Salomo, & Schultz, 2011; Salomo, Weise, & Gemünden, 2007; Sicotte, Drouin, & Delerue, 2014). Although front-end activities are recognized as a driver for successful product launches and business success (Cooper, 1988; Martinsuo & Poskela, 2011; Pinto & Slevin, 1989; Poskela & Martinsuo, 2009; Reid & de Brentani, 2012; Verworn, 2009; Williams & Samset, 2010), CEOs and senior management prefer to enter the arena in later development stages (Cooper, Edgett, & Kleinschmidt, 2004). Surprisingly, also in academic research, ideation and front-end activities are not the main focus in the literature (Page & Schirr, 2008; Williams & Samset, 2010), and studies investigating the consequences of a successful front-end are scarce (Kock, Heising, & Gemünden, 2015). Thus, our current understanding of the impact of front-end success on project portfolio success remains vague. One of the reasons for this lack of research may be the fact that front-end success is rather difficult to measure (Manion & Cherion, 2009) and only few quantitative studies have assessed front-end success on the project (Martinsuo & Poskela, 2011) or the portfolio level (Kock et al., 2015).

Studies analyzing the front end usually deal with it in a conceptual manner (Khurana & Rosenthal, 1997; Kim & Wilemon, 2002; Koen et al., 2001; Smith & Reinertsen, 1991), and quantitative research is limited. Moreover, most studies investigate either the process setting and do not look at success of the front end itself or they have a single project view on a specific innovation. A portfolio view on ideation is neglected (Heising, 2012)—a connection...
Front-End Success and Project Portfolio Success

between the front end and project portfolio management is rarely within the scope of contributions in academic research. Khurana and Rosenthal (1997) point out that there is often a discontinuity between front-end processes and portfolio management and argue for a need to adopt a holistic view.

More importantly, the conditions under which front-end performance affects project portfolios have never been addressed in previous research. While the idea that portfolio performance depends on the quantity and quality of ideas for project proposals seems likely (Kock et al., 2015), we do not know which environmental, firm, or portfolio characteristics affect the relationship between front-end performance and eventual project portfolio success.

Based on an integration of literature from innovation and project portfolio management, the current study addresses the following research question: Under which circumstances do project portfolios profit more (or less) from a strong idea pipeline (i.e., high front-end success)? This research question considers that different context factors, as well as different integration mechanisms of ideation portfolios may influence the impact of the front end on the success of a project portfolio. Such a contingency approach is needed to better understand the complex performance, inducing mechanisms, which link the early front end with the rather late project implementation stage (for contingency approaches in project management research see Hanisch & Wald, 2012).

This study contributes to the literature in project and innovation management in the following ways: First, we empirically investigate the relationship between front-end success and project portfolio success using a large cross-industry sample of firms with multiple informants. Second, we address several contingency factors of this relationship and investigate the moderating effects stemming from the firm’s environment (market and technological turbulence), the firm’s strategic orientation (riskiness), and characteristics of the portfolio (size and project interdependency). This research thus broadens our understanding of the relationship between innovation and project portfolio management and provides guidance for practitioners and academics alike: For portfolio managers the results highlight the importance of paying attention especially to the front end of innovation, when actual projects have not yet been defined. For researchers, this article provides proof of the predictive relevance of the construct front-end success for portfolio performance. Furthermore, the findings show important contingency factors that demonstrate under which conditions front-end success is especially important.

Conceptual Background

**Ideation and the Success of the Front End**

Front end is a general term used for the somewhat unstructured period between the proverbial “blank sheet of paper,” up to the project proposal. Smith and Reinertsen (1991) introduced the term “fuzzy front end” for this phase. The front end is characterized by a large degree of uncertainty (Kim & Wilemon, 2002). Several scholars analyzed how this front end looks like: Khurana and Rosenthal (1998) suggest that the fuzzy front end comprises product strategy formulation and communication, opportunity identification and assessment, idea generation, product definition, project planning, and early executive reviews. Nobellius and Trygg (2002) identify six components of the front-end process following the opportunity identification: mission statement, concept generation, concept screening, concept definition, business analysis, and project planning. According to Kim and Wilemon (2002, p. 270) the front end begins “when an opportunity is first considered worthy of further ideation, exploration, and assessment and ends when a firm decides to invest in the idea, commit significant resources to its development, and launch the project.” Koen et al. (2001) described this period as characterized by those activities and actions that take place prior to any well-structured and formal new product development process.

One of the critical activities in this pre-project phase is ideation (Spanjol, Qualls, & Rosa, 2011). The ideation process has to ensure that a sufficient number of ideas are generated and further elaborated to crystallize new project concepts. Moreover, evaluation and selection mechanisms have to be installed to choose the most promising concepts to formally become projects. Scholars state that especially the ideation phase and the front ends of projects have significant strategic relevance for the success of projects, project portfolios, and eventually the organization at large (Zhang & Doll, 2001). A majority of projects fail in the beginning—here mistakes tend to have the most sustainable impact. The right activities at the beginning of the project funnel can lead to the biggest savings at least cost (Reid & de Brentani, 2004; Verworn, 2009). Surprisingly, ideation does not play a dominant role in the literature on new product development projects. In an extensive meta-analysis of the top journal innovation literature, Page and Schirr (2008) report that only 5% of the identified innovation research has dealt with ideation and creativity.

Despite these approaches, success of the actual front end or ideation phase itself is rarely in the scope of scientific literature (Heising, 2012; Kock et al., 2015). The existing literature is usually conceptual in nature and does not approach this field empirically (Khurana & Rosenthal, 1998; Kim & Wilemon, 2002). Front-end success is often blurred by looking at the overall innovation success or the rate of successful new product introductions. But taking such a success measure does not account for the specific role of the front end in the overall project portfolio process. If an organization is able to successfully launch a new product,
this is not only the merit of a successful front end but also of successful development project portfolio management and several other factors (Jonas, Kock, & Gemünden, 2013; Müller, Martinsuo, & Blomquist, 2008). This implies that a successful front end does not necessarily guarantee that the project will be successful or, vice versa, that every successful project also had a successful front end. Thus, we state that front-end success can be evaluated according to the quantity and quality of implementable ideas and according to the characteristics of the front-end process. It is important to note that the number of implementable ideas is not necessarily equal to the amount of implemented ideas, because there are manifold reasons why even the best ideas can and should be stopped during the later phases of project execution (Meyer, 2014; Unger, Kock, & Gemünden, 2012). We translate this rather broad definition into three dimensions for success measurement (Kock et al., 2015; Verworn, Herstatt, & Nagahira, 2008): \textit{Effectiveness}, \textit{timeliness}, and \textit{efficiency} of the front end.

To assess the effectiveness of the front end we suggest determining if a sufficient amount of \textit{good} ideas are generated in the ideation stage (Reinig, Briggs, & Nunamaker, 2007). Besides the sheer number of ideas, the potential for value generation can be assessed along the lines of the following questions. How much revenue increase is likely to be realized with the current front-end pipeline within the next couple of years? Is the current pipeline likely to strengthen the competitive positioning of the firm (Bertels, Kleinschmidt, & Koen, 2011; Ernst & Kohn, 2007)? Evaluating front-end timeliness and front-end efficiency is more straightforward: these measures deal with the speed and productivity of the system; in other words, how fast ideas are screened and converted into concepts and eventually project proposals, and how well the scarce financial and personnel resources are utilized (Kock et al., 2015).

\textbf{Project Portfolio Management}

Once an idea has evolved through the ideation process and passes the \textit{money gate}—the point in time at which an idea turns into a project and receives considerable resources—it is managed as a project within one of the organization’s project portfolios. A project portfolio is a collection of single projects that compete for the same resources and are carried out under the management of a specific organization (Archer & Ghasezmadeh, 1999). Project portfolio management can be seen as those actions and activities that allow an organization to select, develop, and commercialize a pipeline of new projects that are in line with the organization’s strategy and that will enable it to sustainably grow further (Jonas et al., 2013; Korhonen, Laine, & Martinsuo, 2014). Its ultimate goal is to maximize the contribution of projects to corporate success. Therefore, project portfolio management can be interpreted as the concurrent management of the set of projects that reflect the investment strategy of an organization (Dye & Pennypacker, 1999; Meskendahl, 2010; Patanakul & Milosevic, 2009).

Objectives of project portfolio management are rather well established in the project management literature. The main themes are maximization of portfolio value, a link to strategy, and balancing the projects within the portfolio in consideration of the firm’s capacities (Cooper, Edgett, & Kleinschmidt, 2001; Jonas et al., 2013; Killen, Hunt, & Kleinschmidt, 2008; Martinsuo & Killen, 2014; Martinsuo & Lehtonen, 2007). We follow established definitions of project portfolio success that conceptualize it along five dimensions (Jonas et al., 2013; Teller, Kock, & Gemünden, 2014; Teller, Unger et al., 2012; Voss & Kock, 2013): \textit{business success} focuses on the impact of the portfolio on the firm’s economic performance; \textit{average success of project results} addresses this issue on the individual project level; \textit{strategic fit} corresponds to the degree to which all projects combined reflect and are consistent with the firm’s strategy; \textit{portfolio balance} addresses the strategic perspective of balancing risk and innovativeness within the portfolio; and, finally, \textit{preparing for the future} addresses the long-term opportunities and benefits for the firm that are created in the project portfolio.

\textbf{Framework and Hypotheses}

The conceptual framework in Figure 1 depicts the relationship between front-end success and project portfolio success. We draw on contingency theory (Donaldson, 2001), which has been widely applied in project management (Hansch & Wald, 2012), and propose that the strength of the relationship depends on external and internal

\textbf{Figure 1:} Research framework with hypothesized main and moderating effects.
Front-End Success and Project Portfolio Success

Factors. We argue that front-end success is a necessary determinant of project portfolio success, but the actual benefits of front-end success depend on the task at hand, the environment, and the corporate mindset as well as additional measures taken by management to support the exploitation of promising project candidates. A multitude of potential contingency factors exists. Donaldson (2001) argues that in task-related contingency theory two dominant themes prevail: One stream builds on uncertainty and the other elaborates the consequences of interdependence (Thompson, 1967). With respect to uncertainty, we concentrate on environmental factors such as market and technology turbulence. We interpret interdependence as a portfolio level contingency factor and consider the interdependence between projects as well as the size of the portfolio. Finally, we consider aspects of entrepreneurial orientation, in particular riskiness, as a firm level contingency that is argued to be necessary to actually seize opportunities created in the front end. In the following sections, we argue in detail for the proposed hypotheses.

Front-End Success and Project Portfolio Success

There is support for a positive link between a successful front end and overall success in previous literature (Kock et al., 2015). For Khurana and Rosenthal (1998), the key to product development success lies in the front-end activities. We follow this view and argue that activities and decisions of the front end are the starting point for the subsequent development processes and therefore are the source for competitive advantage. Especially in the portfolio management context it is important to consider the front end (Heising, 2012). The portfolio management process does not just start with the prioritization of project proposals or resource allocation to projects. In fact, these project proposals have to be fed by the right ideas that have to be generated much earlier. Front-loading activities are beneficial, because relatively low efforts have great leverage to facilitate later success. A significant proportion of eventual production costs is already defined in the early stages. If more high-quality ideas are available for selection, structuring of the portfolio will be improved, as more and better options to influence the results of project portfolio management are established and the potential for innovation can be built up. This argumentation is in line with previous academic contributions: In their conceptual paper on the front end, Reid and de Brentani (2004) see the front end as the root for success for organizations. Cooper and co-authors empirically confirmed in their studies that effective front-end activities and up-front homework directly contribute to new product success (Cooper, 1988). Verworn (2009) also empirically shows the positive impact of the front end on single project success. Finally, Kock et al. (2015) show the high relevance for successful ideation in project portfolio management. Based on this line of argumentation and previous empirical results, we propose our base hypothesis:

\textit{Hypothesis 1: Front-end success is positively related to project portfolio success.}

Environmental Contingency Factors

Innovation projects—especially in the front end—face several uncertainties from the environment (Danneels & Kleinschmidt, 2001; Poskela & Martinsuo, 2009). External turbulence is mainly triggered by market and technology uncertainties. Nevertheless, “there are only a few studies reported on the dynamics of multi-project settings and how management tries to coordinate the portfolio in action” (Engwall & Jerbrant, 2003, p. 404). Uncertainty rooted in market or technology turbulence is often chosen as a contingency variable in the literature when analyzing performance (Danneels & Kleinschmidt, 2001; Koutferos, Vonderembse, & Jayaram, 2005; Langerak, Hultink, & Robben, 2004; Poskela & Martinsuo, 2009). This choice of contingency factor can also be underpinned by dynamic capabilities theory (Teece, Pisano, & Shuen, 1997). In their seminal work, Teece et al. (1997, p. 516) define dynamic capabilities “as the firm’s ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments.” Thus, an organization has to be able to change its resource combinations to adequately adapt to a turbulent environment in striving for competitive advantage and success. Eisenhardt and Martin (2000) explicitly identify product development as such a dynamic capability. Some authors have suggested that project portfolio management constitutes a dynamic capability (Killen, Jugdev, Drouin, & Petit, 2012; Martinsuo, Korhonen, & Laine, 2014; Petit & Hobbs, 2010). In an ideation and portfolio context that means that the thorough selection and compilation of the organization’s idea pipeline and thus its front-end success become even more important in a turbulent environment. In a turbulent environment an organization has to be able to innovate faster to successfully stay in business; therefore, the number of high-quality ideas and the speed of idea processing from idea to concept to project proposal gain in importance under turbulent conditions. Thus, we posit the following:

\textit{Hypothesis 2: The positive impact of front-end success on project portfolio success is higher when (a) market and (b) technological turbulence is high (positive moderation).}

Firm Level Contingency Factors

Entrepreneurship literature discusses the necessity to choose an entrepreneurial rather than an orchestrated approach to ideation when it comes to radical ideas and opportunities (Covin & Miles, 2007). The exploitation of new ideas and the pursuit of new market opportunities imply an entrepreneurial orientation of the organization (Talke, 2007). Entrepreneurial orientation refers to processes and policies that provide the basis for
We rather concentrate on the remaining contingency factors, which is why we do not consider these for in the construct front-end success, proactiveness are implicitly accounted text of this study, innovativeness and or technological processes. “In the context, not all components of entrepreneurial orientation may be necessary for the pursuit of new opportunities (Lumpkin & Dess, 1996). Venkatraman (1989, p. 949) defined proactiveness as “seeking new opportunities which may or may not be related to present line of operations, introductions of new products and brands ahead of competition, strategically eliminating operations which are in the mature or declining stages of life cycle.” Following (Lumpkin & Dess, 1996, p. 142), innovativeness is “a firm’s tendency to engage in and support new ideas, novelty, experimentation, and creative processes that may result in new products, services, or technological processes.” In the context of this study, innovativeness and proactiveness are implicitly accounted for in the construct front-end success, which is why we do not consider these dimensions of entrepreneurial orientation as additional contingency factors. We rather concentrate on the remaining component: riskiness. Following Venkatraman (1989, p. 949), “this dimension captures the extent of riskiness reflected in various resource allocation decisions as well as choice of products and markets.” We consider riskiness in the context of this article not as an individual trait, but rather as a construct on the organizational level.

Typically, ideation involves taking risks, because its outcome is unknown. Thus, this study investigates the effects of riskiness on the relationship between front-end success and project portfolio success. We explore whether organizations that are willing to take risks can leverage their front-end performance more successfully in turning it into project portfolio success than risk-averse organizations. Risk taking describes the affinity of pursuing new and unknown ventures or committing a vast amount of resources to uncertain projects where the output could be dubious and costly failure could result (Lumpkin & Dess, 1996; Miller, 1983). In return, risky ventures may obtain higher returns as they may seize opportunities in the marketplace (Lumpkin & Dess, 1996).

Empirical results on the effects of riskiness are mixed. Some studies suggest that riskiness positively influences performance (Lumpkin & Dess, 1996). Others argue for a negative impact of riskiness on performance (Talke, 2007; Venkatraman, 1989). Riskiness may enable the organization to fully exploit new ideas and to explore new opportunities. Consequently, more ideas may be implemented. This is crucial as it is not sufficient to solely identify ideas, but to implement them as well. The implementation of new ideas enables the organization to launch new products and services, which gives it differentiation potential from other competitors and, therefore, competitive advantage. Risk and opportunity lie closely together: a tendency to take risks may encourage a faster implementation of ideas and an efficient use of resources, because a venturesome organization may decide more quickly. Consequently, we posit the following hypothesis:

Hypothesis 3: The positive impact of front-end success on project portfolio success is higher if the strategic orientation of the firm is characterized by high riskiness (positive moderation).

Portfolio Level Contingency Factors

The management challenges to keeping a project portfolio on its road to success increase significantly the more projects are managed within the portfolio and the more distinct interactions between the projects exist (Teller et al., 2012). These interdependencies can result from resource competition or direct dependencies (Archer & Ghasemzadeh, 1999).

Not surprisingly, the concepts of project portfolio size and project interdependency can be found in the literature as contingency factors for complexity in project portfolio management (Teller et al., 2012; Voss & Kock, 2013). Nobeoka and Cusumano (1994), for example, stress the importance of project interdependency as a contingency factor when evaluating the impact on performance. We argue that with higher project interdependency and increasing portfolio size, a strong idea pipeline, in other words, high front-end success, becomes even more essential to achieving project portfolio success, because with increasing complexity a sound basis for decision making within the project portfolio management becomes increasingly important. The higher front-end success is, the more better options are built up and the organization can put together the right set of projects. The better these options are, the better the company is positioned. In light of this argumentation we suggest the following hypothesis:

Hypothesis 4: The positive impact of front-end success on project portfolio success is higher if (a) portfolio size and (b) project interdependency is high (positive moderation).

Method
Sample

This study was part of a large-scale study on the best practices in project portfolio management. We tested...
Front-End Success and Project Portfolio Success

our hypotheses with a cross-industry sample of 175 project portfolios and only included organizations that actually ran several projects simultaneously. We identified two informants for each analyzed portfolio—one from senior management and one project portfolio coordinator. Participating senior managers (e.g., CEO, head of business unit) usually had decision authority over the company’s or business unit’s project portfolio concerning initiation, termination, or reprioritization of projects. Project portfolio coordinators (e.g., head of the PMO, portfolio manager) were typically responsible for actively managing the project portfolio. This dual-informant design on two different management levels was chosen for two reasons: (1) to obtain a broader picture of the processes, information flows, and responsibilities of the analyzed portfolios, and (2) to mitigate the problem of common method bias (Podasakoff, Mackenzie, Lee, & Podsakoff, 2003), because in each firm the coordinator informant assessed the independent variable and the senior management informant assessed the dependent variable. The number of fully completed matched pairs of questionnaires that could be used for our analysis was 175. The sample contained organizations from various industries and of varying sizes from less than 500 employees up to well more than 100,000 employees. The sample incorporated organizations from various industries: manufacturing (27%), financial services (19%), information and communication technologies (18%), energy and infrastructure (10%), pharmaceuticals and chemicals (9%), and other service business (17%).

Measurement

We based our variables on multi-item scales, which were taken from recent literature on innovation and project portfolio management. Unless otherwise stated, the items were measured on a 7-point Likert scale ranging from 1 (“strongly disagree”) to 7 (“strongly agree”). We validated our item scales by applying principal components factor analysis (PCFA), followed by confirmatory factor analysis (CFA) (Ahire & Devaraj, 2001). PCFA checks for the unidimensionality of each scale by investigating whether all items load on a single factor (i.e., only one eigenvalue larger than one). Cronbach’s alpha was used to evaluate scale reliability (acceptable values are larger than 0.7). Finally, a CFA was conducted to confirm the measurement model and the second-order latent factor structure of the independent and dependent variables. We assessed the model fit following the criteria of Hu and Bentler (1998) in that a comparative fit index (CFI) above 0.90 and a standardized root-mean-square residual (SRMR) below 0.08 were considered acceptable. A detailed list of used items and their statistics can be found in the Appendix. All scales fulfill the above criteria and can therefore be considered satisfactory.

Dependent Variable

We measured project portfolio success as a second-order construct with the following dimensions taken from the literature (Jonas et al., 2013; Teller & Kock, 2013; Teller et al., 2012, 2014; Voss & Kock, 2013): Business success of the firm/business unit (four items), average success of project results (four items), strategic fit (three items), portfolio balance (three items), and preparing for the future (three items). The senior management informant assessed project portfolio success.

Independent Variable

Front-end success was assessed as a second-order construct along the constructs front-end effectiveness (four items), front-end timeliness (three items), and front-end efficiency (three items). These items were taken from Kock et al. (2015). The project portfolio coordinator informant assessed front-end success.

Moderators

Environmental contingency factors were measured by two constructs based on Jaworski and Kohli (1993): market turbulence, consisting of four items, and technological turbulence, consisting of four items. The senior management informant assessed both constructs. At the firm level, we measured the riskiness dimension of strategic orientation using three items that capture the willingness to engage in risky projects. The items were based on (Telke, 2007) and Venkatraman (1989). The senior manager assessed riskiness. At the portfolio level, portfolio size was captured using the natural logarithm of the annual portfolio budget in M€ (Unger et al., 2012). Project interdependency was measured with a construct containing six items based on Teller et al. (2012). With this construct we analyzed how strongly the projects influence and depend on each other. Project portfolio size and project interdependency were assessed by portfolio coordinator informants.

Controls

Several control factors had to be considered to eliminate any distorting effects and to isolate the predictive influence of front-end success. We accounted for four factors. First, we included the industry sector of the company since our study contains businesses from different industries. We clustered the participating organizations into six industry sectors: manufacturing, financial services, information and communication technologies, pharmaceuticals and chemicals, energy, and other service businesses. Second, we controlled for the size of the participating organization. We chose organization size as the natural logarithm of the number of employees in the organization or business unit. As organizations grow, structural rigidity and inertia forces might affect the ability of the company to innovate; therefore, the size of the organization is an important variable to control for in the ideation and project portfolio environment. Third, we checked the percentage of internal projects (ranging from 0 to 1 = 100%) in contrast to client projects. This internal
Table 1: Descriptive statistics and correlation table of research variables.

<table>
<thead>
<tr>
<th>Variables</th>
<th>M</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Project Portfolio Success</td>
<td>4.95</td>
<td>0.71</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Front-End Success</td>
<td>4.53</td>
<td>0.93</td>
<td>0.47*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3. Firm Size (ln)</td>
<td>7.17</td>
<td>2.12</td>
<td>-0.03</td>
<td>-0.01</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Internal Project Ratio</td>
<td>0.65</td>
<td>0.35</td>
<td>-0.03</td>
<td>0.05</td>
<td>0.21*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. R&amp;D Project Ratio</td>
<td>0.40</td>
<td>0.38</td>
<td>0.08</td>
<td>0.15*</td>
<td>-0.05</td>
<td>0.12</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Portfolio Size (ln)</td>
<td>3.59</td>
<td>1.71</td>
<td>-0.01</td>
<td>0.05</td>
<td>0.60*</td>
<td>-0.12</td>
<td>-0.13</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7. Project Interdependency</td>
<td>4.60</td>
<td>1.00</td>
<td>0.05</td>
<td>-0.02</td>
<td>0.02</td>
<td>0.07</td>
<td>0.06</td>
<td>0.02</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Technological Turbulence</td>
<td>4.41</td>
<td>1.32</td>
<td>0.25*</td>
<td>0.06</td>
<td>-0.08</td>
<td>-0.10</td>
<td>0.02</td>
<td>-0.12</td>
<td>-0.06</td>
<td>1.00</td>
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<tr>
<td>9. Market Turbulence</td>
<td>3.43</td>
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<td>-0.15*</td>
<td>-0.13</td>
<td>0.36*</td>
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<tr>
<td>10. Riskiness</td>
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<td>0.08</td>
<td>0.01</td>
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<td>0.14</td>
<td>0.03</td>
<td>0.06</td>
<td>0.13</td>
<td>0.23*</td>
</tr>
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</table>

*p < 0.05; n = 175; M = mean; SD = standard deviation.

Results

The hypotheses were tested with hierarchical ordinal least squares regression. Contingency effects were analyzed using the procedures of Aiken, West, and Reno (1991). Variables were first mean-centered. Then the product term of the independent variable front-end success with the respective moderator was included in a new model. This model was then compared with the previous model without interaction term. If the coefficient and the increase in explained variance were both significant, a moderating effect was assumed. Significant interaction effects were further investigated by simple slope analysis in order to illustrate the nature of the effect. Simple slopes were calculated for a standard deviation above and below the mean of the moderator variable.

Table 2 shows the results for different models. Model 0 contained only control and moderator variables. Model 1 included the direct effect of front-end success. The unstandardized regression coefficient was significantly positive (b = 0.34, p < 0.01), supporting hypothesis 1. The overall model was significant and explained 35% of the variance in project portfolio success. This result is highly satisfactory, considering the fact that we used different informants for independent and dependent variables.

The subsequent models tested the interaction effects of contingency variables with front-end success. Models 2a and 2a investigated the moderation effects of technological and market turbulence, respectively. Surprisingly, both interaction coefficients were not significant, so hypotheses 2a and 2b could not find support. Contrary to expectations, the relevance of a successful front end for portfolio success does not increase in more turbulent environments.

Model 3 shows the impact of riskiness on the relationship between front-end success and portfolio success. The results support hypothesis 3 in that with increasing willingness to take risks, the positive effect of front-end success increased (b = 0.10, p < 0.01). The simple slopes in Figure 2 show that also for low riskiness a successful front end was beneficial for portfolio success; however, the benefits were larger for firms with higher willingness to take risks.

Portfolio size had a significant and positive interaction effect (Model 4a, b = 0.08, p < 0.05) and the increase in explained variance was significant. This result supports hypothesis 4a in that with increasing size, the positive effect of front-end success on portfolio success increases. Figure 3 shows that for smaller portfolios the effect was still positive but significantly weaker than for larger portfolios.

Finally, Model 4b shows that project interdependency also positively moderated the relationship between front-end success and portfolio success, supporting hypothesis 4b (b = 0.12, p < 0.01). The relationship and the effect of project interdependency are visualized in Figure 4. The simple slope graph shows that this effect resembles the effect of portfolio size.

Discussion

This article aims at linking the literature on project portfolio and innovation management by investigating the relationship between front-end success and project portfolio success. In line with the previous contributions of front-end literature on the single project level (Reid & de Brentani, 2004), the results of the current study show that front-end success is highly important.
for later success. Project-related "homework" (Cooper, 2011) is therefore not only important on an individual project level, but also on the portfolio level. Findings of this study underscore the importance of an effective and efficient front end for project portfolio success. Decisions and activities of the front end constitute the starting point for the following development process stages and therefore are a key source for competitive advantage. Results show that, especially in the portfolio management context, it is important to pay attention to the front end: Portfolio management does not just start with the prioritization of project proposals. In fact, the right ideas have to be generated and further processed much earlier to become such a project proposal. To front-load activities at relatively low

Front-End Success and Project Portfolio Success

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>(0)</th>
<th>(1)</th>
<th>(2a)</th>
<th>(2b)</th>
<th>(3)</th>
<th>(4a)</th>
<th>(4b)</th>
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<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
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<tr>
<td>Internal Project Ratio</td>
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<td>−0.10</td>
<td>−0.11</td>
<td>−0.13</td>
<td>−0.10</td>
<td>−0.13</td>
</tr>
<tr>
<td>R&amp;D Project Ratio</td>
<td>−0.24</td>
<td>−0.29*</td>
<td>−0.29*</td>
<td>−0.27*</td>
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<td>FES × Technological Turbulence</td>
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<td>F</td>
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Hierarchical regression models with project portfolio success as the dependent variable; unstandardized regression coefficients are reported; all variables are mean-centered; *p < 0.10; *p < 0.05; **p < 0.01; n = 175; FES = front-end success.

Table 2: Results.

![Figure 2: Simple slopes for the moderator riskiness.](image-url)
levels of effort, gives the organization the leverage to facilitate later portfolio success.

More importantly, this study sheds light on key contingency factors that affect the strength of the relationship between the front end and the project portfolio. The framework accounts for influences in the firm’s environment, the firm’s strategic orientation, and the characteristics of the project portfolio itself. First, the study could not show significant moderating effects of environmental dynamics, such as market or technological turbulence on the relation between front-end success and project portfolio success. Thus, our findings indicate that front-end success is important for project portfolio success independently of environmental turbulence, in other words, in both stable and turbulent environments. Therefore, ideation and the generation of a sound idea pipeline for future projects are not only important in dynamic industries such as, for instance, high-tech business, but is also a source of competitive advantage in the less turbulent environments of stable and traditional industries. The absence of the moderating effects of external dynamics is still surprising, because evidence suggests that technological and market turbulence are likely to have an impact on relations where performance serves as a dependent variable (Kohli & Jaworski, 1990). However, the non-significant findings are not completely unexpected considering the mixed and non-significant findings on the contingent effects of external dynamics in performance and success contexts in literature (Jaworski & Kohli, 1993; Koufteros et al., 2005; Langerak et al., 2004).

Secondly, the results suggest that aspects of the organization’s entrepreneurial and strategic orientation, namely riskiness, moderate the positive effect of front-end success on project portfolio success. Risk and opportunity lie closely together: An organization prepared to take risks is able to implement new ideas more quickly and efficiently. This is crucial because it is not sufficient to solely identify ideas; identified ideas also need to be implemented. The results imply that the positive effects of front-end success become even stronger with increasing riskiness. This strengthens previous findings, which indicate that entrepreneurial orientation helps exploiting new ideas and new market opportunities (Talke, 2007). Furthermore, our findings help to reconcile inconclusive findings regarding the performance effects of riskiness. While riskiness on its own might not directly influence performance, it increases the positive effects of proactiveness and innovativeness by facilitating the exploitation of front-end activities. Therefore, this study also contributes to the stream of risk management literature that calls for a coherent view on the effects of opportunities and risks (Teller, 2013; Ward & Chapman, 2003). Riskiness may mean that a vast amount of resources
Front-End Success and Project Portfolio Success

committed to uncertain projects where the output can be unclear and costly failures could result (Lumpkin & Dess, 1996; Miller, 1983). Future studies could consider that project portfolios with interdependent projects sharing scarce resources may encourage riskier undertakings, because each project can be supported by the entire resource pool cushioning costly failures and environmental uncertainties.

Finally, results show a positive moderating effect of both project interdependency and portfolio size on the relation between front-end success and project portfolio success. These findings suggest that front-end success becomes even more important for organizations running a large project portfolio with many interdependent projects. Portfolio size and interdependency of projects add to complexity of portfolio management. Consequently, Dickinson, Thornton, and Graves (2001, p. 518) point out “when projects are interdependent, the complexity of optimizing even a moderate number of projects over a small number of objectives and constraints can become overwhelming.” In this complexity it is even more necessary to be able to rely on a sound basis of the project portfolio that was laid by a successful front end and a valuable idea pipeline. The higher the front-end success is, the more options are built up and the organization can put together the right set of projects. The better these options are, the better the company is positioned. Large and complex portfolios have more potential for synergies to be exploited. The sound foundations therefore play a larger role than in less complex, straightforward portfolios. In small portfolios, it is easier for portfolio management to trouble-shoot, in other words, to dive deeper into specific projects, improve their concepts, and bring them on track.

In addition to the above-discussed implications for academia, this article holds useful implications for practitioners as well. The results underpin the necessity for managers of project portfolios to not only focus on their project portfolio but also to pay attention to the front end. They should make sure that the front-end phase of their project portfolio becomes a success as this positively impacts their project portfolio performance. This holds even more true if their organization’s orientation allows for the willingness to take risks and if their project portfolio consists of a large number of projects that are highly interdependent.

A few limitations should be pointed out for this study when interpreting the results. The study was conducted in Germany. Whether our results can be transferred to an international context can only be shown with an international research set-up that also takes cultural aspects into consideration (Unger, Bank, & Gemünden, 2014). For instance, scholars have often pointed out that risk culture and the willingness to bear risks vary with cultural settings and context. Following de Brentani and Kleinschmidt (2004), this study could therefore be brought to the next level in conducting this research in an international setting that does not only incorporate Europe but also Asia and the Americas to get a profound international perspective versus organizational climate: Which one matters more to dispersed collaboration in the front end of innovation? Journal of Product Innovation Management, 28, 757–772.


References


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Front-End Success and Project Portfolio Success


**Dr. Alexander Kock** is a Professor of Technology and Innovation Management at Technische Universität Darmstadt, Germany. He holds a diploma in business engineering and a doctorate in business administration from Berlin Institute of Technology. His research interests cover organizational issues of innovation and project management, especially the management of project portfolios. His work has been published in various journals, including *Journal of Product Innovation Management, IEEE Transactions on Engineering Management, International Journal of Project Management and Project Management Journal*. He can be contacted at kock@tim.tu-darmstadt.de

**Dr. Wilderich Heising** is a Principal with The Boston Consulting Group, a leading international strategy consulting firm. He has advised clients in a broad range of industries, including healthcare and industrial goods, on strategy issues, product innovation management, organization and profit improvement. Dr. Heising holds a PhD in Engineering from Berlin Institute of Technology and a diploma in Industrial Engineering from Technische Universität Darmstadt, Germany. His research interests include innovation management, product development, and project portfolio management. He can be contacted at heising.wilderich@bcg.com

**Dr. Hans Georg Gemünden** is a Professor of Project Management at BI Norwegian Business School. He holds a Diploma and a Doctorate in Business Administration from the University of the Saarland in Saarbrücken, and a Habilitation degree and an honorary doctorate from the University of Kiel. He has received several awards of excellence for his research e.g., the IPMA Research Achievement Award, which has been published in refereed journals including, among others, *Organization Science, Research Policy, Journal of Product Innovation Management, Creativity and Innovation Management, International Journal of Research in Marketing, IEEE Transactions on Engineering Management, R&D Management, International Journal of Project Management, and Project Management Journal*. He can be contacted at hans.gemuenden@tim.tu-berlin.de
Appendix: List of Items

Project Portfolio Success, second order construct consisting of the following five dimensions ($\chi^2 = 229.84$ (df = 114; $p < 0.00$), SRMR = 0.067, CFI = 0.92):

- Business Success (four items, Cronbach’s alpha = 0.85, Second-order factor loading $\lambda = 0.65$)
  How do you evaluate the success of your organization/entity compared to your competitors...
  - ... regarding the overall business success.
  - ... regarding the market share.
  - ... regarding the revenue growth.
  - ... regarding the profitability.

Average Success of Project Results (four items, alpha = 0.84, $\lambda = 0.71$)
Please evaluate the average success of your project results.
- Our products/project results reach the planned target costs.
- Our products/project results reach the planned market goals (e.g., market share, revenue).
- Our products/project results reach the planned financial goals (e.g., ROI).
- Our products/project results reach the planned payback period.

Strategic Fit (three items, alpha = 0.79, $\lambda = 0.81$)
- The project portfolio is consistently aligned with the future of the company.
- The corporate strategy is ideally implemented through our project portfolio.
- Resource allocation to projects reflects our strategic objectives.

Portfolio Balance (three items, alpha = 0.69, $\lambda = 0.70$)
- There is a good balance in our project portfolio between new and old areas of application.
- There is a good balance in our project portfolio between new and existing technologies.

Preparing for the Future (three items, alpha = 0.82, $\lambda = 0.71$)
- We sufficiently develop new technologies and/or competencies in our projects.
- With our projects we are a step ahead of our competitors with new products, technologies, or services.
- Our projects enable us to shape the future of our industry.

Front-End Success, second order construct consisting of the following three dimensions ($\chi^2 = 64.03$ (df = 32; $p < 0.00$), SRMR = 0.051, CFI = 0.92):

- Front-End Effectiveness (four items, alpha = 0.85, $\lambda = 0.79$)
  - We generate sufficiently "good" and/or "right" project ideas for our portfolio.
  - Our current idea pipeline will strengthen our competitive positioning.
  - With our current idea pipeline we will be able to strongly increase our sales with new products within the next three years.
  - At large, our current idea pipeline has a strong value generating potential.

- Front-End Timeliness (three items, alpha = 0.87, $\lambda = 0.94$)
  - At our organization new ideas are quickly developed into concepts.
  - For the development of concepts resources are made available quickly.
  - Accepted concepts are quickly converted into projects.

- Front-End Efficiency (three items, alpha = 0.88, $\lambda = 0.69$)
  - The available and allocated budget is used efficiently in our ideation phase.
  - The available and allocated personnel resources (engineering-hours) are used efficiently in our ideation phase.
  - At large, our ideation phase has a good cost-benefit ratio.

Market turbulence (four items, alpha = 0.68)
- In our industry it is difficult to anticipate the development of customer preferences.
- Our customers tend to look for new product all the time.
- In our kind of business, customers’ product preferences change quite a bit over time.
- In our industry it is difficult to anticipate competitor moves and activities.

Technological turbulence (four items, alpha = 0.87)
- The technology in our industry is changing rapidly.
- Technological changes provide big opportunities in our industry.
- A large number of new product ideas have been made possible through technological breakthroughs in our industry.
- Technological developments in our industry are rather minor (inverse item).

Riskiness (three items, alpha = 0.74)
- We are not afraid of taking risks when making fundamental project decisions.
- We frequently support projects when the expected return is still uncertain.
- Within our strategic limits we accept a high degree of risk.

Portfolio size
- How high is the annual budget of the project portfolio? (natural logarithm of M€)

Project Interdependency (six items, alpha = 0.83)
• A high degree of alignment between our projects is required with respect to the scopes.
• Scope changes of individual projects inevitably impact on the execution of other projects.
• Often projects can only be continued if the concrete results of other projects are known.
• Delays in individual projects inevitably impact on other projects.
• As a consequence of joint utilization of human resources, projects are highly interdependent on each other.
• Projects must share skilled employees/experts.
ABSTRACT

To attain benefits and value, multiproject R&D management seeks synergy between projects. Selecting or inventing appropriate end-product components within R&D programs is a concrete example of the synergy between projects. Lowering the number of different components used across projects (i.e., increasing component commonality) can lower end-product costs, which can contribute to firm-level profitability. Prior research, however, shows component commonality as a limitation of innovativeness in multiproject R&D. Conversely, this article shows that component commonality can also serve as the source of innovation, making component commonality an area of special interest to multiproject R&D management and research.

KEYWORDS: portfolio management; program management; qualitative research; uncertainty; innovation

INTRODUCTION

Multiproject R&D is intentionally leveraged to harvest strategic benefits (Cooper, Edgett, & Kleinschmidt, 1997). Recently, research has identified "a need to delve deeper and continue to find better ways to comprehensively identify and measure strategic value" (Martinsuo & Killen, 2014, p. 56) from multiproject operations. In high-tech R&D environments with scarce resources, multiple projects must be managed in parallel and these projects have various resource, technology, and market-related interdependencies (Verma & Sinha, 2002). These project interdependencies represent a rationale for multiproject operations, involving the synergy of common technologies and other capabilities (Aubry, Hobbs, & Thuillier, 2007; Meskendahl, 2010). Managing multiple projects with complexities and uncertainties requires context-specific strategic alignment and value measures (Martinsuo, 2013). Indeed, context-specific uncertainties may hamper the management of desired strategic benefits (Korhonen, Laine, & Martinsuo, 2014; Martinsuo, 2013; Martinsuo, Korhonen, & Laine, 2014; Petit & Hobbs, 2010; Sicotte, Delerue, & Drouin, 2014; Teller, Kock, & Gemünden, 2014). Some of the multiproject-level uncertainties stem from single projects (Korhonen et al., 2014; Martinsuo et al., 2014; Petit & Hobbs, 2010); more precisely, uncertainties may stem from the need to customize the end-products for different customers (Petit & Hobbs, 2010).

One remarkable example of utilizing synergy and therefore enhancing the benefits attained from multiproject R&D operations is the platform approach (Aubry et al., 2007; Mäkinen, Seppänen, & Ortt, 2014), where products are developed and managed as family members that share common components, modules, or even processes (Mäkinen et al., 2014). This article takes the example of component commonality in a high-tech R&D context as a remarkable example of technology synergy in multiproject operations and as an elemental part of the platform approach in R&D (Mäkinen et al., 2014). By addressing the case of component commonality within R&D management, this article responds to the need for better understanding the realization of multiproject synergy, which isn’t easily put into practice due to complexities in the operational environment (Meskendahl, 2010). Through component commonality different end-products can be customized for different customers by using a compact set of components.

Recent literature on multiproject R&D management has acknowledged the viewpoint of component standardization and component commonality...
The purpose of this study is to address the broader issue of innovation in multiproject management. The research questions posed in this article are:

**Research question 1:** What kind of influence does component-commonality innovation have on the value and management of multiproject operations?

**Research question 2:** How could multiproject management take advantage of component-commonality innovation?

The study contributes to our understanding of the technological synergy in multiproject R&D operations (Aubry et al., 2007; Meskendahl, 2010; Mäkinen, 2014) by providing an example and a detailed examination of component-commonality innovation in action. In its essence, the study provides a novel approach for innovation and innovativeness to acquire component commonality as a desired strategic benefit in the multiproject-management context, and hence provides an extension to the line of inquiry by Maniak and Midler (2014). The literature concerning multiproject operations has emphasized project selection and coordination (Maniak & Midler, 2014, p. 1147); we argue, however, that there isn’t enough understanding about the actual realization of multiproject synergy through component commonality. As Maniak and Midler state, “We still have few insights about the application of contextual ambidexterity from a multiproject perspective, which could help to better understand the mechanisms of the reuse of concrete knowledge and how it embodies a coherent path towards an expansive range of innovative products” (p. 1149). Because we are interested in the creation of value in the interaction between program and project levels, this study also contributes to the literature that considers the influence of single projects in different ways at the multiproject level (Korhonen et al., 2014; Martinsuo et al., 2014; Petit & Hobbs, 2010).

As a managerial implication, this study shows that the development of common components, which is central to component commonality, might require significant effort and innovation (or at least transfer to new technologies and platforms) within a program; hence, common components are not only a limitation to innovation within R&D programs. Based on our empirical evidence, we also wish to advance the component-commonality literature by providing an illustration particularly of the direct cost implications of component commonality. Our study also responds to the call from empirical commonality studies (Labro, 2004). Our empirical evidence shows the actual cost effects of the component-commonality innovation at hand, but at the same time reiterates that component commonality is embedded in R&D activities within an organization. To truly understand the benefits attained through multiproject R&D operations, managers should perhaps take into account the effects of several component-commonality innovations, along with other implications of R&D activities.

**The Research Setting**

To gain insight into component-commonality development within multiproject R&D operations, this article is based on interventionist research (see Lukka & Suomala, 2014; Suomala & Lyly-Yrjänäinen, 2012; Suomala, Lyly-Yrjänäinen, & Lukka, 2014), which has been used for data collection. The interventionist research approach provides good possibilities to observe the component-commonality innovation within the multiproject R&D operation at hand. More specifically, this article takes advantage of an in-depth case study in a globally operating original equipment manufacturer company in Finland. In fact, the “Company” refers to one division of the original equipment manufacturer, but for simplicity, we call the organization in which the case study took place the “Company.” In October 2011, two interventionist researchers—that is, the two first authors—received access to an ongoing
Innovation for Multiproject Management

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### Table 1: The component–commonality innovation incurred cost implications in the Company’s case (an annual cost summary across different products).

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<td><strong>Total</strong></td>
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<td><strong>1,800</strong></td>
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### Section 2

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### Section 7

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<tr>
<td>Total annual direct costs + engineering-to-order costs</td>
<td><strong>1,797,500</strong></td>
<td><strong>1,791,250</strong> ($6,250 decrease)</td>
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R&D program in the Company; specifically, the interventionist researchers took part in an electrical subassembly component–commonality development project as experts in cost and profitability estimation. The researchers’ role was to estimate the cost implications of component commonality to help with decision making at the Company (Table 1).\(^1\)

Altogether, the researchers were present at 19 product development-related meetings at the Company, both as observers and as active contributors to cost and profit estimates regarding component commonality. The meetings took place as follows: one in October 2011, one in January 2012, four in February 2012, four in March 2012, two in April 2012, one in May 2012, two in June 2012, and two in August 2012. The meetings included primarily design engineers, although business and project controllers, project managers, purchasing engineers, research management, production management, and product line management also participated. The notes from these meetings serve as our data set, along with the component cost data acquired from the component-commonality development effort.

Following the initial data collection, the meeting notes were analyzed in an iterative manner with broader involvement of the co-authors. During this analysis, a narrative of the case study was iteratively written, rewritten, and validated based on the notes and the participating researchers’ experience of the events that unfolded; a data-validation meeting with the Company’s key representatives was also held. Our
in-depth access to the Company’s R&D operations allows us to make conclusions about the aspects of component commonality, acting both as a source of innovation and as a limitation to innovation within multiproject management. On one hand, the events revealed that component commonality was indeed the source of innovation in the one project studied in an R&D program. On the other hand, when subsequent projects in the same program eventually use the previously designed component–commonality innovation as an input, this could potentially limit further innovation.

**Literature Review**

*Technological Synergy in the Multiproject Management Literature*

In the project-management context, "project portfolios are embedded into their context and its cultures" (Unger, Rank, & Gemünden, 2014, p. 38), and in a similar way, single projects are embedded into multiproject operations; in other words, programs and portfolios (Martinsuo, 2013; Petit & Hobbs, 2010). The influence of the single projects and related uncertainties regarding multiproject operations has recently been examined (Korhonen et al., 2014; Martinsuo et al., 2014; Petit & Hobbs, 2010). More specifically, within the multiproject-management (and related) literature, there are a few studies that address multiproject synergy and interdependencies (Aubry et al., 2007; Meskendahl, 2010; Teller, Unger, Kock, & Gemünden, 2012; Verma & Sinha, 2002; Verma, Mishra, & Sinha, 2011). Among the multiproject synergy and interdependencies, technological issues have been distinguished (Aubry et al., 2007; Meskendahl, 2010), especially under the label of the platform approach (Aubry et al., 2007) in the R&D context (Maniak & Midler, 2014; Mäkinen et al., 2014), implying common components, modules, platforms, and processes.

Mäkinen et al. (2014) identify several possible advantages (e.g., cost reductions, desired variety, increased speed of development) and limitations (e.g., rigidity of the existing platforms, restricted innovativeness) of utilizing the platform approach in R&D projects, and call for examining their dynamics in a more detailed manner. Although there are arguably more advantages than limitations identified in the use of common platforms, modules, and components these advantages haven’t been examined in different contexts, specifically with respect to multiproject management (see Maniak & Midler, 2014, for an exception). In fact, “multiproject research focuses on selecting the right projects, allocating resources, balancing the cross-sectional view of the portfolio, technology transfer between projects, and finding connections between portfolio success factors and performance” (Maniak & Midler, 2014, p. 1149). Such coordination is believed to freeze “future” design decisions for strategic alignment purposes; the constraining aspects can be, for example, commonalities in components and project processes (Maniak & Midler, 2014, p. 1149).

The case of component commonality, as used in this article, is not the only example of potential technological synergy that influences multiproject management, yet it provides a concrete example of elaborating on the key possibilities and challenges of multiproject management. In fact, through a detailed understanding of the cost implications and other benefits attained through component commonality, we could transfer the results to the wider context of innovation in multiproject R&D. In order to make that transfer of results possible, a deeper examination of the literature on component commonality, which is at the core of the phenomenon examined in this article, needs to be undertaken.

**Previous Research on Component Commonality and Its Cost Implications**

Component commonality can be defined as the use of the same version of a component across multiple products (Labro, 2004) and is often considered a means to combining product variety with cost efficiency. Literature that discusses the cost implications of component commonality generally analyzes the effects of replacing several product-specific components with a common one (see, e.g., Gerchak, Magazine, & Gamble, 1988; Ho & Li, 1997; Vakharia, Parmenter, & Sanchez, 1996). Some of the literature implies that the number of components is a key driver behind cost implications when commonality is discussed (e.g., Collier, 1981, 1982). This viewpoint, however, does not cover the possible cost implications of the development work needed for a common component, nor the possible increase in the direct costs of more versatile components.

The number of published empirical studies on component commonality remains rather small. The few empirical studies on cost implications of component commonality aren’t very closely connected to the technical prerequisites for increased component commonality, hence underemphasizing the empirical view on cost implications or the actual development of common components (e.g., Lee, 1994; McDermott & Stock, 1994; Park & Simpson, 2005; Ramdas & Shawney, 2001; Ramdas, Fisher, & Ulrich, 2003; Swaminathan & Tayur, 1998; Thyssen, Israelens, & Jørgensen, 2006). Therefore, the literature does not adequately acknowledge that component commonality is realized in real-life product families and multiproject R&D operations. In practice, common components need to be technically feasible and developed within R&D activities. The technical feasibility and dimension of innovativeness aren’t dealt with in models that highlight the importance of indirect cost savings, which would cover certain cost increases in direct materials and assembly (e.g., Thyssen et al., 2006). Contrastingly, this article addresses the issue of innovation in multiproject R&D, specifically from the viewpoint of component commonality.

The aspect of innovation in studies of component commonality is under-
emphasized. This lack of emphasis could be explained by the manufacturing contexts in which commonality and its cost implications have been studied. The component–commonality literature has focused on make-to-stock and assembly-to-order production environments (Fong, Fu, & Li, 2004; Perera, Nagarur, & Tabucanon, 1999). The make-to-stock environment has standard products made-to-stock with (rather) stable bills of materials (Amaro, Hendry, & Kingsman, 1999); the assembly-to-order environment, on the other hand, is based on a standardized product family with well-documented product options; hence, all the potential end-product variants have been engineered beforehand (Amaro et al., 1999). The existing product families with bills of materials make it rather straightforward to simply select common components with the functionality of several components. The classical example would be to replace two electric motors by making the larger motor standard, resulting in increased costs due to cases of over-specification, while also reducing costs through fewer parts.

When moving from make-to-stock and assembly-to-order contexts into engineering-to-order production environments, analyses of the cost implications of component commonality become even more challenging. The engineering-to-order context is typical for products that need unique engineering or a significant amount of customization to be manufactured according to customer-specific requirements (Amaro et al., 1999). Thus, each order results in a unique design, part numbers, bills of materials, and routing in the production (Hicks & Braiden, 2000; Hicks, McGovern, & Earl, 2001; McGovern, Hicks, & Earl, 1999). This is the situation in our case study as well. Unlike in the assembly-to-order environment, products in the engineering-to-order context are not configured using existing modules and product options; rather the product (or at least part of it), is individually engineered for each customer.

Standard product families with relatively stable bills of materials (in make-to-stock) or predefined options (in assembly-to-order) make it easy to analyze component use and try to increase component commonality with over-specification. In the engineering-to-order context, however, the starting point is not that easy. First, managers often need to go through a major process to analyze the engineered-to-order products they have delivered and the engineered-to-order products that customers might be ordering in the future (Lyly-Yrjänäinen, 2008). In other words, over-specification is not simply done by selecting the most “powerful” component, but such a component may need to be developed, which may require (1) rethinking the product architecture, and (2) new technological solutions for a particular industry.

The Need to Study Component Commonality in Multiproject R&D Management Contexts

Overall, still too little is known about the mechanisms through which component commonality incurs cost implications (Labro, 2003, 2004). Moreover, component commonality isn’t often mentioned in the multiproject management literature. Some authors have noticed the portfolio-level effects stemming from the issues of component commonality in multiproject lineage management, including retrofitting and preventing “destandardization” (Maniak & Midler, 2014; Midler, 2013) in overlapping or sequential technology transfer between single projects (Nobeoka & Casumano, 1995, 1997) and with respect to the software product customization needs in single projects (Petit & Hobs, 2010). Additionally, the related issues of simplicity and practicality in “planning and managing risk in innovative and complex projects” have been viewed as issues to address (Conforto & Amaral, 2010, p. 79). In the context of managing multiproject operations, component commonality has been seen primarily as a means for attaining cost reductions, and at the same time, representing a restricting frame for innovative R&D operations (Maniak & Midler, 2014). Another possible alternative is viewing component commonality as innovation or as a starting point for innovative multiproject R&D activities aimed at strategic benefits (cost reductions included), an alternative not sufficiently addressed in the literature.

Taking into account the role of product-development actions and the technological solutions needed to enable commonality in the engineering-to-order context, however, makes cost analyses more complex. Hence, the impact and value of a development project, ultimately also outside the financial domain at the portfolio level, in other words, in indirect terms (Martinsuo & Killen, 2014), remain difficult to identify. In the engineering-to-order context R&D activities tend to result in indirect implications, which are intertwined with the cost implications of common components. This conclusion, again, highlights the need for better understanding the role of component commonality as attempted through multiproject R&D operations. One such endeavor is our following case study of the Company’s distribution-board platform-development project.

Empirical Results on Component Commonality within Multiproject R&D

The Complexity Within the Company’s Operational Environment

The Company manufactures capital goods used in the customer’s production processes. To fit the specific needs of each customer, the products of the case company typically require some engineering changes; some parts of the products must be engineered to order according to the functional requirements outlined by specific characteristics within the customer’s production processes. According to the company’s management, the complexity stemming
from the engineering-to-order operations mode results in a long order-delivery cycle and high costs.

The company started a multiproject R&D program to develop a new, completely re-engineered product generation to create more customer value. In this new product generation the current hydraulic control technology will be replaced by electric control technology, which will mean a major technological transition. This new control technology will not only provide novel ways to add value to the customer’s production processes; the company perceives it as a technology platform, which will enable the process automation to be taken to a new level in the future—first through engineered-to-order deliveries, and later with product updates and new product releases. Within the R&D program, applied research has been carried out to investigate how new technologies could help add value to the customer’s production processes. Based on this applied research, selected technologies have been tested and developed further through concept–development projects. The outcomes of these program-level development efforts have then provided the input needed in the numerous product-development projects, eventually materializing in a generation of new products.

In addition to harnessing the value potential of the new technologies available on the market, the R&D program also aimed at finding solutions to reduce the need for engineering work in the delivery process. Reduction in the engineering work was viewed as one important way to speed up the order-delivery cycle and reduce costs, but it had to be accomplished without sacrificing the customer orientation. Therefore, the R&D program also focused on innovations that would help the company improve its operations while maintaining the necessary flexibility to respond to customer needs. In this case, these innovations would mean new, flexible solutions, enabling the company to maintain its product diversity with reduced operational variance between customer orders; the need to reduce the number of different components had emerged. As a result, some projects in the R&D program focused on finding or inventing the solutions needed for the operational flexibility to enable increased component commonality in this engineering-to-order context, gradually shifting this operations mode to some extent toward the assembly-to-order mode.

This study focuses on the development of a common distribution board within the R&D program, the process of finding and inventing the solutions needed for this distribution board, and the respective cost analyses used by the R&D management to argue for the potential benefits. The distribution board is an entity that enables all the other parts of the product to receive electricity, as illustrated in Figure 1.

Although the different cabinets looked the same on the outside, often there was an entirely new combination of electrical components inside. Within the R&D program, the company had started to develop new, flexible ways to manage the diversity in the field with various options and predefined interfaces, also illustrated in Figure 1. The options and predefined interfaces made it convenient to modify the machines; however, whenever some options were changed, these changes typically had an impact on the bill-of-materials of the distribution board. In addition to the options, the location of each customer’s production site posed a requirement for the machines to comply with varying voltage and frequency ranges in different national grids and different regulations in each country, which also impacted the bills-of-materials of the distribution boards. This, then, posed a problem with regard to the order-delivery cycle; only after the customer had actually

![Figure 1: Practically all distribution boards need to be different from each other because of the destination country and selected optional features of the product.](image-url)
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placed the order could an electrical engineer select and order the electrical components needed for the distribution board. As stated by one leading electrical engineer:

“At the moment, we need to have electrical engineering done six weeks before the start [of manufacturing a customer-ordered product] so that we can order a distribution board for that machine.”

(Leading electrical engineer)

The distribution board itself was not of much interest to the customers; yet, at the same time, the distribution board could not be engineered until all the options for the product had been nailed down, making it a bottleneck for the final assembly. This resulted in the need for coordination between engineering and final assembly to ensure that the assembly processes weren’t put on hold because of the missing components for the distribution board, which would have caused various indirect costs. Because the distribution boards were unique and not always well-documented, the assembly process was slow and had to be made either totally or partially in-house, preventing the company from effectively utilizing subcontractors specialized in the electrical assembly work. As a result, the managers at the Company believed that increased commonality of the distribution boards would most likely result, not only in a shorter order-delivery cycle but also in cost reductions by taking a baby step toward the assembly-to-order operations mode.

Development of a Common Distribution-Board Platform

The company manufactures hundreds of machines per year, resulting in the same number of distribution boards, most of which are different from each other. With regard to the existing distribution-board architecture—the changes in the product options resulted in such modifications in the electric system, which made it impossible for there to be only one board, the most powerful distribution board to serve as a common, over-specified distribution board to be used with all customer applications. Instead, the use of common distribution boards required new ideas for the distribution board itself; the electrical engineers investigated new product architecture and tested new technologies to come up with a solution, which would enable machines with different specifications to be built with a common distribution board. The engineers analyzed various alternative technologies for managing the electrical systems in an attempt to help reduce the complexity related to the distribution boards.

To support the development work, the electrical engineers in the Company also started to analyze the component use within the distribution boards that had been built in the recent past. Increased knowledge of the new technologies available on the market and a better understanding of the product population, in terms of product options and distribution boards used, eventually paid off. The engineers were able to identify three major segments with certain voltage ranges and all of them could be covered with a specific distribution-board architecture, which resulted in three different distribution boards. Furthermore, each of these three distribution boards shared the same common platform, which could vary in terms of the segments, with some small, easy-to-do modifications. Figure 2 illustrates the basic idea of the common distribution-board platform, which itself covered one segment and varied in terms of the other two segments with some additional electrical components. Figure 2 also shows the annual volumes within each segment.

Interestingly, the new distribution-board architecture made it possible to increase component commonality even further to the point where all the segments would have been able to share one common distribution board—the distribution board designed for Segment 2; this, however, wasn’t done. The solution needed for Segment 2 contained some expensive components, and the engineers and managers both suspected that the benefits of a reduced number of distribution-board options might not justify the increase in the direct cost, later verified by the ex-ante cost analyses.

Before going into the cost analyses in more detail, however, it is important to point out that the process resulting in the three distribution boards started with an investigation of the electrical components and control technologies available on the market. This investigation was later combined with detailed

![Figure 2: The innovation: a common distribution-board platform reduces the number of different configurations to only three.](image-url)
analyses of the distribution-board solutions used; together, these provided input for the new distribution-board architecture, eventually enabling all the segments with varying customer needs to be served with only three distribution boards. The distribution-board architecture also set down some design parameters, which needed to be taken into account when engineer- ing new product options and even some solutions that needed to be engineered based on a specific customer order. Thus, within the R&D program, component commonality was not only a predefined limitation, but rather a source of innovations needed to facilitate the operations of the company; it was later used as input for additional projects within the program. Component-commonality innovation was not exactly one specific, innovative piece of technology, but rather a burdensome process of R&D and change in the Company’s operational mode.

“Our commonality-enabling innovation is not one single component, but rather a sum of many choices.” (Electrical engineer)

Supporting the Program with Ex-Ante Cost Information

The participating researchers helped the Company to prepare ex-ante cost analyses for estimating the possible cost implications resulting from the program-level development of common distribution boards. The researchers developed a spreadsheet to keep record of the estimated cost implications at the component level, updated systematically as the process unfolded. Table 1 summarizes the basic idea of the cost analyses provided for the Company’s R&D management during the development process.

Section 1 in Table 1 shows the direct material costs for the distribution boards in each segment before and with the new architecture. The material cost for the distribution boards used before is the average cost of the distribution boards used for each segment during the past year, whereas the cost for the distribution boards based on the new architecture is based on component prices provided by the suppliers. Furthermore, with regard to the new distribution boards, the material cost is divided between the common distribution-board platform and the segment-specific electrical components (Electrical Component 1 and Electrical Component 2). In addition, whenever the assembly work for the distribution board was outsourced, a 10% material overhead was added on top of the materials cost. As shown in Table 1, the direct material costs of the high-volume segment remained the same, whereas the direct material costs of the second segment increased from US$1,800 to US$2,700. Indeed, the components needed for managing a certain voltage range in Segment 2 turned out to be rather costly, especially taking into consideration the need for flexibility. With regard to Segment 3, the direct material costs came down almost 30%; however, this was mainly because of the development work for the platform itself and not for the commonality aspect. This, therefore, provides an interesting anecdote illustrating the “embedded nature” of the cost implications of component commonality. The most important cost reduction in terms of direct costs was only in one segment and based primarily on the platform development needed for the commonality in the first place. The cost benefits in direct materials were based on the real price levels provided by the suppliers and are well validated; the potential economies of scale in terms of volume discounts, however, were not known when the ex-ante cost analysis was prepared. Interestingly, the potential volume discounts emphasized in the existing component-commonality literature were not considered significant by those involved.

Section 2 in Table 1 summarizes the discussions regarding the direct cost implications of the new distribution-board architecture on the labor costs. The new architecture enables the assembly work of the distribution boards in Segments 1 and 2 to be completely outsourced. The impact on the labor cost with these two segments is based on the quotations provided by the subcontractor specializing in electrical assembly work. It is important to note that the outsourcing of the assembly work was previously possible only partially with Segment 1 due to the complexities related to the constant changes resulting from the engineering-to-order operations mode. There was an assumption that the reduction in the distribution-board bills-of-materials would enable some learning-curve effects to be harnessed later, although these speculations are not included in Table 1.

When looking at the total direct costs of each distribution-board version (Section 3 in Table 1), Segment 1 shows a slight decrease, whereas the changes in the other two segments are much more significant; Segment 2 shows an approximate 50% increase, whereas Segment 3 is about a 23% decrease. The analysis becomes interesting when the total direct costs of the old and new ways are calculated by multiplying the direct cost of each distribution-board version with the annual volume (Section 4 in Table 1). The amounts need to then be totaled (at the annual level with the segments combined, Section 5 in Table 1). The calculation now shows a slight increase in the total direct costs (about US$50,000). In this sense, the case is in line with most of the component-commonality literature emphasizing the cost of over-specification. At the same time, however, the impact of the over-specification is relatively small compared with, for example, a situation in which all the segments needed an over-specified common component as costly as the most costly one; in other words, the one for the second segment. Furthermore, the cost increase is rather small (only about 3%), containing only those direct cost implications that could be taken into account without speculation; any speculations regarding volume
discounts and the learning-curve effect would rather quickly break even the cost calculation, even in terms of the direct costs.

Finally, Table 1 shows the engineering needed for each distribution board with the old engineering-to-order operations mode and with the new architecture (Section 6 in Table 1). Theoretically, it would be nice to state that, with the common distribution boards, the need for such customer-specific engineering is completely eliminated; however, at least initially, it will be necessary to go through the electrical systems to ensure that no mistakes have taken place in the development process for increased commonality. Thus, the ex-ante cost analysis was used to undertake some sensitivity analyses to understand the necessary cost reduction needed in the engineering work to compensate for the slight increase in the direct costs caused by the over-specification needed for Segment 2. Eventually, when the annual volumes were also taken into account and summed up with the direct costs (Section 7 in Table 1), it was concluded that an approximate 50% cost reduction in the engineering work would compensate for cost of the over-specification calculated above.

It is important to note that this ex-ante cost analysis does not take into account the speculative changes resulting from the learning-curve effects of the supplier or the possible economies of scale in procurement; while, at the same time, the engineering work needed for each machine will also provide potential for cost reduction. The ex-ante calculations discussed above were openly shared with the engineers and managers involved in the R&D program and iterated with them. The ex-ante cost analysis prepared by the researchers, following more or less the logic discussed above, enabled the R&D program managers to communicate to the top management that component commonality would not—as feared by many stakeholders—result in a significant increase in the direct costs. Thus, the managers of the R&D program mainly used the calculations to show that the innovations made for the development of the common distribution board kept the direct costs more or less constant while still providing potential for cost reduction through simplification of the operations, thanks to the slight shift toward the assembly-to-order operations mode.

The fact that the ex-ante cost analysis described above was, indeed, used to argue for the benefits and potential of the program to top management shows that the managers involved in the R&D program considered it valid enough for decision-making purposes. It is important to note, however, that the ex-ante cost analysis was not prepared to prove whether or not component commonality provides cost benefits, but rather to show that it does not contain—when done innovatively as a part of an R&D program aiming at product renewal—any cost-related risks. Most of the cost benefits would then follow later through the simplification of the operations, learning-curve effects, volume discounts, a faster order-delivery cycle, and even increased flexibility in the production. This flexibility would be seen when a change asked for by the customer for a certain machine during the production process could be more easily adapted to by the Company.

Discussion

How Can Multiproject Management Take Advantage of Component-Commonality Innovation?

Component-commonality innovations with cost and profitability implications are made in single projects, respectively, but their value is harvested within larger multiproject operations. Indeed, component-commonality innovations are a central point for creating value when organizational objectives aren’t aimed at standardized products, but more at standardized operational models. As in the Company’s case, a shift from the engineering-to-order toward the assembly-to-order mode was targeted by more standardized electrical components; developing these common components was, however, a task that required innovation; this innovation was realized as part of an ongoing R&D program. The cost implications and value of such component-commonality innovations aren’t well known in the scientific literature; hence, the value of a component-commonality innovation as a part of R&D needs to be examined in the context of multiproject management.

The program value introduced here, stemming from an individual component-commonality innovation within an R&D program is intended to underline the importance of single projects affecting a larger multiproject operation (continuing the work by, e.g., Korhonen et al., 2014; Martinsuo et al., 2014; Petit & Hobbs, 2010). Specifically, this article provides practical hints for the management of customization and component selection within multiproject management (Maniak & Midler, 2014; Petit & Hobbs, 2010). In fact, this study highlights the importance of component-commonality innovation in the engineering-to-order context, but does not dictate that only the engineering-to-order context could benefit from such innovation. It is possible that, also in the make-to-stock and assembly-to-order contexts, component-commonality innovation creates value in financial terms, even in terms that cover the cost of the over-specification often associated with component commonality. This is something that future studies could delve into, for example, by examining innovations needed to develop common components within R&D in the automotive industry.

The Company’s case shows that sometimes component commonality requires innovation (such as architectural platform development and technological problem solving) to even be possible. This innovation takes place in R&D, often organized as projects.
or multiproject programs. The issue of cost (or value) implications of common components has been brought up in the multiproject management literature (e.g., Maniak & Midler, 2014). There is still room for more detailed examinations of the actual mechanisms and management of value creation stemming from the process of component design and selection (Labro, 2003, 2004), which, especially within multiproject operations, sometimes requires remarkable innovativeness and product-development effort to reach the objectives set for a specific component-selection situation. Indeed, as our case study shows, component commonality is not only a limitation of innovativeness in multiproject R&D (as in Maniak & Midler, 2014), but also a source of innovation itself. The findings of this article suggest that component-commonality innovation affects the value and management of multiproject operations and vice versa. The component-commonality innovation in this article took place within a project that was part of a multiproject program. The engineers for this project needed to develop a common distribution-board platform. In this distribution-board development project, component commonality was not a predetermined limitation (as in Maniak & Midler, 2014), but rather the source of innovation. Although the component-commonality innovation (i.e., the common distribution-board platform) could potentially result in strategic goal achievement and value (flexibility and profitability in the Company’s order-to-delivery process due to a planned change from the engineering-to-order to assembly-to-order mode), the common platform was also viewed as a limitation for upcoming projects. In the projects to come after the common distribution-platform development project, the common platform would possibly be a limitation that could set boundaries for extensions, such as potential new product features demanded by the Company’s customers.

The Company’s case, along with our literature review point out that there is a need to identify specific needs for common components to harvest value at the program level. Importantly, this harvesting of value can take place either by setting limitations for product extensions (as in Maniak & Midler, 2014) or by innovation that provides common components that break existing modes of operation, possible conventions of bills of materials, and generate multiplicative effects by removing bottle-necks, which leads to increased production capacity (as in our case study). By showing both roles of component commonality in multiproject R&D (i.e., a source and limitation of innovation), this contribution extends Maniak and Midler’s (2014) line of inquiry.

Respectively, objectives for value and for costs need to be set for single projects within R&D programs to understand what is actually sought from component commonality, and hence from component-commonality innovation. It is also important to understand that such component commonality and the innovation required will bring uncertainty into multiproject management (as in Korhonon et al., 2014; Martinsuo et al., 2014; Petit & Hobbs, 2010). If a common component is not a limitation or a starting point for innovation, but innovation itself, uncertainty can be expected; we expect that this uncertainty will lead to uncertainty about the attainment of program-level strategic benefits as well. This expectation is justified, because the implications of component commonality are embedded in complex operations that depend on the context studied. Take, for example, the change from the engineering-to-order to assembly-to-order mode of operations: this kind of a change does not happen overnight, nor is this change solely dependent on single components in complex high-tech companies. Indeed, based on our results, we argue that cascading component-commonality innovations will more likely lead to change in the operational mode; this result, however, should be tested in future studies.

On the managerial side, rather than trying to optimize the number of components in one functionality of a product or trying to deal with the commonality of single components as an island, managers in complex high-tech businesses might find use in cascading numerous value-adding component commonalities. In other words, practitioners need to make sure that component commonality is coordinated at the program level when R&D projects are organized in programs. The development of common components needs to be coordinated at the multiproject level, because it is essential that single component development efforts drive the production system toward the same, targeted direction; otherwise synergy will be less likely. When R&D projects are more distant from each other, component commonality needs to be coordinated at the portfolio level. This coordination will likely limit innovation, but is a necessity to harvest large-scale benefits stemming from the change in operational mode (such as from the engineering-to-order to assembly-to-order mode)—leading to benefits from synergy between projects (Aubry et al., 2007; Maniak & Midler, 2014; Mäkinen et al., 2014; Meskendahl, 2010; Verma & Sinha, 2002). Overall, this study paves the way for project, program, and project portfolio research that addresses the viewpoint of technological innovation in single projects, and how this innovation affects the larger entity of a firm’s complex multiproject operations.

What Kind of Influence Does Component–Commonality Innovation Have on the Value and Management of Multiproject Operations?

As an implication for research on component–commonality innovation, we argue that component innovation might need to exist before costs can be optimized or before it is useful to calculate these costs. We argue that this might be the case more so than is examined in
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the prior literature. In our case, component–commonality innovation (i.e., the common distribution-board platform with respective changes in the product architecture) made it possible for the Company to serve its three customer segments more flexibly than before. Without the innovation, it would have been too early to estimate the strategic benefits and value attained from a common platform; the innovation needed to take place first before detailed cost calculations could be made.

Moreover, costs were not optimized in the Company’s case; it was enough that component commonality did not change direct costs significantly within certain error margins. After reaching this suboptimal but favorable level of component commonality, the Company now advanced to search for new bottlenecks in electrical components. The amount of commonality and the attained value were adequate for the Company, so the firm went on to harvest benefits elsewhere (this was not within the scope of our research access).

Limitations and Future Research

Building on the idea of cost and profitability estimation in the case study, management accounting might be one of the most important organizational functions in calculating and visualizing value (as in the Company) to show that sufficient benefits could be obtained (once a component commonality innovation is made). Thus, there is still room for research on the social aspects and dimensions of component commonality, and respectively, the prerequisites for commonality innovation to emerge. This study opens up a potential line of inquiry that attempts to understand the relationship between innovation, multiproject R&D management, and component commonality. Based on our case study, we show that the engineering-to-order context, component–commonality innovation and its strategic value are linked to a change in the operational mode (from engineering-to-order toward assembly-to-order). More inquiries need to be undertaken, however, to understand more thoroughly which factors drive, hinder, and result from component–commonality innovation in other contexts (such as assembly-to-order and make-to-stock). Such studies would potentially cover the importance of approaching component commonality from the directions of incremental and radical innovation—the former being the mindset often seen in previous commonality literature and the latter being what we believe our case illustrates.

The Company case shows that the number of components itself might not drive cost implications, but cost implications can be driven by multiple other aspects, such as innovation and a change in operational mode. Developing common components incurs costs in R&D, and common components might not be simply over-specified. Over-specification of components might require innovation capabilities; hence, we propose there might also be a place for research that disregards the previous research in which the number of components is a cost driver, and starts more with a tabula rasa regarding what is involved in the cost implications of component commonality. We stress that disruptions in the operation environment—also due to a commonality decision itself—might hinder predicting the outcome of a commonality effort.

Indeed, managers in real life seek to gain an understanding of when, how, and as a part of which other decisions it is profitable to increase component commonality. Component commonality is realized as part of and in line with a larger entity of a firm’s multiproject R&D operations, not separately from other decisions and environmental changes (Lyly-Yrjänäinen, 2008). Thereby, with disruptions within a context possible, in component–commonality decisions as well, we need to admit that straightforward optimization, in particular with inadequate premises, hardly captures the requirements of technological developments, unequivocality of stakeholders, ambiguousness of cost implications, or many of the other complex facets in the diversity of real-life industrial manufacturing. In order to capture some of that complexity, future research is called for to study the dynamic role of and emphasis on decision-making tools (i.e., calculations, models, and so forth) in making the commonality decisions that, in any case, have the potential to influence multiproject R&D more widely.

Our account on the embeddedness of component commonality in the Company is an effort to understand the decisions in accordance with which component commonality was realized in one environment. Indeed, we interpreted that commonality was not possible until a component–commonality innovation was discovered. We also inferred that the Company’s engineers did not base their decisions and communication solely on the calculations presented. Rather, organizational policy and time limitations of the wider R&D program guided the engineers’ actions. For the embeddedness of component commonality, we also see implications for further research. The embeddedness of component commonality could imply that researchers might be interested in understanding what particular cost implications or optimization mean or are in a different context more broadly. Future research on component commonality might thus be asking questions, such as: “How is commonality optimization embedded in project, program, or portfolio management?” Moreover, as component commonality is embedded in R&D activities and platform development, commonality researchers might be interested in what management control means within component commonality.

Conclusions

In summary, our empirical evidence gathered from an engineering-to-order context provides an illustration that contributes to research on multiproject
R&D management and component commonality. The previous literature has not focused on truly discussing these aspects, although the research on multiproject management acknowledges the aspect that customer-driven customization within single projects influences project portfolios (Petit & Hobbs, 2010). Issues of commonality are of importance in multiproject (lineage) management (Maniak & Midler, 2014; Midler, 2013), and technology transfer between projects occurs (Nobeoka & Cusumano, 1995, 1997). Vice versa, component commonality has organizational impacts (Lyly-Yrjänäinen, 2008), although this aspect hasn’t been adequately addressed in terms of project portfolios in the component-commonality literature. There has also been too little understanding of the actual mechanisms through which component commonality has cost implications (Labro, 2003, 2004). By providing empirical evidence of the direct cost implications of component-commonality innovation, which is mainly unclear in the extant knowledge base, we wish to give insights with the potential to elaborate the research on component commonality as part of a firm’s wider multiproject R&D and as being influenced by incremental and radical innovation. Through our contribution, which shows component commonality as both a source and limitation of innovation in multiproject R&D management, we specifically hope to stimulate research that will examine and test this extension in different contexts. Such research could be of a qualitative or quantitative nature. Based on our results, we make three propositions for researchers to address:

**Proposition 1:** Component commonality can have a dual innovation role in multiproject R&D, acting both as a source of innovation and as a limitation for innovation.

**Proposition 2:** Technology synergies from multiproject R&D require a detailed examination of cost implications on a case-by-case basis; component commonality is one example of this kind of a synergy.

**Proposition 3:** Multiproject-management models need to take into account the dual role of component-commonality in multiproject R&D in order to harvest technology synergies (related to common components).

Finally, further research on the social and technical prerequisites for component-commonality innovation is still needed in order to bridge the more qualitative characteristics of commonality (such as innovation and uncertainty), with those models that are more quantitative in nature (such as the number of components and costs).

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Innovation for Multiproject Management


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Tuomas Korhonen received a DSc (Tech.) in Industrial Management from Tampere University of Technology (TUT), Finland, in 2014. He works as a postdoctoral researcher in the Cost Management Center (CMC) at TUT and has published in high-quality academic journals, including *Project Management Journal*, *International Journal of Project Management*, and *Journal of Management and Governance*. His research interests lie in studying management accounting in relation to actual managerial work and decision making, and in conducting interventionist research within real-life organizations. He can be contacted at tuomas.korhonen@tut.fi

Teemu Laine received a Dr. (Tech.) in Industrial Engineering and Management in 2009 and completed his dissertation focusing on the infusion of services into manufacturing. Teemu has published in high-quality academic journals, including *International Journal of Project Management, Managing Service Quality*, *Project Management Journal*, and *Journal of Management and Governance*. Currently, he works as Research Team Manager for the Cost Management Center (CMC) and Assistant Professor (tenure track) at Tampere University of Technology (TUT), Finland. His current research interests include management accounting in service business and R&D management contexts. He can be contacted at teemu.laine@tut.fi

Jouni Lyty-Ryjänäinen works as a University Lecturer in Tampere University of Technology (TUT), Finland. His dissertation (2008) focused on the cost implications of component commonality in engineering-to-order contexts, and he also has several patents related to the area. In his research, Jouni has focused on interventionist management accounting research, published in *Management Accounting Research* and also by Routledge (*Management Accounting Research in Practice: Lessons Learned From an Interventionist Approach*). In addition to interventionist research, his current research interest focuses on the use of cost and profitability information in sales and marketing. He can be contacted at jouni.lyty-ryjanainen@tut.fi

Dr. Petri Suomala is Professor of Profitability Management and Management Accounting in Tampere University of Technology (TUT), Finland. He is the Dean of the Faculty of Business and Built Environment and co-founder of Cost Management Center (CMC) research team at TUT. Suomala has published in several international top-tier journals, including *Management Accounting Research*, *Industrial Marketing Management*, *Technovation*, *International Journal of Innovation Management*, *International Journal of Production Economics*, and *Accounting and Business Research*. He is author of several books and book chapters on management accounting and interventionist management accounting research published by Routledge (*Management Accounting Research in Practice: Lessons Learned From an Interventionist Approach*) and Springer ("Customization of Capital Goods: Implications for After Sales,“ in: *Moving into Mass Customization: Information Systems and Management Principles*). His research interests relate to the versatile utilization of management accounting in industrial companies and other organizations. He is particularly experienced in life-cycle costing and the long-term evaluation of organizations’ performance. He can be contacted at petri.suomala@tut.fi
ABSTRACT

Researchers have long recognized that standard approaches to project management are ill-suited to address changes in the environment or business needs, particularly in innovative contexts characterized by uncertainty and complexity. Instead of being concerned with the efficient implementation of a deliberate strategy, a project in such a context becomes a process for strategy formulation. Three imperatives for project management arise as a result: managing the explorative phase, managing the involvement of stakeholders in the project, and managing the project in relation to the strategizing process of the firm. We propose that design thinking, a recent evolution in the field of design, can make some important contributions to these imperatives. Design thinking has been highlighted by practitioners as well as academia as a novel methodology that is potentially valuable for improving innovative outcomes, whether they are products, services, or strategies. We examine and articulate these possible contributions through 10 propositions that could form an agenda for future experimentation and empirical research on innovation project management.

KEYWORDS: project management; design; innovation; uncertainty; design thinking

INTRODUCTION

The literature and professional guidance on project management have long remained rooted in a mechanistic paradigm of control, explicitly assuming that project management only begins once the requirements are defined. In this paradigm, project management is a set of concepts, tools, and techniques on how to execute projects on time, within budget, and to required customer specifications within the context of an explicit company strategy (Morris, 2013).

This approach to project management is ill-suited to address changes in the environment or in business needs (Morris, 2013; Shenhar & Dvir, 2007). Researchers (Brady & Davies, 2004; Brady, Davies, & Nightingale, 2012; Lenfle, 2008; Loch, De Meyer, & Pich, 2006) point out that in innovative contexts where uncertainty is prevalent, such as in large and complex projects or new markets, this approach results in poor performance. In such contexts, problems are initially ill-structured and neither technologies nor customer requirements are necessarily known at the start. Hence, the basic assumptions of standard project management do not hold. This is particularly problematic, because in a world characterized by rapid change, intensive innovation, and increasing complexity, such uncertain contexts are becoming the norm rather than the exception.

Therefore, in such contexts, the role, the basic assumptions, and the purpose of project management are fundamentally redefined: From the efficient implementation of a deliberate strategy, the project becomes a process for strategy formulation. From operative, it becomes creative.

Three streams of work have emerged in the project management literature to redefine project management in such contexts: (1) A first stream has highlighted the importance of an exploration phase in projects to allow requirements and specifications to emerge through learning and trial and error (e.g., Atkinson, Crawford, & Ward, 2006; Lenfle, 2008); (2) a second stream has highlighted the critical role of stakeholders and the need to mobilize them to build the political context in which the project will develop (Eskerod, Huemann, & Savage, 2015; Eskerod & Vaagasaar, 2014; Morris, 2013); and (3) a third stream has highlighted the need to link project management to firm strategizing by, for example, replacing project management within the broader concept of knowledge creation through multiproject portfolio selection approaches (Arto & Kujala, 2008; Cooper, Edgett, & Kleinschmidt, 2001; Korhonen, Laine, & Martinsuo, 2014; Midler, 2013; Midler & Silberzahn, 2008; Petit & Hobbs, 2010; Teller, Koch, & Gemuenden, 2014).
Yet, relatively little work has been done on the practical approaches and tools that should be used in this renewed perspective. We argue in this article that recent developments in design theories and practice, especially design thinking, can address this gap and make a valuable contribution.

Design thinking has been highlighted in practitioners’ publications (e.g., Brown, 2009; Kelley & Littman, 2006; Liedtka & Ogilvie, 2011; Martin, 2009) as well as in academic ones (Glen, Suciu, & Baughn, 2014; Gruber, de Leon, George, & Thompson, 2015; Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013; Liedtka, 2014; Seidel & Fisson, 2013) as a novel methodology and a potentially valuable practice for improving innovation outcomes, whether those outcomes are products, services, or strategies. Design thinking is a structured process of exploration for ill-defined problems. According to Lockwood (2009), it is “a human-centered innovation process that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis.”

Its practice and thought process aim to bring designers’ principles, methods, and tools to management and business strategy (Brown, 2008). We intend to illustrate how design thinking can provide project management with new perspectives for addressing innovation challenges; by doing this, we highlight and address the following gap: both fields have experimented parallel trajectories and yet did not engage in any conversation despite the proximity of the questions addressed. Both fields emerged from practice. Project management has now developed into an academic field of its own, and design thinking is following the same path. Although most articles developing theory on design are still found mainly in design journals, articles on the topic have started to appear in management journals such as the Journal of Product Innovation Management, Creativity Innovation Management, and the Academy of Management Journal. Design thinking has been attracting the interest of management scholars only since the beginning of the 2000s (Johansson-Sköldberg et al., 2013). In fact, 80% of management publications that mention the term design thinking in their abstracts date from after the year 2000.

Design thinking and project management are both evolving rapidly as transformation factors and processes in firms and the economic landscape change. Both fields are anchored in a practice characterized by methods and tools, but they are moving beyond that operational perspective toward a strategic one. Academics and practitioners view the two fields as a way to manage organizations: managing by projects and managing by design. They are both highly associated with knowledge workers: Designers and engineers are either integrated within a firm or act as independent consultants. In both cases, professional associations play a critical role in the development and diffusion of the practice. Both design thinking and project management are integrative approaches and both claim to enhance and improve organizational outcomes as related to innovation.

Such dynamics create opportunities for fruitful cross-learning between the two fields in terms of tools and methodologies. As project management more and more comes to address creative issues in the upstream of projects, design approaches can be mobilized. As the design field grows from being centered on individual creative tasks to engaging in collective design through small teams and incorporating more strategic innovation issues as part of the firm’s scope, its contribution to multi-project and firm levels develops as well.

Yet despite these similarities and the potential for mutual learning between the two fields, one finds no cross-references between them. The few articles in project management peer-reviewed journals (e.g., International Journal of Project Management, Project Manage-
between sectors were perceived as less important than common values such as meeting tight deadlines, coordinating a large number of contributors, controlling costs, and so forth (Söderlund & Lenfle, 2013). The model involves methods and techniques that were mainly developed and mastered by engineers (Pinney, 2001; Scranton, 2015). It distinguishes between two main phases: planning and implementation. Planning consists of a specific delimitation of the project scope: the tasks, the resources required, the budget, the scheduling, the risks, and so on. Implementation involves the identification of deviations from the planned budget and schedule using a set of measures (task execution and earned value management). In the project management view, resources should be optimized for a stated goal, and clearly defined specifications are assumed not to change during the course of a project.

This approach to project management, which is based on a predictable, relatively simple, and rational model, is largely decoupled from changes in the environment or in business needs (Morris, 2013; Shenhar & Dvir, 2007) and has been challenged by researchers, who observe that in contexts where uncertainty is prevalent, such as large projects or new markets, it has resulted in poor performance. This is because in such contexts, problems are initially ill-structured and neither technologies nor customer requirements are necessarily known at the start, so the basic assumptions of standard project management do not hold. In today’s world, characterized by rapid change, intensive innovation, and increasing complexity, uncertain contexts are becoming the norm rather than the exception.

Projects and Exploration

Klein and Meckling (1958) highlighted the limits of the project management’s optimization perspective with projects in uncertainty. Midler (1995) and Lundin et al. (2015) pointed out that for projects in an uncertain situation, management is about balancing learning about the project with executing decisions through in a limited time process. Turner and Cochrane (1993) suggested that projects should be distinguished on the basis of how well the goals and the methods of achieving them are defined. In the specific case of product development projects, Clark and Wheelwright (1992) argued for the necessity of adapting project management methods according to the extent of change in product and process.

Boutinet (2004) characterized projects as a specific human way of dealing with future and uncertain actions, and showed how the project approach could be applied to many different domains of human activity, from construction and industrial projects to social and political ones. Acknowledging this diversity, contemporary research on project management (Loch et al., 2006; Shenhar, 2001) criticized the one-size-fits-all approach. Shenhar and Dvir (2007) proposed a typology of projects based on novelty, technology, complexity, and pace, highlighting the innovation dimension.

Loch et al. (2006) and Lenfle (2008) went beyond the classification perspective and suggested specific project management methods for projects with high uncertainty—that is, “exploration” projects, for which neither technologies nor customer requirements are known at the start. Exploration projects, referred to by Atkinson et al. (2006) as “soft” projects, are characterized by experimentation in uncertainty, and their primary objective is knowledge creation.

Lenfle (2008) showed how this type of project challenges the standard “rational” view of project management as the accomplishment of a clearly defined goal in a specified period of time and within budget and quality requirements in five distinct ways: (1) Exploration projects are emerging and strategically ambiguous; (2) there is no explicit demand and therefore no clearly identified client; (3) there are no specifications, nor a clearly defined objective at the start of the project; (4) the team will have to explore and develop new knowledge; and (5) these projects have a specific temporality that mixes objectives to be achieved on short term as well as long term horizon. There are necessarily managerial implications for such projects. Lenfle (2008) pointed out that: (1) Experimentation and concurrent exploration play a central role, as opposed to scheduling and task breakdown, which are impossible with constantly changing objectives; (2) there are two different dimensions of performance (the value of the products and the accumulated knowledge explored) to take into account (Maniak, Midler, Lenfle, & Le Pellec-Dayron, 2014); and (3) a reformulation of the objectives is allowed along the way. Broadly speaking, in this context, project management moves toward an approach that is much more creative and open-ended than optimizing. But little conceptual work has been done in the project management field to define how this might be done.

Project Strategy and Project Stakeholder Management

As the previous section has suggested, an important development in the project field is the enlargement from an engineering view to a broader business and strategic perspective. In general, as a result of a recent reorientation of strategy research on the everyday activities of strategists (Jarzabkowski & Spee, 2009), there is a need for research to provide intellectual ground for bringing strategizing and project management closer together. Projects may constitute the action needed to realize intended strategies. The need to improve the link between projects and strategy is highlighted by recent research (e.g., Cattani, Ferriani, Frederiksen, & Täube, 2011; Kaplan & Orlikowski, 2013; Manning & Von Hagen, 2010; Sicotte, Drouin, & Delerue, 2014).

This development of strategy in project management has two different implications. The first is the need to
introduce a strategy perspective into the management of a single project. Arto and Kujala (2008) show that, depending on its situation in the environment, a project cannot always be the vehicle for implementing its parent strategy. In a complex environment with an unclear governance scheme (especially for megaprojects), a project’s strategy is self-originated and related to its own governance (Floricel & Miller, 2001; Flyvbjerg, Bruzelius, & Rothengatter, 2003; Miller & Lessard, 2001).

The ongoing development of the literature on project stakeholder management (Eskerod et al., 2015; Eskerod & Vaagaaas, 2014; Eskerod & Jepsen, 2013; Jepsen & Eskerod, 2009), and project governance (Miller, 2012) within the academic project community reflects such “upstreaming” dynamics of project management to strategic issues.

**Project Business and Projectification to Address Strategic Issues**

The second implication is the recognition of the importance of projects and project management to the business strategy of firms or modern organizations. In fact, projects are the core business matrix for many sectors, such as construction, consulting, and engineering. In mass-production sectors such as manufacturing, innovation-based competition creates a context where the number of projects increases their importance as a strategic capability.

Since the 1990s, the development of the project management field has expanded beyond the project manager-centric and single-project approach to a perspective where projects are managed within organizations and society (Lundin et al., 2015; Morris, 2013). Morris’s (1997) book, Lundin and Söderholm’s (1995) paper on temporary organizations, and Midler’s concept of the projectification of the firm (1995), as well as the literature on complex projects (Hobday, 2000; Miller & Lessard, 2001) and project business (Arto & Wikström, 2005; Davies & Hobday, 2005), all constitute landmarks in this domain. They analyze how project-based firms are structured to cope with project business specificity (Söderlund & Tell, 2009, 2011).

This perspective goes beyond the project to address links between projects (which are temporary) and the permanent organization. Research addresses the connection between the management of projects and a firm’s strategy with developments such as program management (Maylor, Brady, Cooke-Davies, & Hodgson, 2006) for better multiproject coordination, organizational learning within and through projects (Brady & Davies, 2004; Lundin & Midler, 1998; Schüßler, Wessel, & Gersch, 2012), and project management offices (Hobbs, Aubry, & Thuillier, 2008). The concept of project lineage management, inspired by CK design theory (Le Masson, Weil, & Hatchuel, 2010) was introduced (Midler, 2013; Midler & Sibertz, 2008) to address the issue of managing a sequence of projects associated with a firm’s strategizing process.

**Conclusion**

We identified three streams of work that have emerged in the recent project management literature to improve project management in innovative contexts: (1) A first stream has highlighted the importance of an exploration phase in projects to allow requirements and specifications to emerge during the life of the project through learning and trial and error; (2) a second stream has highlighted the importance of the stakeholder dimension and the need to mobilize stakeholders to build the political context in which the project will develop; and (3) a third stream has highlighted the need to link project management to strategizing at the firm level.

These three streams, however, lack effective methodologies, tools, and professional attitudes that could enable the implementation of these recommendations. In the following section, we examine how the field of design can help address this lack.

**Design Thinking: From a Problem-Solving Method to an Innovation Capability**

In the following sections, we examine the field of design with a focus on one of its recent developments, design thinking, because of its ambition to contribute to the field of management in general.

**Design as the Field of Innovation**

According to Simon (1969), design is the process by which we devise courses of action aimed at changing existing situations into preferred ones through the creation of artifacts—objects created by humans through creative reasoning. Design is concerned with innovation: It is the science of the artificial (Simon, 1969). In this sense, it is different from other cognitive approaches such as decision making because it requires us to define the options among which the choice and the optimization is realized.

For a long time, design was considered the creative activity whose aim was to determine the formal qualities of manufactured objects (Maldonado & Cullars, 1991). Loewy renewed this perspective by emphasizing the functionality dimension through industrial design. The Bauhaus (Droste, 2002), a landmark in the academic field of design that was founded in 1919 by Walter Gropius, is generally considered the birthplace of design that went beyond the pure aesthetic and artistic perspective. It was based on the union of all arts and crafts, Gropius developed a craft-based system of teaching that aimed at developing skills, resulting in the creation of useful and beautiful artifacts for mass-production products that achieved functional and aesthetically satisfactory design. In Gropius’s thinking, designers were to integrate the materials and colors as well as the artistic, the visual dimension, and, progressively, the technology. They were encouraged to produce their own creative designs based on their subjective perceptions. Though the Bauhaus school existed for only 14 years, it had...
Contributions of Design Thinking to Project Management in an Innovation Context

a strong influence on design and structured the field’s future practice.

Beyond form, aesthetic, and functionality, design is also about sense-making and meaning: “Something must have form to be seen but must make sense to be understood and used” (Krippendorff, 1989, p. 14). Hence, to design is to make sense of things (Vergantl, 2009).

Design moved progressively from the world of products to other situations that involve humans and require the understanding of their behaviors, attitudes, and emotions. Therefore, the outcome of a design process can be a graphic, a shape/form, a product (tangible or intangible), a system, an interaction, an interface, or an experience. Whatever the outcome is, it is designed to solve a problem and answer any dislikes experienced by users.

Design methods can be compared to and contrasted with the models of reasoning and the processes adopted by engineers in their own design activities (Chakrabarti & Blessing, 2014), such as parametric design, rooted in the German engineering community for complex machines, and systematic design (Pahl & Beitz, 2006) for “science-based products” such as electrical machines (Le Masson et al., 2010). They suggest a sequential process: an initial step to clarify the task, a second phase of conceptual design, a third phase of “embodiment,” and a last step of detailed design (Ulrich & Eppinger, 2004). This rigorous sequencing can be seen as a way to focus on the specificity of the problem to be addressed—in other words, complex assembly designing. Increasingly, however, engineers have to deal more and more with ill-defined problems characterized by high uncertainty (related to either technology or the market), such as with smart cities or electrical vehicles. Le Masson, Hatchuel, and Weil (2011) designate these situations as “innovative design situations” that require a specific design process that acts as an interplay between two spaces: the space of concepts (C) and the space of knowledge (K) (Hatchuel & Weil, 2002, 2009). This design theory (CK) goes beyond traditional problem-solving models by proposing an analytical formalism for open-ended exploration reasoning, where knowledge as a space for exploration expands during the process. This relatively recent theory has rapidly expanded within the engineering design academic community and has generated applied developments in various sectors of industry (Chakrabarti & Lindemann, 2015; Le Masson et al., 2010).

Defining Design Thinking

Simultaneously to the development of this design theory (CK), design thinking originally developed with the objective of “bringing designers’ principles, approaches, methods, and tools to problem solving” (Brown, 2009). However, design thinking has conceptual foundations. It was opposed to linear and analytical problem-solving approaches that are unlikely to resolve “wicked” problems (Rittel, 1972) that lack both definitive formulations and solutions and are characterized by high uncertainty and ambiguity. These situations require an uncertainty reduction strategy that can be achieved through a learning-focused, hypothesis-driven approach (Beckman & Barry, 2007; Owen, 2007; Schön, 1982); this learning associates abstract reasoning with action in order to launch a “reflective conversation with the situation” (Schön, 1982).

According to Liedtka (2014), design thinking “is a hypothesis-driven process that is problem, as well as solution, focused. It relies on abduction and experimentation involving multiple alternative solutions that actively mediate a variety of tensions between possibilities and constraints, and is best suited to decision contexts in which uncertainty and ambiguity are high. Iteration, based on learning through experimentation, is seen as a central task.”

Design thinking simultaneously addresses the desirability of the solution, its technical feasibility, and its viability—that is, its ability to be converted into customer value and market opportunity (Brown, 2008). According to Brown (2008), design thinking is a system of spaces rather than a predefined series of orderly steps. Design projects pass through three spaces: inspiration, ideation, and implementation. Projects will loop back through these spaces—particularly the first two—more than once as ideas are refined and new directions taken.

For Lockwood (2009), design mobilizes diverse and practical approaches such as observation, collaboration, fast learning, the visualization of ideas, rapid concept prototyping, and concurrent business analysis. Finding needs and dislikes especially relies on a variety of ethnographic research techniques, such as participant observation, job-to-be-done analysis, and journey mapping. Following Liedtka (2014), we will focus on three phases that occur iteratively in cycles: (1) an initial exploratory phase focused on data gathering to be inspired, identifying user needs, and defining the problem as a hypothesis to be explored; (2) a stage of ideas and concepts generation; and (3) prototyping to experiment and implement the concepts proposed as an answer to the hypothetical problem. Table 1, inspired by the work of Liedtka (2014), presents the common design thinking tools and the tasks they achieve.

Design thinking moves design upstream in the innovation process and involves players other than designers, such as users and other stakeholders. It aims to go beyond the design of artifacts and to contribute to the organization’s strategy. It is, therefore, of interest to all managers (Lafley, Martin, Rivkin, & Siggelkow, 2012; Liedtka, King, & Bennett, 2013; Liedtka & Ogilvie, 2011; Martin, 2009).

The Three Perspectives of Design Thinking

From the literature, design thinking can be presented through three
The first relates to decision makers’ inability to see beyond themselves and escape their own pasts (projection bias), their current state (hot/cold gap), and their tendency to be unduly influenced by specific factors (focusing illusion). Collecting deep data and improving the ability to imagine the experiences of others can help mitigate this category of biases.

The second category relates to the inability of users to articulate their future needs and provide accurate feedback on new ideas, making it difficult to develop value-creating ideas for them (say/do gap). Through journey mapping and participant observation, for instance, design thinking helps improve users’ ability to identify their own needs.

Finally, the third category of biases relates to flaws in decision makers’ ability to test the hypotheses they have developed. By working with multiple options and reflecting on the results of real experiments, design thinking can help mitigate such biases.

Organizational Perspective
Design is not just a cognitive activity; it is also a collective one that involves and accommodates the participation of different stakeholders. These stakeholders may be internal (within the team or the company) or external. Hence, the social dimension is critical for design. Krippendorff (2006) observes that design relies on two types of intertwined understanding: of the artifact being proposed and of stakeholders’ understanding of this artifact. Krippendorff (2011) also emphasizes the fact that artifacts are created in networks of stakeholders among which the “end user” is one stakeholder among others. Indeed, the stakeholders can be representatives from several specialties involved in the creative process. According to Krishnan and Ulrich (2001), designing an artifact involves making decisions about aesthetics, technology, and meaning, all of which require strong interactions between design, marketing, and technology within the new product development team (Perks, Cooper, & Jones, 2005). Research has highlighted that strong interactions between R&D, marketing, and designers and the designation of multidisciplinary team results in successful processes and innovative products (Borja de Mozota, 2003; Crawford & Di Benedetto, 1991; Hooge & Dalmasso, 2015; Ulrich, 2011; Veryzer & Borja de Mozota, 2005).

A key aspect of design thinking’s explorative potential comes from the fact that it relies on empathy (Brown, 2008): the ability to imagine the world from multiple perspectives—those of colleagues, clients, end users, customers (both current and prospective), and all parties involved.

Stakeholder involvement is achieved through various tools and practices: ethnographic studies, the early realization of prototypes to test design hypotheses, the setting up of so-called “living labs” where real-life situations are simulated.
Contributions of Design Thinking to Project Management in an Innovation Context

and observed to create insight into users’ needs and expectations, and so on. Space is also an important way to ensure stakeholder mobilization. The seminal experience of the Bauhaus school (Droste, 2002) highlighted the importance of diverse teams mixing artistic and technical profiles and being located in the design studio, a key space for exchanging visions and knowledge and challenging creative propositions. This is why an important development in design is taking place around “spaces” such as co-working places, fablabs, and living labs (Fabbri & Charue-Duboc, 2013; Magadley & Birdi, 2009).

Strategic and Management Capability Perspective

Product design was largely ignored by management scholars for many years (Bloch, 2011). More recently, research on product design has highlighted how design can provide firms with a differentiation factor and value driver (Borja de Mozota, 2003). Empirical evidence has shown the positive impact of design on performance and value creation (Chiva & Alegre, 2009; Hertenstein, Platt, & Veryzer, 2005). Krippendorff (2006) and Verganti (2009) show that design has the ability to provide new meanings to artifacts, which is also an important driver in value creation. As a result, the integration of design as a business capability of a firm is now increasingly being investigated. Recognizing this strategic role, researchers point out the importance of diffusing design practices and orientation throughout the firm, beyond the specific scope of innovation (Borja de Mozota, 2003; Gorb, 1990; Vervaek, 2009). Design is becoming more a culture attribute than a specialized expertise.

Recent developments in design thinking claim that it needs to move “upstream,” where strategic decisions are made (Brown, 2009). Brown (2009) calls for design to be dispersed throughout the organization and beyond the sole designers: “design has become too important to be left to designers.” Indeed, scholars interested in design such as Simon (1969), Schön (1982), and Hatchuel and Weil (1995) have long shown the analogy between designing and managing. Along this same line of thought, Boland and Colillopy (2004) argued that managers are designers as well as decision makers. Managers need to adopt a “design attitude” that complements analytical perspectives and methods. Indeed, managers and especially executives have to deal with decisions under circumstances of uncertainty and ambiguity: They address messy and ill-structured situations for which analytical thinking is not suitable and, therefore, they can benefit from design thinking as a way to approach indeterminate organizational problems (Martin, 2009). This approach has led to the creation of a toolkit for managers (Liedtka & Ogilvie, 2011) that can be applied in several situations (Liedtka, King, & Bennett, 2013) such as post-merger integration, rethinking strategic planning, industry collaboration, and so forth.

Conclusion

As we have noted, design thinking addresses complex problems in uncertain contexts and mobilizes tools and attitudes to that end.

Design thinking is a problem “defining and solving” approach that deals with ill-structured situations where the problem is not articulated and is considered a hypothesis where action stimulates thoughts to inspire better hypotheses.

Design thinking emphasizes the need to involve the various stakeholders in the innovation process and proposes methodologies, tools, and processes for easing their interactions.

Design thinking is a strategic capability that contributes to value creation based on a generic managerial competency.

With all this in mind, we now examine the extent to which design thinking could, through these perspectives, contribute and help address the challenges encountered by project management in innovative situations.

Contribution of Design Thinking to Project Management in Innovative Situations

The first section of this article identified three major challenges and limitations that project management encounters in innovative situations: exploration, stakeholder involvement, and firm strategizing.

The second section presented design thinking as following three perspectives: a cognitive one referring to the creative and explorative activity of design, an organizational one referring to the stakeholders involved in the design process, and a strategic one referring to the strategic process of the organization and more generally to managerial capability.

We suggest that design thinking can strongly contribute to addressing the three challenges encountered by project management and presented in the first section. In the following sections, we will examine how design thinking can provide significant contributions and we present propositions calling for further research to investigate these potential contributions empirically.

Exploration

Lenfle (2008) characterized projects in an innovation context as exploration projects and highlighted their ambiguity and the absence of an established problem formulation. This characterization is very similar to situations in which the design thinking process is specifically well suited. It is best suited to decision contexts in which uncertainty and ambiguity are high (Liedtka, 2014).

Proposition 1: Exploration projects or projects characterized by high uncertainty are wicked problems similar to those for which design thinking is relevant.

Research on project management (Atkinson et al., 2006; Loch et al., 2006)
has highlighted the critical role of learning and knowledge acquisition through experimentation in order to reduce the uncertainty of situations. Lenfle (2008) pointed out the need for iteration and rearticulation of project objectives along the way. McGrath and MacMillan (1995) suggested that managing an exploratory project is a discovery-driven approach that consists of identifying and articulating hypotheses that will be transformed into validated knowledge through experimentation (Conforto et al., 2014).

Because of its emphasis on learning and knowledge acquisition to identify and articulate several hypotheses that will further be tested, design thinking is well suited for managing exploration projects.

**Proposition 2:** Through its focus on learning, hypothesis identification, and articulation regarding the problem before searching for solutions, as well as its emphasis on experimentation, design thinking can contribute to the exploratory dimension of projects.

**Proposition 3:** Through its tools supporting deep data collection and idea generation that encourage managers to work with multiple options such as generating and evaluating multiple hypotheses and moving multiple solutions into active testing, design thinking represents an effective and practical approach to manage the exploratory dimension of projects.

Design thinking tools are an effective way to frontload problem and risk detection (Thomke, 1998).

**Stakeholder Involvement**

Managing projects in an innovation context requires the adoption of a specific stakeholder management approach to identify stakeholders dynamically. Innovations developed within ecosystems and platforms (e.g., Gaver & Cusumano, 2002) put a strong emphasis on this issue. Identifying and involving the relevant stakeholders in the upstream phase of a complex and uncertain project has been recognized, by project management scholars, as one of the key challenges to avoid drifts of projects. Design thinking is a user-centered approach that includes a wide perspective of stakeholders, be they internal (within the team and more broadly within the firm) or external.

**Proposition 4:** Based on its strong and wide user-centered orientation, design thinking can help address stakeholder management within the exploration project phase.

Design thinking emphasizes the iterative identification of stakeholders and promotes frequent and rich interactions with them, involving several artifacts such as stimulators to develop empathy (Ben Mahmoud-Jouini, Midler, Cruz, & Gaudron, 2014). Design thinking tools involve qualitative methodologies, visualization, ethnographic approaches, journey mapping, and personae characterization that help the players involved in the design process better imagine and apprehend the experiences of the stakeholders, which can help mitigate the effects of the say/do gap (Liedtka, 2014).

**Proposition 5:** Through the use of tools that enable rich and multiple interactions with users (personae) and favor empathy, design thinking represents an effective and practical approach for achieving stakeholder identification and involvement in exploration projects.

Design thinking also emphasizes the mobilization of a multidisciplinary team in order to develop a wide understanding of the problem and to favor interaction and knowledge combination, resulting in innovative ideas. Through the use of rapid prototyping that results in demonstrators, design thinking enables effective dialogue and understanding to reveal the unstated needs and expectations of stakeholders. It also highlights the critical role of colocation and sharing a common physical space, which favors interactions and quick communication, as in design studios (Schön, 1982). In such spaces, interaction between stakeholders is eased.

**Proposition 6:** By emphasizing the diversity of the team involved in the design process well beyond the designers, the artifacts, and the space they share, design thinking represents an effective and practical approach for managing stakeholder interactions in exploration projects.

**Strategizing**

At this level, we are concerned with the challenge of project strategy formulation. Artto and Kujala (2008) introduce four types of strategies for a project (obedient servant, independent innovator, flexible mediator, and strong leader) depending on two dimensions: the project’s independence and the number of strong project stakeholder organizations. The challenge of project strategy formulation is to analyze the project context, formulate the type that fits the environment, and structure project governance and management in line with the chosen type. Artto and Kujala (2008) show that in a complex environment with an unclear governance scheme (especially for megaprojects), project strategy is often self-originated. Design thinking is a hypothesis-driven process that is problem, as well as solution, focused, which means that it does not define the problem to be solved at the outset. Defining the problem to solve—and thereby articulating the project’s strategy—is indeed a critical task for design thinking.

**Proposition 7:** By starting with a problem definition phase, design thinking can contribute to the articulation of the project strategy.

In addition, through the collection of deep data and the articulation of multiple assumptions to be tested simultaneously, design thinking ensures that multiple options are considered before the problem to be addressed is articulated.

**Proposition 8:** Through its tools and the attitudes it promotes, design thinking...
ensures that multiple options will be considered and tested. Because of this, it represents an effective and practical approach for defining and articulating the project strategy.

Modern strategy emphasizes learning processes as a key dynamic capability of a firm. How this capability can be developed, however, is not well addressed. Project management is clearly an interesting candidate for bridging this gap. But to do so, it needs to develop a larger perspective on strategic issues. Design thinking can provide inputs in this perspective. It provides a method for creating knowledge on strategic orientation through, for example, needs findings and inspiration. This knowledge is documented and capitalized within the design studio where the process usually takes place—in other words, beyond the projects themselves.

Proposition 9: Design thinking tools provide a firm-level capitalization vehicle that enables the reuse of knowledge from one project to another.

Finally, by addressing the key issue of meaning (Verganti, 2009) in the innovative effort, and thus enlarging value from a functional to a symbolic dimension, design thinking contributes both to strategy orientation and strategy formulation.

Proposition 10: Design thinking complements the traditional project management analytical and functional perspective by emphasizing the meaning of the innovative project. By doing so, it makes an important contribution to strategy orientation and formulation.

The recognition that design is an important driver for value creation has led to its integration as a business capability of firms. Recognizing this strategic role, researchers have pointed out the importance of diffusing design practices and orientation throughout the firm, beyond the specific scope of innovation (Borja de Mozota, 2003; Gorb, 1990; Gruber et al., 2015; Vervaeke, 2009). The idea is that design is more a cultural attribute of a firm than a specialized expertise: It needs to move upstream, where strategic decisions are made (Brown, 2009). Yet, for the firm-level stakeholder dimension, design thinking has not developed tools and concepts to go beyond a generic imperative, and little research exists that explores the strategic contribution of design thinking at the firm level in relation to innovative project management.

Hence, design contributes most to two particular project management challenges: the exploration challenge and the stakeholder challenge. Potential contributions also exist for addressing the strategy formulation challenge, although such contributions need to be more specified and call for further research.

Conclusion
The aim of this article was to examine how design thinking can contribute to the limitations of project management in innovative situations. We analyzed design thinking along three dimensions: a cognitive dimension referring to the creative and explorative activity of design thinking, a social dimension referring to the stakeholders involved in the design thinking process, and a strategic dimension referring to the strategic process of the organization and more generally to managerial capability. We showed how design thinking can provide significant contributions to the challenges encountered by project management in terms of exploration, stakeholder involvement, and firm strategizing. We formulated 10 propositions that can form the basis for an agenda for further experimentation and empirical research crossing project management and design thinking approaches in innovative situation contexts.

Such results make sense given that, as we have noted, design thinking and project management share many similarities. Yet for all of design thinking’s potential contribution to project management, the link between the two is still under-researched. In addition, the contribution of design thinking does have limits. Proponents of design thinking claim that it is suited to address organizational and strategic issues, but this claim remains to be substantiated and supported by conceptual and empirical research. To date, empirical evidence shows that design thinking has mainly been applied at the project level. As we have argued, design thinking is well suited to addressing the exploration and stakeholder involvement efforts required in projects confronted with complexity and uncertainty. It helps frame ill-defined issues and develops them into clearly defined problems around which key stakeholders can be mobilized. As far as strategy formulation is defined, however, design thinking has yet to develop its ability to contribute. In this regard, project management is still the main dominant paradigm for addressing large, complex projects.

References


Contributions of Design Thinking to Project Management in an Innovation Context


Siham Ben Mahmoud-Jouini, PhD, is Associate Professor at HEC (France) and researcher at GREGHEC. She is a research fellow at IMM—Ecole Polytechnique. She holds a PhD from the Université Paris 9 Dauphine and was Visiting Professor at Stern Business School (New York University) and Babson College. She is interested in the organizational design of exploration units within established firms and the management of innovation projects. She also studies the management of innovation in a context where resources and markets are global. Her work has been published in *Creativity and Innovation Management, International Journal of Project Management, Journal of Product Innovation Management*, and *Management International*. In 2012, she edited a book on managing breakthrough innovation with R. Maniak and C. Midler and in 2015 a book on innovation.
Contributions of Design Thinking to Project Management in an Innovation Context

management and globalization with F. Charue-Duboc and C. Midler. She can be contacted at jouini@hec.fr

Christophe Midler, PhD, is Research Director at the Management Research Center and Innovation Management Chair Professor at École Polytechnique. He is doctor honoris causa at Umeå University, Sweden, and a 2012 PMI Research Achievement Award recipient. He is cofounder of the IRNID research network and chair of the Project Organizing Strategic Interest Group at the European Academy of Management. He is a member on the editorial board of Project Management Journal® and has collaborated on the International Journal of Project Management. His research topics include innovation strategy and project and R&D management in relation to organizational learning theory and he has explored these topics in various industrial contexts. His favorite methodology is long-term interactive research, which he has extensively experienced within the automotive industry. He has published many articles in journals such as Project Management Journal®, International Journal of Project Management, Journal of Project Innovation Management, and Research Policy: Some of his books include Managing and Working in Project Society—Institutional Challenges of Temporary Organizations (co-authored with R. A. Lundin, N. Arvidsson, T. Brady, E. Ekstedt, and J. Sydow; Cambridge University Press, 2015), Management de l’Innovation et Globalisation (co-authored with S. Ben-Mahmoud-Jouini and F. Charue-Duboc, Dunod, 2015), The Logan Epic (co-authored with B. Jullien and Y. Lung; Dunod, 2013), Working on Innovation (co-authored with G. Minguet and M. Vervaeke; Routledge, 2009), and Projects as Arenas for Renewal and Learning Processes (co-edited with R. A. Lundin; Kluwer Academic Publishers, 1998). He can be contacted at christophe.midler@polytechnique.edu

Philippe Silberzahn, PhD, is Associate Professor at EMILYON Business School and research fellow at École Polytechnique, Paris, France, where he obtained his PhD. His research interests lie at the intersection of strategy and entrepreneurship and he studies how businesses deal with radical uncertainty. Philippe is the author of several articles in International Journal of Innovation Management, International Journal of Project Management, and Journal of Manufacturing Technology Management. He is also the author of five books on innovation, entrepreneurship, and strategic surprises, including Objectif Innovation: Stratégies Pour Construire l’entreprise Innovante (co-authored with Jean-Yves Prax and Bernard Buisson, Dunod, 2005), The Balancing Act of Innovation (co-authored with Walter Van Dyck, LannooCampus, 2010), Constructing Cassandra: Reframing Intelligence Failure at the CIA, 1947–2001 (co-authored with Milo Jones, Stanford University Press, 2013), and Effectuation: Les Principes de l’entrepreneuriat Pour Tous (Pearson, 2014). He can be contacted at silberzahn@em-lyon.com
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Jonas Söderlund – BI Norwegian Business School
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PMI is a not-for-profit professional organization whose mission is to serve the professional interests of its collective membership by: advancing the state of the art in the leadership and practice of managing projects and programs; fostering professionalism in the management of projects; and advocating acceptance of project management as a profession and discipline.

Publisher

Donn Greenberg; donn.greenberg@pmi.org

Wiley Executive Editor

Margaret Cummins; mcummins@wiley.com

Product Editor

Roberta Storer; roberta.storer@pmi.org

Copy Editor

Linda R. Garber; linda.garber@pmi.org

Publications Production Associate

Kim Shinners; kim.shinners@pmi.org

Publications Production Supervisor

Barbara Walsh; barbara.walsh@pmi.org

Book Review Editor

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Manager, Academic Resources

Carla M. Messikomer, PhD; carla.messikomer@pmi.org

Academic Research Administrator

Jake Williams; jake.williams@pmi.org

Projects and Networks

SPECIAL ISSUE EDITORS:

Robert DeFilippi, Strategy and International Business Department, Suffolk University, USA; rdefilippi@suffolk.edu

Stephen Pryke, Centre for Organisational Network Analysis, University College London, UK; sp@soc.ucl.ac.uk

John Steen, Australian Institute of Business and Economics, University of Queensland, Australia; jsteen@business.uq.edu.au

Jörg Sydow, Department of Management, Freie Universität Berlin, Germany; jorg.sydow@fu-berlin.de

Two basically different perspectives have brought projects and networks together. We welcome contributions from both viewpoints and integrative views. To this end, all papers should be based on theoretically informed and empirically rigorous research using qualitative or quantitative designs and methods.

PROJECTS FROM A SOCIAL NETWORK PERSPECTIVE

Social or organizational network analysis not only provides a means to analyze project networks and develop theories of the flow of information and other resources through projects, it also provides a theoretical lens on control and coordination. There is scope here to extend beyond network analysis and apply network theory (Borgatti & Hann 2011) to generate broader theories of project-based organization.

PROJECTS FROM A NETWORK GOVERNANCE PERSPECTIVE

Project networks as a specific form of governance are characterized by latent as well as activated ties with project entrepreneurs and/or organizations. In its purest form, project networks embed projects as a form of temporary organization (Johndson & Söderlund, 1995) into longer-term, open-ended networks (Sydow et al., 2016). As a consequence, their analysis requires not only investigations of the particular modes of organizing but also their specific contexts (DeFilippi, 2015).

Submissions: Full papers must be submitted by 31 October 2016 via the journal submission site. Papers accepted for publication but not included in the special issue will be published later in a regular issue of the journal. If you have any additional questions, please consult any of the guest editors.

For additional details about this call for proposals, please visit

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