

THE PRACTICE OF PROJECT MANAGEMENT IN PRODUCT DEVELOPMENT: INSIGHTS FROM THE LITERATURE AND CASES IN HIGH-TECH

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Executive Summary

Project management is said to have lost its relevance for innovation initiatives because it overemphasizes planning and control over flexibility, leading to approaches that are poorly adapted to high-uncertainty endeavors (Lenfle & Loch, 2010). In response, the concepts of targeted flexibility (Lenfle & Loch, 2010) and adaptive project management (Shenhar & Dvir, 2007) have been proposed. Under this paradigm, the specific characteristics of a project—its uncertainty (Lenfle & Loch, 2010), structural and dynamic complexity (Brady & Davies, 2014), or complexity, novelty, technology, and pace (Shenhar & Dvir, 2007)—are systematically considered to tailor project management approaches that are adapted to project needs.

This research investigates how proposed adaptation of project management occurs in a context that organizes all work in projects and has very high levels of innovation—product development in small and medium technology companies with manufactured products. These companies manage incremental and highly innovative product development projects within the same R&D organization, rather than separating high-uncertainty, explorative research from product-focused development. Because of the physical nature of their products, they have limited opportunities to iterate through design-build-test cycles and need to make investments in fixed assets (e.g., for specialized tooling) relatively early in the development process. The study thus samples cases with extreme needs for project adaptation to understand challenges and practices of other, similarly demanding project settings. It has three research objectives: (1) to understand how existent project management frameworks, such as the *A Guide to the Project Management Body of Knowledge (PMBOK®Guide)* and Stage-Gate® (SG), inform current product development practice, (2) to understand how product development projects are managed with standard versus project-adapted management practices, and (3) to understand what challenges arise in the context of project adaption.

To achieve these objectives, this study poses several research questions. The dominant process for organizing product development is Stage-Gate. It is intended to provide high-level charters for interdisciplinary teams and executive decision makers and organize work around phase-review gates before major development phases are entered and additional resources are committed. As a so-called meta-framework that guides R&D investments, SG is designed to be adaptive and is also generally compatible with many project management methodologies, such as waterfall or agile approaches. However, how the SG framework is leveraged for adaptive project management on the project level and how it is combined with project management methodologies is currently largely unknown. Accordingly, this research investigates the following questions:

1. How does company-specific and project-specific “tailoring” of SG project management occur?
2. How is complementarity of project management and SG achieved?

A key driver of the need for adaptive project management is uncertainty, which can exist for different project aspects (e.g., market response, technology, financials, schedule) with different intensity and at different times in the project flow. This study is particularly interested in projects with so-called deep uncertainty, or unknown unknowns. In product development, this type of uncertainty is associated with novel markets and technology solutions that can lead to breakthroughs. “Unk unks” are understood to be unmanageable with traditional, planning-based project management approaches, such as risk management. Instead, projects focus on facilitating learning through trial and error or selectionism, allowing many aspects of the project plans to emerge, rather than being determined up front. The recommended approaches, however, are challenging to implement, as they are fundamentally different from the way most projects are managed, possibly incompatible with the philosophy

and training of project managers, and currently insufficiently supported by project management methodologies. It is therefore unclear to what extent and how these recommendations are implemented in practice, leading to the research question: What project management approaches are used for high-uncertainty projects?

The decision on project management approaches includes the choice of standard or tailored SG framework, learning strategy (up-front planning, trial and error, selectionism), and fundamental project management methodologies. It occurs in the so-called fuzzy front end before the project is approved. Front-end practices differ between companies: Some emphasize structured approaches, while others rely more heavily on gatekeepers and culture (Florén & Frishammar, 2012; Khurana & Rosenthal, 1998). Also, breakthrough new product projects typically experience a more fluid and less data-driven front end than more incremental new product projects (Reid & de Brentani, 2004). This likely has implications for how much project-specific adaptation occurs. For example, a front end that is focused on creating a complete set of plans may leave limited room for the approval of projects that follow a more emergent, learning-based strategy. A fluid, largely unstructured front end, on the other hand, may make it impossible to introduce the discipline needed to quickly tailor project approval and project approaches to project needs, leading to lengthy, unproductive front ends. Currently, however, the transition point between the front end and the more structured project phases is underresearched and often reduced to a simple “fund the project or not” decision, with no explicit consideration of project adaptation. Accordingly, this research also investigates the question: How do projects move from fuzzy front end to product development?

The answers to these questions were pursued in three consecutive phases. Each phase provided insights and additional questions that were addressed in the design of the subsequent study. Phase 1 compared company-specific standard project management processes for the product development of seven companies against the tailored process the companies had actually employed in earlier projects. Phase 2 replicated the same line of questioning but within the context of a single company. Respondents in different management roles were asked to describe their company’s standard process, the actual project management practice as it had occurred for selected past projects, and the organizational context in which project decisions were made. Phase 3 was focused on theoretical replication of cases from the earlier studies to see if the conclusions from earlier studies would still hold true in other settings. In total, 17 individuals, representing 12 different companies, were interviewed. Interview results were analyzed by the authors, first for each study and then across studies. Furthermore, results were presented and discussed with a four-person project advisory panel, which consisted of academic and industry experts in project management and new product development (NPD). Key research results can be summarized as follows:

Project management approaches in product development are heavily influenced by the Stage-Gate (SG) framework, which is focused on supporting investment decisions in R&D and providing high-level charters for interdisciplinary teams and executive decision makers. It organizes work around review gates before major development phases are entered and additional resources are committed. SG is explicitly not intended to provide project monitoring and control, for example, with regard to time lines, budgets, and time allocations. Project management frameworks and methodologies that have these capabilities, such as the *PMBOK® Guide*, are frequently unknown and, even if they are known, are rarely used. Respondents find them to be poorly adapted to the many changes that occur in new product projects, which frequently lead to a 30% to 50% difference between initial project plans and actual project results. Given such variance, they find the overhead for documentation and change reporting to be too high. The detailed documentation does not provide much value for steering the project because in new product development, competing constraints of project scope, quality, schedule, budget, resources, and risk (PMI, 2013) play out in such a distinct way that the direction for

optimization and the project decision is often evident without much detailed analysis. Moreover, all innovative projects are different, causing project data from one project to be poorly applicable to other projects, which limits the usefulness of detailed documentation.

As a result, the dominating new product SG framework is often the only approach to managing R&D projects and, through its gate reviews, the only mechanism to create transparency and discipline around budgets and schedules. For that reason, it is frequently overused. For example, attempts are made to apply it to incremental product maintenance projects that do not necessitate interdisciplinary coordination or higher-level management buy-in. Or it is applied to technology projects that are not focused on customers and markets, but only on technology fundamentals and therefore do not require much strategic marketing input. This common practice is at odds with the current SG literature, which recommends different SG approaches for these types of projects. Many companies in our research instead prescribe the “full” new product SG but, in reality, do not apply it. Sometimes maintenance and technology projects are managed outside the standard process, making them close to invisible to the organization and lacking a mechanism to ensure that resources are spent wisely. At times, a massively stripped-down version is used, often with gate reviews that are done by gatekeepers who represent a single function, rather than through a multidisciplinary approach. The practice weakens the rigor of SG for the new product projects it is intended to support by modeling an “everything is optional” approach to SG. As a result, there is limited discipline with regard to project selection and review, and individual decision makers and their personal approaches, rather than recognized good practices, have a strong impact on how projects unfold.

The early, “fuzzy” stages for new product development are focused on gaining a fundamental understanding of what will determine the success of the future product and result in key project definitions, including markets, product concept, key features, and technologies. The companies in our study, however, very frequently experience projects entering later stages with what turns out to be insufficient clarity around these parameters. Even though the new product SG fails to deliver early and stable product definitions, it is applied unchanged to all projects without any attempt to broaden the search for undiscovered unknowns in the front end or to implement more flexible approaches downstream. Project approaches such as selectionism or trial-and-error learning are rarely used proactively and systematically but only in response to downstream problems with the earlier plans. As a result, budget and schedule overruns, as well as projects that do not fit market needs, are reported frequently.

Overall, adaptive project management is still in its infancy. Practices differ widely, even within the same organization. They are rarely reviewed with regard to the results they deliver, limiting the possibility of improving them. Decisions to adapt practices are frequently made ad hoc, without any clear standards and, in more than one case, without the knowledge of the program office. Because of this lack of demonstrated best practices, managerial recommendations have to be given with some caution.

We propose to decouple maintenance and technology products from the Stage-Gate system, rather than managing them with tailored SG processes, as the literature proposes. To this end, a percentage of engineering resources can be allocated for ongoing product improvements and technology explorations. For these budgets, project selection occurs within the R&D organization. Project management approaches are kept simple and focused on informing the team about responsibilities and time lines, rather than management control and/or documentation. In most cases, a simple task list with dates and responsibilities is sufficient. This approach takes into account the fact that these types of project rarely require an alignment of schedules and tasks in different areas, nor do future projects benefit from detailed documentation of resource needs. The recommendation further responds to the fact that many of the organizations in our study have limited capacity for project

adaptation and operate without a project office that could help with process design and selection. Moreover, they often struggle to create sufficient discipline around the management practices of “normal” product development projects and therefore should focus their processes on the type of projects that are known to benefit most from a disciplined approach—namely, new product projects with normal levels of uncertainty.

There also needs to be a clear differentiation of roles. Technical project management activities, such as scheduling and tracking, may be best put into the hands of a project management professional, such as an analyst, who informs the project managers (typically an engineer or scientist with limited knowledge of project management tools) about the state of the project so that everyday decision making is supported by data. SG, however, is the responsibility of the project managers and focuses on go/no-go decisions and cross-functional handoffs at pivotal project moments. Given how prevalent late-stage “unknown unknowns” are, much more consideration needs to be given to how projects can move forward while still maintaining flexibility to minimize risks. This will require parallel trials, quick build-and-test cycles, and agile contractual arrangements for internal budgets and external customers of custom projects. Project outcomes should not only be monitored based on tasks completion, but—more important—based on learning. This can occur by tracking a list of assumptions to see how many of them have turned into tested knowledge and how many are still uncertain.

What is sound management practice for incremental innovation—where speed, cycle time, and quick cash recovery are primary objectives—might actually hamper the radical innovation's progress.

(Rice, O'Connor, Peters, & Morone, 1998, p. 52)

Introduction

The project management discipline has been accused of having lost its relevance for innovation initiatives because it overemphasizes planning and control over flexibility, leading to approaches that are poorly adapted to high-uncertainty endeavors (Lenfle & Loch, 2010). In response, the concepts of targeted flexibility (Lenfle & Loch, 2010) and adaptive project management (Shenhar & Dvir, 2007) have been proposed. Under this paradigm, the specific characteristics of a project—its uncertainty (Lenfle & Loch, 2010), structural and dynamic complexity (Brady & Davies, 2014), or complexity, novelty, technology, and pace (Shenhar & Dvir, 2007)—are systematically considered to tailor project management approaches adapted to project needs. Suggested adaptations include project and contracting frameworks that focus on testing assumptions through iterations and parallel trials (Lenfle & Loch, 2010; Pich, Loch, & Meyer, 2002) and “tight-loose” management approaches that grant procedural freedom for some project aspects, while tightly controlling and standardizing others (Brady & Davies, 2014). Moreover, the length of project phases, the degree of formality and documentation, and the extent of team autonomy are adjusted to the profile of each project (Shenhar & Dvir, 2007). However, to date there is no accepted practice for identifying the needs of a particular innovation project in its early stages and for proactively choosing the appropriate project management approach. To close this gap, this research investigates current industry practice and its challenges and successes, and synthesizes recommendations for managers and researchers.

The investigation is focused on a context that organizes all work in projects and has high levels of innovation: product development. The inquiry is focused on small and medium technology companies with manufactured products that manage incremental and highly innovative development projects within the same R&D organization. In these settings, projects fall into three categories (Cooper, 2011): (1) fundamental technology or platform efforts that are not yet focused at a product launch, but spawn multiple future new product projects; (2) maintenance projects for already-launched products, such as extensions, modifications, improvements, and cost reductions; and (3) so-called new product projects. The latter are “major, bold and innovative product developments” (Cooper, 2011, p. 289) aimed at the launch of differentiated products with compelling value propositions. Because of the breadth of projects, the studied R&D organizations provide an ideal setting to study the practice of adapting project management approaches to varying degrees of innovation. The study itself is inductive in nature. After a review of the pertinent literature, this paper presents three consecutive studies that cumulatively lead to the results. Each study informed the questions and analysis of the subsequent study. In total, 17 individuals from 12 different companies were interviewed. Interview results were analyzed by the authors, first for each study and then across studies. The results and their analysis were also discussed with an advisory panel made up of academic and industry experts.

The paper makes several contributions: As one of the first papers of its kind, it unpacks the relationship between the Stage-Gate (SG) framework, which dominates new product development practice, and the Project Management Institute (PMI) project management framework. To this end, it provides a systematic review and integrative framework for the currently largely distinct streams of literature on product innovation, organizational ambidexterity, and project management. Moreover, it opens the black box of project management practice in new product development and identifies company-specific and project-specific adaptations of new product development and project management practices. Some of these adaptations are explicit, while others occur “under the radar” and are therefore insufficiently addressed in the literature. Moreover, this research reports on challenges and tensions, and proposes avenues for improvement.

Research Framework: Product Development in Context

This research is interested in project management practice with regard to adaptive project management. Specifically, it is concerned with how project management practice influences innovation outcomes, such as the degree of innovation (radical versus incremental), innovation success (e.g., market acceptance), and efficiency of the innovation process (e.g., budget adherence, amount of rework). It assumes that the relationship between project management practice and innovation outcomes is moderated by uncertainty, i.e., that the same project management practice yields different results if it is applied to a high- versus low-uncertainty projects. It further assumes that managers are aware of the fact that “no size fits all” and are already adapting their project management practice to the level and nature of uncertainty of the project. It aims to identify these practices for adaptive project management and synthesize recommendations for how to approach innovation projects of different nature. **Figure 1** illustrates the main elements and relationships of this work.

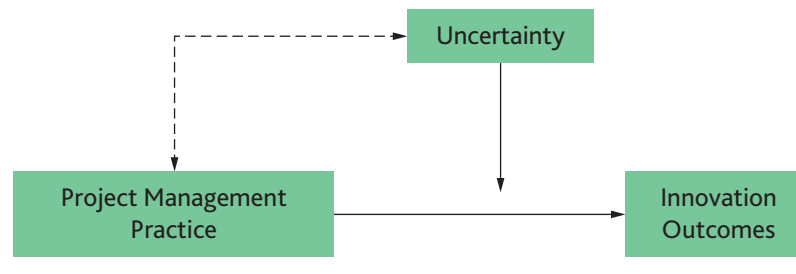


Figure 1: Research overview.

The following literature review investigates the current state of the art in relation to the key elements above. To this end, it reviews the literature on organizational ambidexterity, product innovation, and project management.

Exploitation Versus Exploration

Organizational theory has long been interested in so-called ambidexterity, which enables companies to hone and exploit an existing knowledge base, as well as to explore innovative opportunities that build on new competencies. Exploitation initiatives are looking for solutions inside the existing technologies and for the existing market, and therefore, are more likely to have a predictable return on investment (ROI). They increase the fit and alignment of the organization with evolutionary changes that are occurring in the marketplace, for example, by lowering costs or modifying product offerings to accommodate new customer requirements. In contrast, exploration initiatives are seeking solutions beyond the company’s existing technologies or markets. They are vaguer, less certain, and slower to produce results, but they give new competencies to the organization through which it can confront revolutionary changes in the business environment, such as market shifts and the emergence of disruptive technologies (Govindarajan & Trimble, 2010; He & Wong, 2004; Lubatkin et al., 2006; March, 1991; O’Reilly & Tushman, 2008; Tushman & O’Reilly, 1996). Ambidexterity is a prerequisite for competitive success, unless the business environment never changes or is so extremely volatile that knowledge becomes obsolete too quickly for much exploitation to be possible. In the first case, heavy emphasis on exploitation, paired with an incremental growth of the knowledge base, suffices. In the latter case, the necessity to “unlearn” old knowledge and frequently create new knowledge results in a strong emphasis on exploration.

The literature generally agrees that exploitation and exploration require different structures, processes, management styles, cultures, values, and even measures of success (Christensen & Overdorf, 2000; Govindarajan & Trimble, 2010; Gupta, Smith, & Shalley, 2006; McLaughlin, Bessant, & Smart, 2008), and that organizations typically emphasize one aspect over the other. Projects that do not fit the preferred model either are not approved at all; morph into a different, more familiar project type; or are defunded during execution.

Table 1, adapted from Govindarajan and Trimble (2010), highlights the key differences between typical planning approaches for exploitation-oriented projects and planning principles for exploration.

Planning Principles for Radical Innovation	Project Management Practices for High Performance
Invest heavily in planning	Planning and management attention in proportion to budget
Create a plan and metrics for success from scratch	Use the last project as a template and modify
Discuss data and assumptions	Focus on data
Document a clear hypothesis of record	Document clear expectations
Find a way to spend a little and learn a lot	Be on budget, on time, and on spec
Create a separate forum for discussing radical innovation projects	All innovation projects are discussed in the same forum
Frequently reassess the plan	Deliver the results in the plan
Analyze trends	Analyze totals
Allow formal revisions to predictions	Revisions are frowned upon
Evaluate innovation leaders subjectively	Evaluate based on results

Table 1: Planning approaches for exploration versus exploitation projects.

Because of these differences, organizational theory frequently proposes to separate exploitation and exploration in space or time. In the case of structural differentiation, these activities occur through two or more separate organizational units, such as a central research organization, a spin-off company, or an external design firm for exploration and product-focused development for exploitation (O'Reilly & Tushman, 2008; Raisch et al., 2009; Tushman & O'Reilly, 1996). This separation enables the organization to plan, lead, and evaluate exploration and exploitation teams with different styles and methods while using appropriate individuals and managers for each. A separation in time occurs when the organization practices exploitation or exploration for some period of time and then switches its emphasis and activities to the other practice (Birkinshaw, Cristina, Gibson, & Organization, 2004; He & Wong, 2004; O'Reilly & Tushman, 2008; Uotila et al., 2009). This process of transitioning is sometimes characterized as punctuated equilibrium.

The organizational separation of exploitation and exploration is theoretically intriguing, but comes with considerable practical challenges. Separation by time forces companies to undergo times of major disruption, if not crisis, to make the transition from one stage to the next. Separation by organizational unit may result in exploration that ventures too far from what the market accepts. Companies may therefore prefer to keep cutting-edge technology development in the business units to provide strong product and market focus. The demise of central research labs, such as Xerox Parc and Bell Labs, speaks to this problem. Smaller organizations in particular may find separation impractical if they do not have enough engineers and scientists to staff and consistently employ a separate research organization. They may also have little duplication of skills among their employees and therefore cannot assign individuals either to exploitation or exploration projects because their skill sets are needed in both. With blurry boundaries like this, however, all projects are likely to inherit the dominant organizational paradigm, and separation is impossible. The problem is aggravated when products have high exploration content in product development, such as the design and manufacture of customer-specific specialty machinery. Finally, exploration is not only necessary in technology or product development, but may take the form of planning and testing a new service offering, logistics approach, or business model. Exploration projects of this nature are likely to include so many business functions that separation is impossible, short of re-creating an entirely separate organization.

In response to the challenges of separation-based approaches to ambidexterity, organizational theory increasingly emphasizes the concept of integration. Integration refers to the degree to which the individuals who are responsible for exploration and exploitation organically relate to one another and transfer knowledge, information, and experience (Birkinshaw et al., 2004; O'Reilly & Tushman, 2008; Raisch et. al., 2009; Tushman & O'Reilly, 1996). In its extreme form, integration occurs by charging individuals with both, explorative and exploitative activities, at the same time. Although people are unlikely to equally excel at both activities (Gupta et al., 2006), it appears that most individuals can perform ambidextrously to some extent. However, having ambidextrous individuals does not make an organization ambidextrous (O'Reilly & Tushman, 2008). A supportive organizational context with strong social support and performance management (Birkinshaw et al., 2004) is needed, as are dense social relations (Jansen, Van Den Bosch, & Volberda, 2006). Integration is dependent on how project management is implemented: Decentralized decision making, such as the use of empowered project teams, improves explorative innovation without negative impacts on exploitation, and a formalization of decision making through standard processes and manuals improves exploitation without harming exploration (Jansen et al., 2006). Project teams in complex projects can achieve temporal separation on the project level, rather than on the level of organizational units, as they "cycle" through phases of exploration and planning when they start working on new work breakdown structure items and execution and exploitation when they execute these plans (Liu & Leitner, 2012).

Product Innovation Management

The product innovation literature has long been dominated by empirical research that investigates the link between product and project characteristics and product success. The research is not theory-driven and does not typically investigate the inside of the project management "black box" (Brown & Eisenhardt, 1995), but provides managerial recommendations based on project factors that correlate with success. It explains the success of new products as the result of carefully planning a superior product for a well-chosen business opportunity and executing this plan flawlessly (Brown & Eisenhardt, 1995). Accordingly, it recommends rigorous up-front planning, documentation of plans, and progress to improve communication and commitment, cross-functional teams, and decision gates that secure senior management buy-in.

This perspective has been highly influential in managerial practice. The most common approach to organizing new product development (NPD) projects is a linear process model with decision points that separate sequential project phases, such as the Stage-Gate® (SG) system (Cooper, 2008) or the generic product development model by Ulrich and Eppinger (2008). Gate reviews are based on objective criteria that reflect what the organization knows to be important for project success (see **Figure 2**).

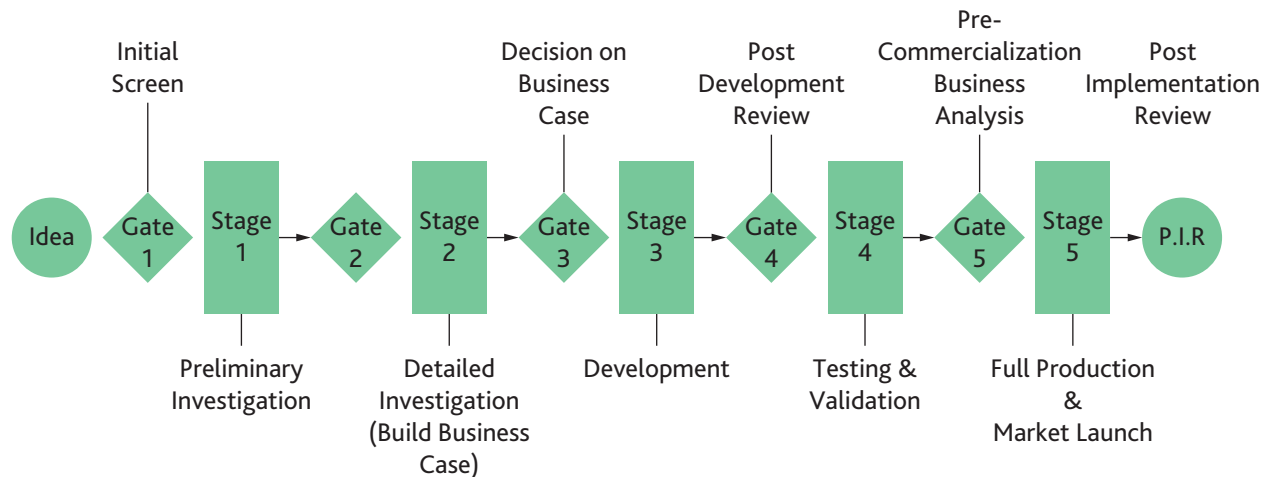


Figure 2: Stage-Gate (SG) system for new product development (NPD).

Each gate review requires a specific set of deliverables that spell out what actions should be taken and what information needs to be presented for the review (Cooper, 2008; Pina & Gomes, 2003). The self-documenting nature of the process enables continuous process improvement (Krishnan & Ulrich, 2001). Linear process management approaches with gates have been linked to improved product success, but have also been criticized for being too specification-driven rather than customer-driven, too heavyweight for simple projects, and too constraining for radical innovation (Cooper, 2008; Ettl & Elsenbach, 2007; Sethi & Iqbal, 2008). One set of concerns focuses on the potential of introducing too much rigidity into organizational routines and cultures. To obtain approval, product development teams may commit to precise project parameters and freeze product specifications early in the development process, even against their better judgment (Krishnan & Bhattacharya, 2002; Krishnan & Ulrich, 2001; Verganti, 1999). After approval, a project team may engage in a project execution mind-set and focus on the project plan and whatever is required to sail through the next gate, rather than making changes to the project in response to new market and technology insights (Sethi & Iqbal, 2008). The problem is aggravated because the fact that a project has passed formal reviews—often with high-level management involvement—may make it difficult later to propose an alternative course of action or to terminate it (Daly, Sætre, & Brun, 2012). Proponents of gated product development frameworks, such as Cooper (1990), therefore point out that such frameworks need to be applied differently for different types of projects (Cooper, 2011).

Fuzzy Front End

A key challenge of the “rational plan” (Brown & Eisenhardt, 1995) approach to managing new product development is reaching stable project plans. This occurs in the so-called fuzzy front end that precedes formal project evaluation and culminates in a go/no-go funding decision (Khurana & Rosenthal, 1997). It entails all activities up to and including gate 3 in Cooper’s (1994) model (see **Figure 2**), is highly interdisciplinary because insights into market opportunities and product technologies are developed in parallel, and is characterized by high levels of uncertainty.

Accordingly, Koen, Ajamian, and Burkart (2001) describe the front end as experimental, often chaotic, difficult to plan, and characterized by unpredictable commercialization dates, uncertain revenue expectations, and variable budgeting approaches that often include bootstrapping. In contrast, the actual new product development project begins after the front end. It is structured, disciplined, and goal-oriented, and is managed with a project plan. SG is a response to manage front-end fuzziness by keeping the front end short and focused on developing stable project definitions, as well as creating a system of evaluation points that is capable of quickly identifying and funding projects that will be technically and commercially successful, fit company strategy, and support the desired project portfolio mix (Cooper, Edgett, & Kleinschmidt, 2001; Reinertsen, 1999; Zhang & Doll, 2001). To achieve this objective, two contrasting approaches are used (Khurana & Rosenthal, 1998): Some companies employ a formal front-end approach that prescribes a process with clear standards for building, documenting, and approving a business case for a new product development project. Others rely on a culture-driven, more emergent approach to develop a joint project vision and buy-in for development projects that relies on strong cross-functional interactions and subtle control through management and stakeholder agreement. This informal process is more commonly applied for radical new product innovations (Khurana & Rosenthal, 1998). Florén and Frishammar (2012) synthesize the differences between the front ends of radical innovations with new technologies in new markets and more incremental new product projects: Front-end processes for radical innovation are less formal and structured than those used for incremental innovation and should emphasize individual motivation, entrepreneurial drive, and access to external networks over operational efficiency and predictability. Some authors emphasize a need for slack time and flexible decision rules and the fostering of skunk work projects (de Brentani & Reid, 2012; Reid & de Brentani, 2004). Radical innovation is also less customer-driven (Betz, 2003) because customers have difficulty expressing latent needs and judging solutions when they have no prior experience. Development teams should therefore test early versions of the future product with lead users or in a plausible initial market, and refine product and market definitions as well as the scope and detailed expectations of the project as the results of this “experiment” come in, instead of relying on detailed up-front analysis with traditional market research methods and estimates (Lynn, Morone, & Paulson, 1996; O’Connor, 1998; Veryzer, 1998).

Some of the front-end fuzziness associated with radically new products appears to carry over into later product development stages. Product development teams in radical innovation projects still engage in considerable prototyping, lead-user testing, and design modifications after project approval and engage in design and (formative) prototyping, which are typically considered execution steps of product development projects, as a means to clarify customer need (Veryzer, 1998). Verworn, Herstatt, and Nagahira (2008) find that in radical new products, there are lower levels of clarity on competitors, market size, and customer price sensitivity, even after the project is approved. Also, Lewis, Welsh, Dehler, and Green (2002) investigate project management styles and project uncertainty within a single company from six months after project start to project completion. Despite all having cleared front-end evaluation within the same organization, the projects differ greatly with regard to uncertainty levels in later stages of product development. One explanation is inconsistency in the front-end process that allows some projects to enter the pipeline with lower levels of up-front project planning and less rigid reviews than others, resulting in high uncertainty during project execution. However, an alternative interpretation is that radical innovation projects carry hidden uncertainties, sometimes also called “unknown unknowns” or “unk unks” (Pich et al., 2002; Sommer & Loch, 2004a), into project execution because the same planning and review activities that work well for incremental innovation are less successful in the case of radical innovation.

Project Management Approaches for High-Uncertainty Projects

The product innovation and the project management literature have long attempted to characterize project contexts with regard to how much uncertainty they introduce to projects. Uncertainty can exist with regard to marketing and technology aspects of the product (e.g., what the customer needs to address and which

technical solutions to implement), as well as with regard to how markets, technologies, and the general business environment will evolve in the future. Moreover, appropriate resource allocations to projects and within projects are also uncertain (Schröder & Jetter, 2003).

Most studies focus on *what* is uncertain (markets, technologies, environments, etc.) and do not further conceptualize *why* uncertainty occurs. Some authors understand uncertainty as an objective lack of information that can be healed by gathering additional information until only “residual” (Courtney, Kirkland, & Viguierie, 1997) uncertainty remains. This unavoidable uncertainty, for which no information is available, is relatively straightforward to manage through traditional risk management: Areas of uncertainty are documented, assessed with regard to their likelihood of occurrence and the severity of consequences, and addressed with various risk mitigation strategies. The underlying notion of these approaches is that decision makers fundamentally understand how project elements and the project environment are linked. They may, for example, know that a weaker dollar affects project costs, but they do not know the dollar exchange rate at the time that payments come due. Other authors (Milliken, 1987; Schrader, Riggs, & Smith, 1993), however, point out that uncertainty is perceptual. It exists when a decision maker is unable to fully understand the relationships between project elements. Miliken (1987) differentiates between state uncertainty (the inability to predict the future state of a variable), effect uncertainty (the inability to judge the impact of a changing variable), and response uncertainty (a lack of information about response actions and their effects). These uncertainties preclude the decision maker from using traditional risk management approaches. They persist because the situation is so novel (e.g., markets with entirely new usage patterns or emerging technologies) *and* so complex that it is impossible for the decision maker to articulate relevant variables and their functional relationships (Sommer & Loch, 2004a, 2004b; Sommer, Loch, & Pich, 2008). This situation is characterized as ambiguity (Schrader et al., 1993), unforeseeable uncertainty (Sommer et al., 2008), unk unks or unknown unknowns (Pich et al., 2002), or “deep uncertainty” (Lempert, Popper, & Bankes, n.d.). It is a result of a lack of information, as well as the persistence of so-called “rugged” project landscapes in which adjacent points of project performance are loosely related (Sommer et al., 2008) and project interdependencies cause small changes in one project element to result in large changes in overall project performance. A common analogy for this phenomenon is a search in a geographical region: In projects with lack of information, but without unk unks, project managers know where the point of best project performance is because the one peak in the region is clearly visible from everywhere, similarly to the view of a volcanic peak, like Mount Fuji, from the surrounding valley. Project management aims for the peak and plans for risks that might occur along the way. In uncertain projects, managers are instead operating in a deep fog and cannot see the performance peak or peaks. However, they can see a little bit of road in front of them and they can see if it slopes upward or downward. In a non-rugged landscape, consistently moving forward on a road with an upward slope will eventually cause the project to get to or very near the performance peak. In a rugged landscape, however, the project may end on a relatively small local peak, far away from the highest peak.

Building on the recommendations of the project management and new product development literature, Sommer et al. (2008) have identified two strategies to complement traditional risk management for cases of unk unks: trial-and-error learning and selectionism.

Trial-and-error learning builds on experimentation by introducing an early version of the product to the customer. The experiment can take the form of a product concept test (e.g., based on concept descriptions or prototypes) or sales of a functional early product version. Tests can also pertain to critical business model elements. In entrepreneurship practice (and increasingly in established companies), this culture of rigorous experimentation is increasingly characterized as the “lean start-up approach” (Blank & Dorf, 2012; Ries & Eucher, 2013) and linked to the concept of minimum viable product (MVP) testing (Eisenmann, Ries, & Dillard,

2012). MVP aims at gaining market validation before investments are mounted on scaling the business. In this context, MVPs are often mock-ups of software, e-commerce offerings, or landing pages of future companies. Customers demonstrate their willingness to accept the product either by buying the offering despite its limited feature set or by attempting to buy the future product and making some kind of early-stage commitment (e.g., preordering or leaving their email to receive further notice when the offering becomes available). In the context of extreme programming (XP), experimentation takes the form of building products iteratively through a number of short feedback cycles: A first product release is designed to fulfill customers' very basic needs and as a means to obtain feedback. Complexity is added to each following release to address unfolding customer needs, but always guided by the principle of implementing the fewest features that can be expected to fulfill the expressed need. Releases occur in short intervals (two months) and plans, schedules, and sometimes even contractual agreements pertain to the work required until the next release, rather than everything that needs to be done to complete the project. Experimentation-based approaches are different in what they test, ranging from entire business ideas to specific functional aspects of a software product, but they all are characterized by the use of boundary objects to facilitate high-quality feedback from real-world customers.

Selectionism is a strategy of pursuing multiple candidate solutions until the best solution can be identified (Dahan & Mendelson, 2001; Loch, Terwiesch, & Thomke, 2001; McGrath, 2001). Similar to Darwinian selection, in selectionism, success depends on creating solutions with sufficient variability so that at least one of the variations is good enough to solve the problem and apply evolutionary pressure. The latter takes the form of clear decision points and withdrawal of resources to force the selection of the best available solution and the end of all other trials (Loch, De Meyer, & Pich, 2007). Pharmaceutical companies, for example, often fund research of different target molecules for addressing the same medical problem in order to have backup if their lead molecule fails (Sommer et al., 2008). The practice of set-based design at Toyota follows the same principle: Different functional groups participating in the development process (e.g., mechanical design and manufacturing) pursue several solutions in parallel and communicate them to the other functional groups. The groups then identify which solutions in each set are also in the feasible set of the other groups and pursue those further. The final design evolves because each group continues to narrow down its solution set while also making sure that the solution remains within the feasible set for the other groups (Sobek, Allen, & Jeffrey, 1999).

A question of fundamental importance is the specific context under which trial and error and selectionism should be used. Sommer and Loch model various scenarios and conclude that trial-and-error learning is superior to selectionism for all but one scenario, in which the unforeseeable uncertainty of the project is caused by its many interdependencies, rather than its sheer size, and in which there are credible trials for true market performance (Sommer & Loch, 2004a).

Project Management Frameworks Versus SG Frameworks

In the new product development literature, project management is largely synonymous with the application of the SG framework or a similar approach that separates project phases with distinct decision points or gate reviews. The project management (PM) framework promoted by PMI (Project Management Institute) and globally used by project management practitioners, however, is rarely mentioned. Both frameworks share the same early origins in NASA's phased project planning (PPP) in the early 1960s, but SG adds—among other things—a strong customer focus, cross-functionality, and linkage to portfolio decision making. **Figure 3** maps the new product SG phases (top row) against project life-cycle stages as described in PMI's standards (Project Management Institute, 2013). Each project phase is characterized by its emphasis on particular project management processes (so-called Process Groups). The life-cycle stage "start," for example, encompasses a

variety of initiation activities, some of which may carry over into later stages, even after the output of the phase, the project charter, is produced. Within the project management framework, a development project is typically considered complete when the product is handed off to manufacturing.

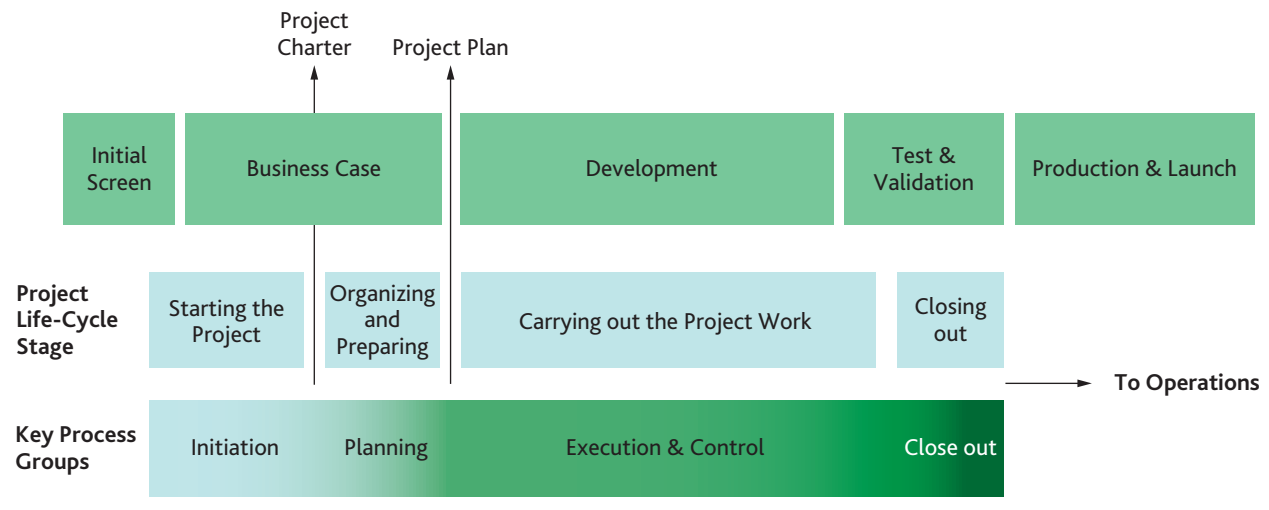


Figure 3: Stage-Gate and project management phases.

Table 2 compares key activities and instruments of SG, as described in the new product development literature, to the key processes (as defined by PMI’s standards). Notably, both frameworks have some similar phases, approaches, and outputs.

In Phase 1, the SG framework puts heavy emphasis on the prioritization and selection of new product programs for longer-term organizational goals (Schultz, Salomo, de Brentani, & Kleinschmidt, 2013), which occurs in a pre-project stage or the front end. This stage, which does not exist in the PMI framework, but rather outside, in the project portfolio process, is considered central to product development success and is one of the key contributions of SG models to NPD practice (Cooper, 2008).

In Phase 2, both the SG framework and PMI framework are more similar than not. The principle purpose of Phase 2 in the SG framework is to define the product and the business case that is used to justify moving forward with development. In other words, the SG framework is intended to make a go/no-go decision based on market and financial criteria. The principal purpose of Phase 2 in the PMI framework is to define the project, align the project’s purpose with the stakeholders’ expectations, and obtain authorization to start the project. Moreover, it is not uncommon to validate the initial business case that was developed externally to the project against the planned project schedule and budget to assess authorizing the project plan prior to execution. Phases 3, 4, and 5 in the SG and the PMI frameworks are also similar in that both produce the product, validate the quality through testing, and roll out the product. However, in the SG framework, Phase 5 continues to monitor the results of the launch, whereas in the PMI framework the project ends once the product is rolled out.

The most fundamental difference between the SG and the PMI framework is that the PMI framework is built on the philosophy of monitoring and controlling project execution against plans. It measures project success by comparing product and project quality, timeliness, budget compliance, and degree of customer satisfaction against

	New Product Development (NPD)/SG	PMBOK Guide® Process Groups
Phase 1	<p>Initial Screen, Followed by Preliminary Investigation</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Preliminary market, technical, and business/financial assessment, based on quick, low-cost research, resulting in the approval to move to the next phase 	
Phase 2	<p>Detailed Investigation/Business Case, Resulting in a Go/No-Go Decision</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Product and project definition (target market, product concept, product attributes and features, value proposition and positioning, engineering requirements, and high-level specs) (2) Project justification and alignment with strategy and portfolio (business analysis, financial analysis, risk assessment) (3) Detailed project plan for development; preliminary plans for later stages (time lines, deliverables, resources) <p>(1) & (2) are often documented in a product innovation charter</p>	<p>Initiation</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Stakeholder analysis (2) Development of project charter, consisting of: <ul style="list-style-type: none"> • Project purpose and justification • Measurable project objectives • High-level project descriptions and scope • High-level risks • Summary milestone schedule and budgets • Project approval requirements • Project manager assignment <p>Planning</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Establish the scope of the project (2) Refine the objectives and define the course of action required to attain the objectives that the project was undertaken to achieve (3) Quality planning (4) Risk management planning
Phase 3	<p>Development</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Rapid prototyping (2) Collect customer feedback (3) Alpha testing 	<p>Execution</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Complete the work defined in the project management plan to satisfy the project specifications (2) Perform quality assurance
Phase 4	<p>Testing and Validation</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Further alpha testing with validation through: <ul style="list-style-type: none"> • House of quality • Quality function deployment (QFD) (2) Beta testing (3) Develop launch and post-launch plans 	<p>Control</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Quality analysis through: <ul style="list-style-type: none"> • Paretos, control charts • House of quality (2) Cost and risk monitoring (3) Scope verification
Phase 5	<p>Full Production and Market Launch</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Rollout (2) Produce at full capacity (3) Monitor results (4) Plan full life cycle 	<p>Close-Out</p> <p>Key activities:</p> <ol style="list-style-type: none"> (1) Postmortem meetings

Table 2: Comparison of the key activities of the SG and PMI processes (based on Cooper, 2011 and PMI, 2013).

set targets (PMI, 2013). It also describes the role of project managers as monitoring and controlling the work of producing the products, services, or results that the project was undertaken to create. This view is somewhat at odds with that of NPD scholars, who emphasize that “Stage Gate is not, and never was, intended to be a control mechanism” (Cooper, 2011, p. 113) that allows management to manage projects on a micro level, such as through time lines, staffing levels, budgets, or costs. Instead, the NPD literature conceptualizes SG as a “business” or “macro” process or “macro planning framework” that is broader in scope than project management but should be combined with project management on the micro level during later project phases—namely, development, testing, and launch (Cooper, 1994; Cooper, 2008). Accordingly, the review gates in the SG framework are not a review against project plans, but rather against criteria that support go/no-go decision making.

The idea of SG and project management as complementary approaches can be found in the project management literature. For example, a 2008 study concludes that project management, while applicable to new product development, provides “incomplete perspectives on NPD,” and therefore needs to be applied in combination with NPD approaches (Pons, 2008). A recent empirical study (Schultz et al., 2013) confirms this assessment: Project management practices, if used on their own, fail to deliver positive results when innovativeness is high, whereas SG has a positive effect on both incremental and highly innovative new project efforts. This effect is reinforced when project management practices are applied within an SG framework.

At the current state of the research, however, it is unclear how this complementarity can best be achieved (i.e., how the implementation of project management processes, such as traditional waterfall or agile development, should be coordinated and responsibilities assigned). Moreover, the process for implementing a complementary SG/project management system has not been researched: Schultz et al. (2013), for example, point out that project management may be a low-hanging fruit that is relatively easy and inexpensive to implement, while a functioning SG process may take years. If this is the case, companies may go through years in which two frameworks on very different levels of maturity have to be orchestrated.

An additional challenge is that the SG framework itself is becoming increasingly varied. An increasing number of publications raises concerns about the practicability of SG under special conditions, such as innovations that require a very high level of user involvement (Veryzer & Borja de Mozota, 2005), projects that follow an open innovation paradigm (Grönlund, Rönnerberg Sjödin, & Fishammar, 2010), projects that are focused not on product but on process innovation (Kurkkio, Frishammar, & Lichtenthaler, 2011), or incremental projects for which a full gate review may be overkill. These issues have typically been addressed by both theoretical expansions of the basic linear process model (Cooper, 2008) and modifications of standard linear practices as they occur in industry practice (Barczak, Griffin, & Kahn, 2009; Ettl & Ettl, 2007). Among others, these changes allow companies to “fast-track” decisions by dropping stages, to revisit earlier stages, and to add iterative design-test-build cycles to acquire more meaningful customer input when knowledge is sticky (Cooper, 2008). This has led to a considerable expansion of options. When the SG system was first conceptualized, it was intended to bring process management thinking to the innovation process by providing a “skeleton from which to develop a custom-tailored model” (Cooper, 1990, p. 52). In current publication, the recommendations are more complex and differentiated: The oldest and most commonly described SG model (Cooper, 1990) is characterized as the “new product” SG. It is intended for projects that lead to a product launch and are large enough undertakings that they require the involvement of higher-level decision makers and collaboration across technical disciplines and marketing. The product in question can be relatively similar to already-existing products (e.g., relaunch in a new market or product line extensions) and pose limited uncertainties. Cooper’s objective, however, is to facilitate new product launches that are “bold” and lead to differentiated products with superior value to the customer. Accordingly, SG is applicable to projects where aspects of the technology and market reactions are

initially unknown. If these projects require intense customer involvement to iteratively elicit requirements and build solutions, the new product SG is replaced with the “significant customer request (SCR)” variant of SG (Cooper, 2008). Projects that are typically considered product maintenance (e.g., fixes in response to a bug report, changes to the product design to reduce costs) are managed with different SG processes—namely, SG Lite and SG Xpress, because they require minimal strategic marketing input and are executed within the R&D organization. Platform or technology projects are addressed with a technology Stage-Gate that has very limited market criteria and only requires one financial estimate, for the five-year cumulative contribution to profitability.

In recent publications, Cooper goes even further with regard to adaptive project management and anticipates that SG frameworks for new product projects will be replaced by a completely customized individual project “canvasses” that, among other things, put less emphasis on documentation than the current approach; define deliverables in accordance with key assumptions, rather than a standard list; and rely less on cross-functional collaboration and more on heavyweight, integrated project teams (Cooper, 2014b). This recommendation bears a strong resemblance to the lean start-up methodology described above and its learning-based approach of formulating and rigorously testing assumptions: Instead of developing one tailored SG model, or multiple SG models tailored to different types of projects, companies will have to develop an SG approach for each project and integrate it with project-specific project management practices.

Framework and Research Questions

For the purpose of this study, we are focusing on high-technology companies that create manufactured products. Their fast-paced technology environments force them to have high levels of exploration to stay current, while the manufacturing of products introduces the need for exploiting process knowledge and long-term capital investments. These companies thus face the challenge of ambidexterity. We further focus on product development organizations that execute maintenance projects, new product projects, and platform/technology projects within the same research and development organization.

Figure 4 characterizes these projects further: Because maintenance projects have little uncertainty with regard to customer benefits and technologies and limited need for cross-functional collaboration, they do not go through a fuzzy front end. In contrast, new product projects generally require up-front homework; some of

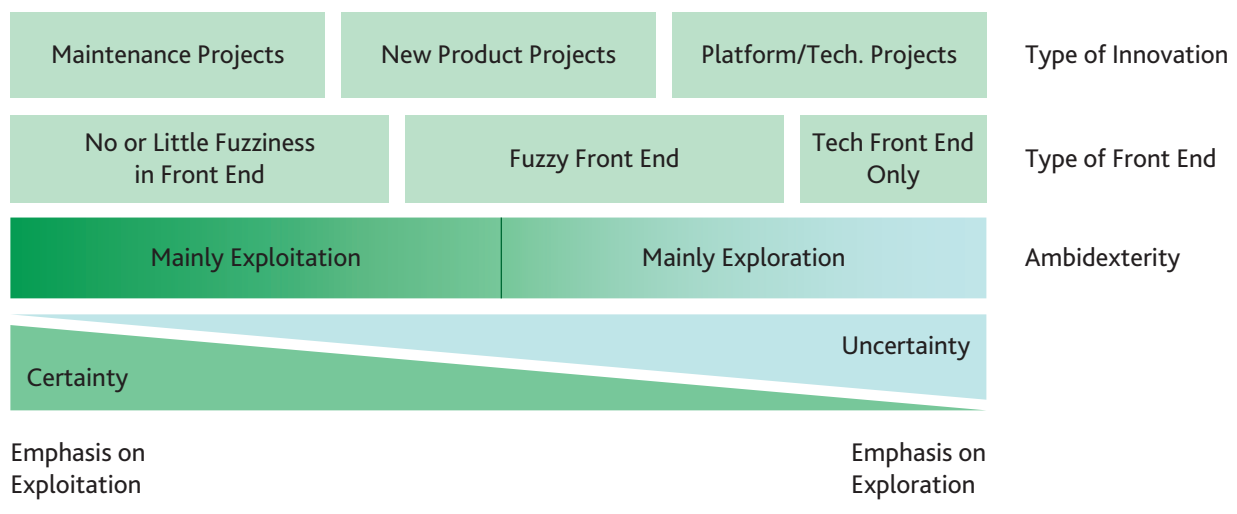


Figure 4: Characterization of innovation projects.

them are relatively incremental, with only limited uncertainty and simple front ends. These projects, however, provide limited differentiation from the competition. Companies, therefore, strive to also pursue radical product innovations, which are typically associated with higher levels of uncertainty and complexity and more unstructured front ends. They are the type of projects that front-end research concerns itself with and that the SG processes aim to improve. Technology projects are not focused at a product launch but lay the technology foundations for future innovation. Uncertainty is generally high, but, because product concepts and market response are not yet a focus, collaboration between engineering, marketing, and other functions is limited. The front end is predominantly structured around technology questions: The team typically knows which variables to focus on and designs project plans around experiments that address uncertainty about the state of these variables (Koen et al., 2001). Although uncertainty is high, the front end is not “fuzzy.”

The characterizations in **Figure 4** are only a general representations of phenomena that occur as continua, for example, no project is completely certain or uncertain. Also, there are naturally blurry boundaries between product improvements (i.e., maintenance), particularly those that are relatively complex and touch on several aspects of the product, and new product projects that are focused only on incremental product innovation. The question of adaptive project management is thus not a simple exercise of matching the project with the right type of generalized project approach (e.g., matching maintenance projects with a SG Xpress framework) but requires more project-specific “tailoring” with regard to the overall approach and the project management tools in use. This idea is echoed in the project management (e.g., Patanakul, Shenhar, & Milosevic, 2012) and the product innovation management literature (Cooper, 2014b). However, how this occurs in practices is currently largely unknown, resulting in the first research question of this study:

How does project-specific “tailoring” of SG project management occur in practice?

The choice of SG and project management framework and tools needs to occur during the fuzzy front end, when the project is initially defined, approved, and planned. However, the front ends for different product development projects unfold differently, depending on the uncertainty of the project, on how radical or incremental the innovation is, and on whether it is exclusively focused on technology or also on the launch of a new product. To understand the process of project specific SG/project management adaptation, this research therefore investigates:

How (and with which levels of uncertainty) do radical and incremental development projects move from fuzzy front end to product development (project execution)?

A key determinant of adaptive project management is uncertainty. It determines the general “macro” approach to project management (i.e., the use of a particular SG framework) and also what micro-level project management actions should occur—if, for example, project plans should account for phases of trial-and-error learning or selection, and how tightly budgets and schedules can be realistically planned and should be controlled. The practice of adapting to project uncertainty, however, is currently rarely discussed in the product innovation context, leading to the next research question:

What project management approaches are used for high-uncertainty projects?

The discussion above further demonstrates that the PMI project management framework and the SG framework are distinct, but should be applied in combination, resulting in the research question:

How is complementarity of project management and SG achieved?

Research Methodology

This research follows an inductive design, commonly used to develop theory from case studies (Eisenhardt, 1989; Yin, 2009). It is based on three consecutive data-collection rounds. Results of earlier study steps inform the research questions, research instruments (i.e., interview questionnaires and code books), and case selection for subsequent work. Insights gained from later data collection and analysis are used to revisit and reanalyze earlier studies.

	Phase 1	Phase 2	Phase 3
Sample and Respondents	7 R&D managers from 7 high-tech companies, mainly focused on manufactured high-technology products	5 respondents from one medium-sized high-tech equipment manufacturer Respondents: 4 top-level R&D managers and 1 lead of project management office (multiple interviews per respondent)	6 R&D managers, chosen per theoretical sampling, comment on 8 companies to represent different company sizes, different levels of project management sophistication, and different products (software and hardware)
Research Emphasis			
<i>How does company-specific and project-specific "tailoring" of SG project management occur?</i>	X	X	X
<i>How do projects move from fuzzy front end to product development?</i>	X	X	
<i>What project management approaches are used for high-uncertainty projects?</i>	X	X	
<i>How is complementarity of project management and SG achieved?</i>		X	X

Table 3: Study description.

Table 3 shows the main focus and sample for each of the study phases: Phase 1 investigates adaptive project management in the front end and at later product development stages. It identifies various themes of interest—namely, adaptive project management as an ad hoc adaptation, the prevalence of SG as the only project management approach with limited complementarity between SG and project management practice, and the persistence of uncertainty in later project phases. Phase 2 was designed to investigate the linkages between

these themes by pooling multiple perspectives in one organizational setting. This, in combination with Phase 1, enables a cross-case analysis or “pattern search” (Eisenhardt, 1989) that leads to initial data interpretations and working theories. Phase 3 is conducted to test these interpretations in additional, theoretically sampled cases to either gain additional confidence in the interpretations or reject them and replace them with new working theories. In total, the practices of 12 companies were investigated and 17 different respondents were interviewed.¹ Case notes and summaries prepared by the researchers were used for the analysis. A subset of interviews was transcribed and coded against standardized code book. To ensure reliability, case data within each study were analyzed by a minimum of two researchers who, with very few exceptions, worked independently of one another and only discussed their results after their initial analysis. Cross-study comparisons were jointly done by the two lead researchers, who discussed the findings and implications. Additionally, the data from this research step and the initial interpretations were presented to a four-person advisory council in order to gain additional perspectives, lines of inquiry, and ways to interpret the data.

Phase 1

Phase 1 focused on the product development practices described by R&D managers from seven technology companies, which frequently launch new products with varying degrees of innovativeness. The companies selected for the research were small to midsize (with a maximum annual revenue of US\$800 million, and most of them substantially less) and organized R&D activities within the same organizational units. The interviewees had responsibility for multiple product innovation projects as managers or directors of R&D, product development, and product management. They were familiar with projects that range from incremental improvements and product maintenance to fundamentally new products and platform initiatives.

The study was built on the theoretical framework in **Table 4**, which is adapted from Sperry and Jetter (2009) and synthesizes the literature recommendations on how to match project management approaches to different types of R&D projects. The framework includes one strategy that is focused on up-front planning (linear, similar to the new product SG), three variations of strategies for learning through experiments (trial and error, recursive, evolving), and one strategy for parallel trials (selectionism).

The approximately one-hour interviews were based on a semi-structured protocol that consisted of three main parts. In the first part, the respondent was asked to describe the standard process (or processes) that their organization employs for managing product development projects. This served as a means to establish a baseline understanding of company practices and put respondents at ease by acknowledging that the company usually follows a rational, structured approach. The second part of the interview used episodic interviewing and asked respondents to recall a past project that deviated from this baseline process. The respondent described the reasons for the deviation, the way in which the project unfolded, the people involved, and the project outcomes. He or she was also asked to characterize the project uncertainty and the project management approach by selecting descriptive statements from a list of options and to show the uncertainty level of the project on a graph. For example, a project was identified to have “medium to low” technology uncertainty when the respondent agreed with the statement that at the onset of the project: “We had a good understanding of the technology with only few uncertainties.” In the third part of the interview, respondents were asked to recall another project that deviated from the baseline process, but differed from the first project in that it had

¹There is some overlap between the case samples: One of the respondents from study 1 also participated in study 2 and a company represented in study 1 was also represented in study 3, though by a different respondent. Moreover, one of the respondents in study 3 commented on the practices of three different companies that he was familiar with.

Nature of the New Product Project	Technology Uncertainty	Market Uncertainty	Recommended Project Management Approach
Innovative New Product New functionality with potential to change current technology paradigm; market adoption by visionaries	High	High	Trial and error: Initial planning steps are nonlinear, nonorderly, and nonpredictable and simultaneously focused on discovery and feedback learning
Significant Improvement Product Significantly improved functionality through adding and removing of features, making the product attractive to mainstream adopters and adjacent markets	Medium to Medium-High	Medium to Medium-High	Planning steps are focused on testing/validating assumptions through experimentation and feedback, but approaches differ with regard to their initial structure: <ul style="list-style-type: none"> • Recursive: Loosely coupled, unstructured steps are decided on as feedback information becomes available, making the actual project activities and outcome relatively unpredictable. • Evolving: Project steps and feedback loops are planned up front, but the length and outcome of each feedback cycle are unknown. • Selectionism: Project steps are designed to generate and test alternative solutions in parallel and select the best alternative after testing. Learning occurs after the fact.
Incremental New Product Moderate changes in existing functionality, targeted at existing markets	Low to Low-Medium	Low to Low-Medium	Linear: Process consists of a fixed sequence of several defined gates and stages.

Table 4: Recommended project management approaches for different levels of uncertainty.

a different outcome or different reasons for not employing the standard process. The interviews contained information about the standard process and at least two different projects that did not follow this process. All interviews were recorded and two researchers wrote their field notes and interview summaries separately.

Phase 2

Phase 2 of this research investigated how a classic SG for new products is employed across a company with very different product innovation projects. The chosen case study company is a high-tech equipment manufacturer in the semiconductor industry (with about US\$110 million in annual sales, international locations,

and 400 employees) that adopted SG management as a standard project management approach in 2011/2012 but was still in transition from its former ad hoc approaches. The company was chosen because of the number of projects it manages (about 60 at any given time) and because of the diversity of its projects, which results from the nature of the products. It develops and manufactures complex measurement tools that consist of a base for handling samples and logging and analyzing data, modules that attach to the samples that are to be tested, and measurement heads that take measurements of samples. Some of the system components, such as the measurement heads, can be swapped out for other designs to accommodate specific customer needs. The design of the entire system and its interfaces (platform), however, is complex and represents a long-term commitment that stretches out over years and only occurs every three or more years. The company still sells and services products that are based on a 15-year-old platform.

Interviewees were heads of all functional groups of the R&D organization (system design, design of the modularized measurement, probe station development), which consists of around 60 scientists and engineers. Using a modified version of the interview questionnaire used in Phase 1 of this study, each interviewee was asked to give three cases of past projects that they had knowledge of. The resulting 12 case descriptions were analyzed with regard to the project management process used, the type of the project, its origin, and the level of ambiguity/uncertainty associated with the project. In addition, three interviews were done with the head of the project management office. Each interview was conducted by one or two researchers using a semi-structured format, was tape-recorded, and transcribed. Two researchers manually coded the transcriptions. Based on the information from the interviews and the field notes, a within-case analysis was conducted.

Phase 3

The first two phases resulted in a number of sometimes competing explanations for our observations and recommendations. To gain additional perspectives, the study results were discussed with interviewees—all in managing positions in R&D—who had not been involved in the first two phases of this study. These interviewees were chosen for their ability to add additional insights that were currently not represented in the study. In particular, they offered the perspectives of marketing and product management professionals (four respondents, representing five different companies), as well as project management practitioners with formal PMI training (two respondents in two companies with sophisticated project organizations). The sampling strategy was based on literal and theoretical replication (Eisenhardt, 1989; Yin, 2009). Literal replication resulted in the inclusion of cases that were structured like those already investigated. Theoretical replication sampled cases from distinctly different companies. The following example illustrates this approach:

Our study observed that project management practices in product innovation rarely go beyond simple task lists and schedules and thus fall far behind the body of knowledge that PMI represents. One possible explanation is that the companies under study and their project managers generally lack project management sophistication (i.e., have no formal project management training and no dedicated project office) and are therefore not aware of what project management has to offer. An alternative explanation, however, is that “PMI-type” project management is known but is not used in product innovation because it is poorly adapted to high uncertainty in product innovation. To test these alternative explanations, we searched for respondents with high levels of project management knowledge and asked

them how they manage projects with different levels of innovation. If they do not apply project management tools, even though they are very knowledgeable in project management practice, the first explanation is rejected and more credibility is given to the second, alternative theory.

Interviews lasted between 40 and 90 minutes and were tape-recorded (with two exceptions) and fully transcribed. In addition, the researcher created notes and interview summaries. The interviews did not follow a structured protocol, but started with a high-level description of project results and an invitation to the interviewee to comment on the findings. Accordingly, each interview touched upon different aspects.

Results

Observations from Phase 1

Tables 5 and 6 summarize the main data from the first study phase. With the exception of the software company in the sample, which uses agile development, the companies follow a linear product development approach, which was frequently referred to as an SG or phase-gate process. In all but two cases, this linear process resembles Cooper's (2011) SG model for new products. The two exceptions were a small company that did not do any gate reviews, because all decisions were made by the owner, and a large company that had gates that either included the marketing or the technology decision makers, but not an interdisciplinary decision team. Within the linear process frameworks, the front-end/ideation stage is treated as a distinctly different phase with little structure. It puts emphasis on learning-based approaches that aim to reduce uncertainty and ultimately provide clear project scopes and time lines for later stages.

None of the respondents mentioned a simultaneously occurring "micro" project management process. Instead, the plans, milestones, and gate deliverables of the SG are also used for project management activities, including monitoring and control. Respondents frequently emphasized the importance of adhering to the company's standard process(es) and often mentioned the need for more discipline and fewer rogue projects. This was predominantly driven by the need for project monitoring and control to create better transparency about budgets, resource allocations, and timelines. In contrast, the desire for better SG discipline was not linked to portfolio considerations: The question of whether the company addresses the right markets with the right mix of novel and more incremental offerings was not mentioned as a concern.

Despite the desire to standardize approaches, the data in Tables 5 and 6 show that all respondents modify their baseline process for some projects² with different needs and thus engage in a practice of adaptive project management. Most modifications of the standard process occur early in the project and are compressions of the early project phases, made possible by skipping review gates entirely and quickly moving the project toward a funding decision and definite plans. The practice thus resembles recommendations for the SG Xpress and SG Lite (Cooper, 2011) process, which applies to projects with moderate and low uncertainty, such as products created in response to similar competitor products or simple extensions into similar markets. In our study, however, we found compression not only for cases of relatively low uncertainty but also at opposite ends of the spectrum: High-uncertainty projects enter product development with limited up-front research because learning without doing appears impossible and/or there is a strong sense of urgency. This urgency is caused by a variety of factors, including stakeholder requirements and upper management decisions to move a project ahead because of a closing market window or a competitor's action. The deviation from the agreed-upon standard process occurs ad hoc, is not guided by clear criteria (e.g., project characteristics) or transparent deliberations, and is frequently described as a lack of discipline.

² One exception is the only "software-only" company in the sample, which could not name any exceptions to its agile approach.

Company	1	2	3	4		
Industry	Semiconductor	Financial software and services*	Optical devices for biotechnology and semiconductors	Medical equipment for doctors' offices		
Standard for front end	Relatively linear, focused on the creation of two business plans	Evolving	Evolving/recursive	Selectionism (parallel concepts benchmarked against one another), based on job mapping with customers		
Standard for new product development overall	Linear but not fully developed SG (e.g., only vice president approval required, not cross-functional) No linear process for radical technology innovations 25 to 40% of approved projects are canceled after initial design because of market shifts	Evolving (agile product development)	Linear SG for market-driven projects; separate process for technology projects	Linear SG		
Process formalization	Yes	Yes	Yes	Yes		
When does the front end not follow the standard?	Lack of discipline (new team member) New information forces revisiting of earlier plans Lack of information, but company feels that the information isn't attainable and therefore moves forward	No	Great urgency/short market window Top executive wants project	Top executive wants project in response to a competitor product Low levels of uncertainty and proven need make detailed up-front investigation obsolete		
Types of process exception	Recursive front end	Evolving Front	Evolving throughout project	Evolving throughout project	Evolving in front end and execution	Linear (no up-front homework)

Table 5: Short overview of study interviews, part 1.

Company	1	2	3	4			
Nature of the project for which the exception occurred	New product to new market	Existing product to a new market		New product introduced to a known market	New product to new market	Modification of an already-existing product to a known market	Modification of an already-existing product to a known market
Level of technological uncertainty exception project	4	2		4	4	3	1
Level of market uncertainty of exception project	5	4		3	2	3	1
Uncertainty score	9 High	6 Medium		7 Medium	6 Medium	6 Medium	2 Low
Project success	Yes	No		?	?	No	Yes

Table 5: Short overview of study interviews, part 1. (continued)

Overall, it is very challenging for the companies to fully understand project characteristics up front. The study shows that initial assumptions about market and technology uncertainty are frequently incorrect and unknown unknowns emerge during project execution. They force the project teams to adopt a more recursive or evolving approach “on the fly,” without having prepared for it.

The state of adaptive project management is thus characterized by a paradox: To respond to the needs of different innovation projects, adaptation frequently occurs and leads to the use of learning-based approaches. Industry practice thus already implements—at least to some extent—what the literature proposes as the future frontier of project management. However, the practice of project adaptation is shaped ad hoc, based on inconsistent criteria, and with very limited understanding of the drivers of project uncertainty and the appropriateness of alternative project approaches. Moreover, the systems that are in place rely on the notion of a single standard process, modeled after SG, and are therefore not set up for managing adaptive project practices from a project management perspective. This causes companies to push back against their own adaptive practices and work toward increased standardization.

Company	5		6		7	
Industry	Software development group for large consumer electronics company		Measurement equipment for semiconductor industry		Laser technology	
Standard for front end	Evolving (agile development)		Recursive		Evolving	
Standard for NPD in general	Evolving (agile)		SG, but only recently introduced		Loose, closer to evolving than to linear	
Process formalization	Yes		Yes		Very little (some standards for documentation and analysis)	
When does the front end not follow the standard process?	Internal customer provided detailed requirements, enabling a shorter exploration phase Third-party needs determined SG		Made-to-order custom products with relatively low market uncertainty made the fuzzy front end relatively linear Technology challenges caused project to follow an evolving pattern, even after it was in execution		Difficult to determine, as there is no clearly defined process Strong internal sponsor (e.g., top management) changes project dynamics	
Type of process exception	Shortcut Evolving in early stages	Linear (Stage-Gate) to comply with third party throughout project	Linear (compression), particularly in early stages	Evolving in late stages	Front end more linear than usual	Front end more recursive than usual
Nature of the project for which the exception occurred	Modification of an already-existing product to a known market	New product to a known market	New product to an existing market	New product to existing market	New product to a known market	Existing product for a known market
Level of technological uncertainty of exception project	5	4	5	4	2	1

Table 6: Short overview of study interviews, part 2.

Company	5	6	6	6	7	7
Level of market uncertainty of exception project	5	3	3	3	1	1
Uncertainty score*	10 High	7 Medium	8 Medium-High	7 Medium	3 Low	2 Low

*Uncertainty score is the sum of market and technological uncertainty, as perceived by the respondents when the project was started. Scores for market and technology uncertainty range from 5 (very limited knowledge) to 1 (full understanding). The sum score ranges from 10 to 2.

Table 6: Short overview of study interviews, part 2. (continued)

Observations from Phase 2

In the second study phase, we investigated the drivers for adaptive project management and the formal and informal practices for adaptation within a single company. The company has defined a standard process that consists of five phases (ideation, definition, investigation, development, pilot), which are separated by a phase-gate review. Gate reviews require approval by the executive management team, consisting of the CEO, CFO, and the vice presidents of engineering, marketing, sales, manufacturing, and human resources. During a monthly meeting, all projects are reviewed by these executives. Phase-gate meetings are conducted during the same meeting, whenever a project has completed a phase. A phase-gate review can result in the cancellation of the project, a pass with exceptions that are tracked, or an unconditional pass that moves all aspects of the project into the next phase. The company’s process framework emphasizes feedback control through the tracking and reassessment of exceptions that occur at review gates, as well as by revisiting project plans through a program change process. Project management tools and procedures, such as a project charter, work breakdown structures, schedules, resource plans, risk assessment and mitigation, scope change management, and weekly project updates, are part of this standard process. These methods are used as early as in the definition stage.

The company executes a broad range of product innovation and technology development projects that it classifies into the following categories:

Strategic projects: These are very innovative and research-focused projects, which aim to create the next-generation technology. They are fuzzy in nature, have a high level of uncertainty and no clear expectations of the results, and are usually managed by trial and error, with poor documentation. Influential product champions often trigger strategic projects, such the company founder who is a recognized technical expert. They start with a relatively limited budget for exploration that is increased as results come in. They are not typically considered time critical. These projects are similar in nature to Cooper’s (2011) technology projects.

Product development projects: These innovations respond to needs that were identified through market research. They are targeted at creating the next generation of an already-existing product. Every few years, a product development project can take the form of a new platform project. Small projects have budgets upwards

of US\$10,000. Large initiatives exceed US\$100,000. Results of these products are targeted at specific market opportunities, and hitting the market window is critical. Projects of this nature are relatively well planned and have clear objectives and medium-low levels of uncertainty. The company's phase-gate process is predominantly used for this type of project. In Cooper's (2011) framework, some of the small projects would fall under the category of maintenance projects, whereas the larger initiatives have the characteristics of a new product project.

Customized projects: Customer-driven projects represent special cases of product development projects that are initiated and funded by customers and may be targeted at adding features to existing products or merging the capabilities of two different products. They are relatively small because they only add to or adjust an existing feature set. They typically only involve engineering work within one of the functional R&D groups with minimal interfaces to other groups, with the exception of manufacturing. Because the customer orders the modification, these projects require quick action and are managed with priority. For these reasons, customized projects have been managed outside of the phase-gate process. A key challenge for these projects is the bidding process: When customers inquire about a customization, they expect a binding quote in a relatively short period of time, leaving little time for up-front homework. Moreover, the company does not want to overinvest in planning activities for a project that may or may not happen, because, as one interviewee explained, "8 out of 10 times" the customer decides not to order. As a result, customized projects can have very different levels of uncertainty and unknowns. In some instances, uncertainty was perceived to be low at the start of the project, but increased in the later stages when customer requirements became clearer or technical challenges became apparent. This has resulted in larger than anticipated development budgets and feature and schedule creep. The customized projects are new product projects in Cooper's (2011) definition.

Sustaining projects: Sustaining projects are a second special case of product development projects. They are planned and executed within a functional team in R&D, typically in order to address a technical or business need, such as cost reduction or standardization across different products. Project budgets are small (typically less than US\$10,000) and the need for coordination with other functions or upper management is minimal. Sustaining projects are therefore managed outside of the phase-gate process with approaches that are up to the project team. One example given by a respondent was a cost reduction of the bill of materials by US\$1,500. The project was managed as a WIG (wildly important goal) project, which means that the project team had a sense of urgency and ideas for improvements were solicited, evaluated, and quickly implemented. Progress was tracked weekly against a task list and simple measures (total cumulative savings, percentage of ideas in evaluation, implementation, etc.). The process had no gate reviews. It had very little uncertainty because the objectives were clear and the course of action was technologically clear as well. These projects would be categorized as product maintenance projects in Cooper's (2011) framework.

The company is relatively new to formalized project management in its R&D organization (fewer than three years at the time of the study) and is implementing new product SG and general project management practices in parallel and without any clear delineation between them. The plan is to expand the new phase-gate review process, which is integrated with project management, to all projects with a significant development effort, including large sustaining efforts and large custom projects. The criteria for determining if a project is significant or not are unclear: In general, small projects with budgets of less than US\$10,000 are excluded, but exceptions can be made. In this case, they go through simplified gate reviews, where (by one respondent's estimate) as much as 90% of the review documents and criteria may not apply. When fully implemented, the project management office targets to have 70% of the R&D budget managed under the phase-gate process. The actual number of projects managed through this framework, however, appears to still be small. One engineering

manager estimated that three years into the process change, only about 10% of all projects (but most major initiatives with large development budgets) follow phase-gate processes.

Respondents give different reasons for why the company is adopting this process. The respondent from the project management office emphasizes transparency, which will allow upper management to more precisely forecast finances (project budgets and expected future project returns), project completion and product release dates, and current and future use of engineering resources. Gate reviews, therefore, require updated financials, a comparison of project budget and actual, a short report on risk factors (including impacts and contingency and mitigation), and information on staffing actuals and needs. These insights are expected to support a streamlining of the project pipeline so that it only contains projects that are important and will be successful, that are actively worked on, and that are sufficiently staffed.

Engineering managers agree that the company has difficulties in prioritizing and culling projects in its development pipeline and understand that upper management wants more visibility. However, they are generally more concerned with how best to manage individual projects and express doubts that one framework fits all needs, particularly as they are often using (planned and unplanned) iterative approaches that, they feel, are difficult to plan up front. They therefore worry that a lot of time will be spent on constantly revising initial plans. Moreover, they are concerned that projects that occur within functional groups, such as many of the sustaining projects (also known as maintenance projects), will not only *not* benefit from being more closely managed and monitored but may actually suffer because their efficient self-organization and flexibility is bogged down. The managers doubt that added reporting will result in substantial improvements with regard to delivering projects on budget or on time.

The issue of budget and schedule overruns was frequently raised and attributed to changes in customer requirements, which prompted changes to the product, technical difficulties during development, manufacturing issues, problems with supplied components that did not work flawlessly in the new system, and logistical problems. When asked to visually characterize project uncertainty for these projects, respondents provided graphs like the one shown in **Figure 5**.

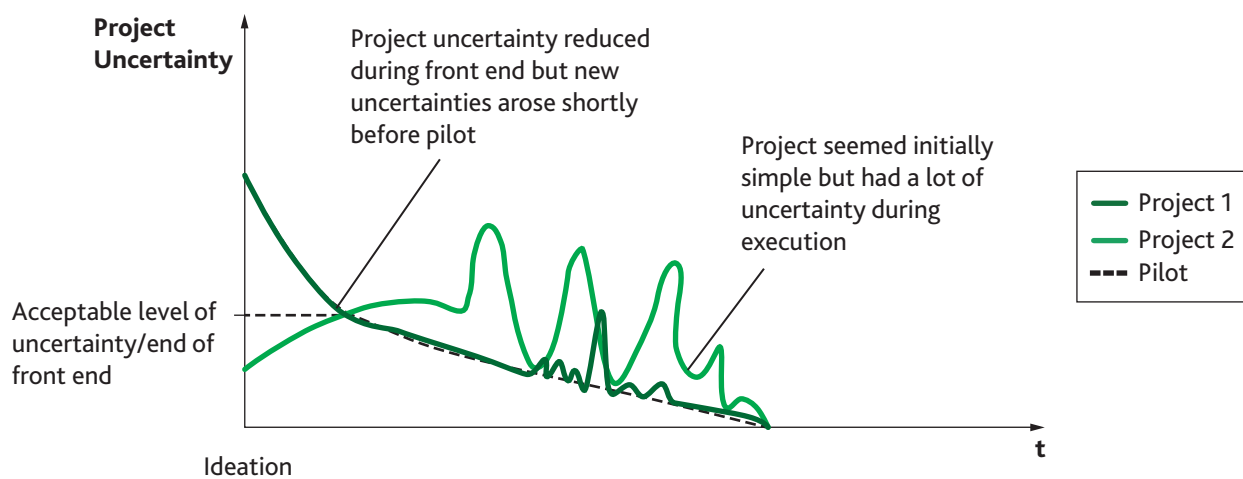


Figure 5: Uncertainty level for two different projects represented by a respondent.

The respondents' explanations for these problems fall into three broad categories and often occur in combination:

1. There was insufficient up-front planning because the project was rushed to project execution ("management wanted it"; "it was already on the project road map") or because there weren't enough resources to do a more thorough job, as is the case with some of the custom projects in study 2. A lack of planning and coordination also occurs when the technologist takes a project that originated in engineering too far without getting marketing involved.
2. The problems arising in the later stages were probably unavoidable and a result of doing something new and/or complex.
3. The initial planning was correct, but the business environment shifted over the course of a (too) long development cycle.

The large number of projects suffering from uncertainty after the front end cannot be explained by a rushed front end: The investigation stage, which occurs after project approval but before product development, can stretch out over nine months or more. Similarly lengthy front ends that consume up to 60% of total development time even before the project is funded are also reported in the literature (e.g., Smith & Reinertsen, 1997).

The case company is currently considering adding a new phase between definition and investigation, which would force project teams to plan and document how they want to approach the investigation phase—for example, by specifying how many cycles of experiments may be used in the next period, how long each cycle will take, and how much will it cost. The investigation phase ends with a review of a relatively large number of checklist items, including the completion of project schedule, resource, and risk plan; a report on a proof of concept; a validation test plan; the submission of invention disclosures; a product support strategy; and key supplier initial evaluations. These checklist items correspond with the recommendations of the SG process, which requires these issues to be addressed on a high level and recommends "spend[ing] enough time and money here so that you are reasonably confident that the product could indeed be developed . . . but don't develop the product!" (Cooper, 2011, p. 216). As a rule of thumb, this stage should not consume more than 10% of the development budget (Cooper, 2011), though practitioners on the project advisory council for this research report that higher percentages are common to improve up-front homework.

There clearly are competing philosophies at play: The new product SG requires gate reviews whenever a project is thought to be ready to pass a gate, by multidisciplinary decision teams that consist of owners of the resources that are required for the next step. A project (status review) meeting, on the other hand, occurs on a regular basis (e.g., monthly), regardless of progress, by people who need to know about the project status in order to decide if the already-approved resources, time lines, and deliverables are still realistic and how to keep the project "on track." The monthly meetings that occur in the case study company mix the two philosophies, which means that vice president-level managers participate in meetings that are purely status updates and do not require their decision. Although this is different from the recommendations of the SG framework, it appears to currently work for the size of the company and may actually improve knowledge exchange between functions. However, as more and more projects are added to this management approach, including those that require no interdisciplinary interaction, this may put undue strain on management resources—for example, it makes little sense for a vice president of marketing to listen to the status report of a pure research project, focused on innovating technology for taking measurements. As a result, the case company has started to differentiate between SG projects with executive reviews and SG projects without executive reviews.

Observations from Phase 3

Phase 3 of this study focused on explaining and drawing conclusions from the first two study phases by comparing observations across projects and case study companies, creating initial theories that explain the observations and collecting additional data (through follow-on literature review, additional case studies, and the expert advisory panel) to corroborate or reject the explanations. The road map of these lines of inquiry and the results are visualized in **Figure 6**, which will be discussed in the subsequent section.

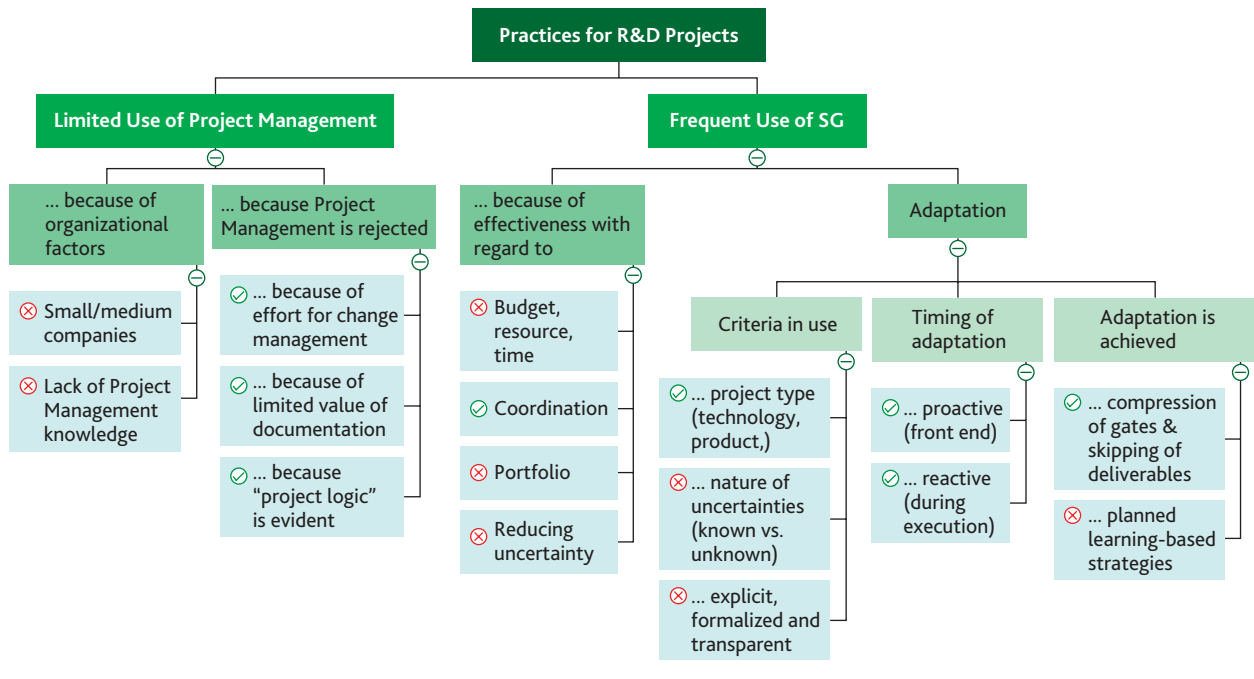


Figure 6: Lines of inquiry and results.

Analysis

Limited Use of Project Management

Project management practice in R&D organizations is very limited, even though product development fits the definition of project organizations (PMI, 2013): Development projects task a team of engineers, scientists, and marketing people to create a new product/technology for the benefit of the business. In doing so, they establish temporary organizations, supply them with resources, and hold them accountable for achieving objectives by a project completion date.

Organizational Reasons for Limited Project Management Use

We first investigated the assumption that project management use is limited as a result of company size or limited project management knowledge: We did not see a pattern with regard to company size.³ With regard to project management knowledge, we found that project managers in R&D, indeed, very rarely have formal project management training—the certifications for project management practitioners, as well as common terms and concepts in project management (e.g., work breakdown structure, earned value management, Gantt chart), were unknown to several respondents. With the exceptions of checklists and reports that were used at gate reviews and engineering change management, there also is little project documentation.

However, a lack of project management knowledge is not a sufficient explanation. Our study included multiple R&D managers who were familiar with PMI's standards, either through personal training/certifications or because their company maintains a project office that works with the R&D managers. One company in our sample even expects Project Management Professional (PMP)[®] certification from managers of its development projects (so-called program managers) and staffs each project with a program analyst whose job it is to implement the project management process. Nevertheless, even in these companies, several reasons were given why the project management body of knowledge does not fully apply to R&D. Those reasons included the following:

Project Logic

In R&D, the dynamics of budget, schedule, and quality play out in a distinct way. Budgets, even if large in dollar values, are often small in comparison to the sales revenues that the new product generates over a lifetime, even in fast-paced markets. They may amount to as little as 1% of product revenues. Even the most R&D-extensive industries rarely top out at more than 15% of R&D expenditures as percentage of sales. In such an environment, it matters much more that the project is completed and delivers on its promise than what it costs to get there, as the following quote from a respondent illustrates: "Honestly, budget is not that big of a deal for us. The timing is more of an issue, and I say budget is not a big deal, but if we said, hey, we can still make the timing but we need to bring on fifty contractors, that's a big deal, we're not going to do that. But, if it's, oh, yeah, we got 10 people on this and if we had one more contractor we'll still be on schedule, no problem, hire a contractor and

³ One of the least formalized project management processes in our study was used by the largest company (around US\$800 million in annual sales).

keep going.” Moreover, a very large percentage of R&D costs are typically caused by permanent staff. A budget overrun may therefore only have minor cash flow implications, though it may cause staffing problems for other projects in the development pipeline.

Quality of deliverables matters immensely—a project that isn’t completed at all or does not deliver what it was designed to provide has immediate impacts on revenues, positioning in the competitive landscape, and brand image. Design errors can cause very high costs for rework, as is the case in more traditional domains of project managements, such as construction. However, there is typically no way to offset these added costs by adjusting the scope: The product simply has to deliver what it was planned to do or it is useless to the marketplace. However, differences exist as to how this “full scope” is achieved. Some products are sold in small numbers, are manually assembled, and can still be modified and upgraded after they are at the customer site. In these cases, teams may ship an early version and improve upon it later. Other products are produced in the millions, with mass-manufacturing equipment, and would have to be recalled and scrapped if they were to have a problem. In addition, expensive production investments (e.g., for specialized tooling) would become obsolete.

Timing matters in fast-paced high-tech, but not everything is equally fast. The companies in our sample reported on product development times between one and three years. Platform innovation in manufacturing and measurement equipment can have a product life cycle of 10 or more years, while the market cycle for one of the consumer electronics products was fewer than two years. Some of the companies need to align their product releases with the calendar of customers (e.g., the Christmas season), whereas others have more freedom to pick a market entry date. One of the respondents, therefore, differentiated between scope-driven projects, where the schedule may be extended to make sure the scope is met, and time-driven projects, where the scope is determined by what can confidently be guaranteed within a particular time line.

The competing constraints of projects scope, quality, schedule, budget, resources, and risk (PMI, 2013) thus play out in such a distinct way that the direction for optimization is evident without much detailed analysis and much of the data that project management provides. For example, in time-driven projects, the market window needs to be hit at all costs, even if this means increasing budgets or accepting higher technical risks. This underlying logic of a project—the “why,” “what,” and “how”—that governs all decisions is sometimes referred to as project strategy (Patanakul et al., 2012; Patanakul & Shenhar, 2012). It is known to the project team and guides decisions, though implicitly, in such a focused way that project management tools are rarely referred to. Our data, however, hint at one possible exception: R&D organizations with mainly time-driven projects seem to use project management tools for scheduling more frequently and with more rigor than organizations with mainly scope-driven projects. This would make sense because demanding timelines need to be kept under control. Also, in comparison to companies with assembled business-to-business products (measurement equipment, dental chairs, lasers), we found slightly more rigor with regard to project management and SG in companies with mass-manufactured products that cannot be modified at the customer site. However, most of the data come from scope-driven projects and assembled products, so we cannot draw strong conclusions.

Documentation: Value Versus Effort

A common assumption in project management (PMI, 2013) and in product development (Ulrich & Eppinger, 2008) is that there is inherent value in documenting project changes because this improves coordination, facilitates learning, and makes future budget or schedule forecasts more precise. This leads us to the assumption that respondents would value and strive for project documentation, even if a project’s internal “logic” makes it simple to make trade-off decisions with very limited data. In reality, however, much of the project is managed

informally and with little documentation, other than, in some cases, engineering change management. One reason is that time-driven projects often need to be reduced in scope to be on time for the product release date: Reduced documentation is one area to find time savings. The decision of what to skip and what to do is characterized as a negotiation with project stakeholders. Another reason given is the limited usefulness of documentation for some types of R&D projects—namely, those that do not go into production (e.g., projects that are focused on technology validation or demonstrating a product concept) and those that require a lot of innovation. For example, the project management office lead of the very large and sophisticated company who was interviewed as a contrasting case in study 3 explained, “The effort to maintain that as people try, and try, and try, and try five different things to find what’s going to work, there’s no value for that overhead.” The same thinking leads to the recommendation in the SG literature to require very little documentation for innovation projects (Cooper, 2011).

Frequent Use of Stage-Gate

Our findings show that SG is the dominant way to organize R&D projects. Eight of the 12 companies in our sample use a process that implements the SG model.⁴ For each gate, the SG framework prescribes outcomes and the format in which they need to be presented (e.g., structure and content of a business case or marketing requirements document). Activities within each stage are not prescribed in detail, so teams in one part of the project can use one approach (e.g., agile approaches to project management in software engineering) while other teams use another approach. In several companies, diverse approaches are used in parallel, though typically not by the same group. The following sections describe the nature of project adaptation.

Project Adaptation by Type of Project

Within the SG framework, project adaptation occurs in two forms: adaptation of a single standard process by skipping gates, and deliverables or the selection of different SG frameworks for different types of projects. The latter is less common. Most companies use a *single* new product SG with company-specific review criteria, checklists, and supporting documents that are adjusted for project needs, typically by dropping gate requirements that do not fit the specific project. As a result, gates can be spaced much more closely, but the project still has to go through all formal gates. This approach is frequently used for incremental maintenance projects, which are treated like any other new product project but simply need to provide less documentation. One manager mentioned that adjustments to the company’s standard process can be drastic and estimated that for a small project for which prototypes already exist, up to 90% of the SG process does not apply.

This practice differs from current SG literature, which recommends *different* SG for new product, maintenance, and technology projects. The main reason for building off a single, rather than separate, SG framework is the desire to create discipline around the new product SG process and to ensure that technology and maintenance projects retain market focus. Accordingly, most respondents never refer to “research” or “technology” projects,

⁴The four nonusers of SG were:

- a very small company, in which all product development decisions were made by the company owner;
- a large company that had a rudimentary SG process in place; this process lacked formalism and was not designed to be cross-functional;
- a software company; and
- a premarket product development group in a very large company, which is briefly described in (Observation from Phase 3).

even if projects are exclusively focused on technology creation and do not consider customer acceptance, business model, or manufacturability. Instead, they are considered product development because they develop the technologies that will go into future products and therefore need to retain a strong market focus. Accordingly, one respondent warned against excluding projects too easily from the full SG review of the new product SG: “[T]he biggest detractor is the Stage-Gate (review) or people that say, ‘Well, it’s too big. It’s something else. It doesn’t belong in a Stage-Gate or it’s too small, we don’t need to spend all this time.’” A similar sentiment was expressed by a director of engineering, who employs a separate SG project for technology investigations. He points out that this practice can lead to technology projects that take on a life of their own and are poorly linked to market needs.

The desire to retain market focus for all projects and enforce discipline for new product projects explains why so few companies in our sample follow current SG recommendations and choose alternative SG models. Additionally, there clearly is a time lag between academic research findings on SG and their implementation: Even though the new product SG dates back to 1990 (Cooper, 1990), the companies in our study are relatively new to SG management. Even the most experienced company only had a 10-year track record. Companies may simply still be focusing on the new product SG because it is the first one they have implemented. They may also not yet be aware of more recent recommendations with regard to project adaptation (Cooper, 2011, 2014a).

Three companies in our study employ different SG processes for different types of projects. Among them is case company 3, which is the second largest company in our sample, with US\$600 million in annual sales; it has been using a sophisticated SG framework for almost 10 years. It uses two different linear project processes—one for market-driven development projects that respond to market opportunities, and one for technology development projects that originate with an idea by technologists and/or a gap in the technology road map. The market-driven projects are carefully analyzed and planned up front and only receive approval if a detailed business case is presented. Technology projects that show future promise for the market are approved with less formality and up-front planning. Their budgets are typically small (under US\$100,000). The vice president of engineering explains the process as follows: “On the technical side of things, it is much easier to get a project started. Basically, somebody has to have a bit of enough of a good idea and they need to convince the CTO [chief technology officer] and me . . . here’s how much money it will take me to look at this, and if that fits in our budget and basically the opinion of two or three people, they can decide, ‘Yeah, let’s launch something.’ You know, if projects are less than US\$100,000, it’s pretty easy to get something launched. . . . It’s three PowerPoint slides.”

This approach to technology projects is chosen to make sure that the source of radical innovation—new technology potentials—are funded. If a new product SG process were to be employed for these projects, fundamental developments may never be funded because they do not fit the approval criteria. Alternatively, they may be eventually funded (possibly with delays), based on planning activities that provide little value and result in poor data, such as market estimates despite a fundamental lack of market understanding. Accordingly, a different respondent in a different company was worried that too many research projects are managed with the SG process: “I really think that there is a bar that you have to be above where it’s really going to help increase efficiency. It’s not as simple as the project is going to cost this much or whatever. You’ve got to put in the uncertainty, how much uncertainty is there in the marketplace, how much uncertainty is there in the technical aspects of the project. I think those really should be part of the equation as to whether or not it goes through the PLC [PLC is the product life cycle—in this company, PLC is an SG process].”

In phase 3 of the study, a program manager explained why radical product innovations, such as a new platform, should also not follow a new product SG and be managed without too detailed project plans (the company develops printers): “If we know exactly what we need to do in the front, we’re not investigating anything. We’re not innovating. [In R&D,] we’re trying to increase speed, we’re trying to increase the performance of the printer, reliability . . . the drying time needs to be less so the paper comes out quicker. We’re in R&D! We have to research these things! Once all of our research is completed, we have a mock-up of a printer that we create. Once we play with the mock-up, we pick up a defect that’s a problem or the spinning isn’t happening. We go back to the drawing board to see why the spinning is not happening. Was the physics wrong? Maybe the motor was bad. We’ll update the motor to a different motor style. We do all that.” He compares this work style to writing a research paper for a class project: “You have an idea, have the go-ahead from your professor to do it. That’s the part of the project where you get approval, need a commitment from your stakeholder. . . . You have a slight plan of what you do. You know what you’re going to do, you know where you are, but you still don’t have all the pieces. As you’re hitting the books, you’re learning new pieces, you’re taking notes down as you’re going through, you find new articles, and then all of a sudden it doesn’t seem like this might be exactly what I want to do so I’m going to change it slightly here, but we still have the same target.”

This last quote illustrates that projects go through periods of trial-and-error learning. The respondent, who is a PMP® and PMI-ACP® (PMI Agile Certified Practitioner) program manager in product development, felt that this kind of approach is at odds with traditional project management training because it requires acceptance that there are project aspects that are not part of any plan (or contingency plan) and evolve as the project progresses. He saw this practice as being better aligned with the SG framework. However, we found no evidence that the SG framework is systematically used to implement trial-and-error learning or selectionism: Once a development project has received a “go,” the prevailing mind-set is to execute on the plans and hit the preset targets immediately. Accordingly, it is uncommon to budget for parallel trials, which is considered too expensive or simply too difficult to justify. If prototypes are part of the project plan, they are typically targeted at later stages, such as integration with manufacturing or as sales samples, not as means to support early market validation. Also, with the exception of software groups, we did not find evidence of planned iterative approaches. This does not mean that project teams do not employ them—many projects in our sample have a strong trial-and-error component in response to unk unks that occur during project execution. One respondent reported on limited parallel trials for a challenging technical problem. But these activities are funded with a static budget and time line—if more experimentation is needed, the team needs to go back to the decision makers, justify why the original estimates were wrong, and ask for additional time and funding. If teams have “played it safe” and have secured more time and resources for learning than they end up needing, they have no real incentives to complete the project phase earlier and leave the budget untouched, leading to inefficiencies.

Only one company reported attempting to explicitly integrate SG and learning-based approaches. In an attempt to make its SG process more iterative, one company has broken up the development stage into a development stage, during which new product functionality is developed, and a validation stage, in which customer response to the development is tested to inform the next development cycle. The company has formalized a gate review for each iteration to force a fundamental decision if and in which form the project should be further pursued. However, in reality, the iterations are reviewed informally within the development gate while the project moves along because “the overhead of this process is a little bit too much right now.”

Criteria for Project Adaptation

The section above shows that adaptive project management is practiced by modifying existing standard processes to address project-specific needs, by selecting a tailored process from multiple standard approaches and by employing learning-based strategies within projects. However, none of the companies in the study uses a framework, checklist, or project profile for making these decisions. The choice among multiple standard approaches was simply based on the origin of the project (technology project versus project from the product road map) and the nature of the project outcome (engineering build project for internal customers versus projects for external customers). The questions of whether gate deliverables should be skipped and gates combined were answered without a structured analysis for project characteristics, such as uncertainty, risk, complexity, or pace. Moreover, no single decision maker or decision-making unit was responsible for approving adaptive practices. Instead, the process is described as a negotiation between the project manager, the project management office (if it exists), and the gate-review panel. This rarely causes controversy in practice, but the lack of clear criteria and accountability is of concern and was raised by multiple respondents. After all, in some companies in our study, the technology SG can commit budgets of up to US\$100,000, based on limited data and with a small executive group, without full transparency about when it should be applied. Moreover, the process adaptations leave only 10% of the standard process, which supposedly prescribes essential (!) activities and reviews, intact. Because these stripped-down projects are maintenance projects that do not require cross-disciplinary collaboration, they often include gate reviews that are done by gatekeepers who represent a single function, rather than a multidisciplinary approach. By modeling an “everything is optional” approach, this practice weakens the rigor of SG for the new product projects it is intended to support because individual decision makers and their personal approaches, rather than recognized good practices, are at the core of project decisions.

Timing of Project Adaptation

Our study found frequent instances of initially unplanned project adaptations in response to project needs: Gates are cleared pending the results of a still outstanding trial; product requirements are still developed iteratively far into the project, even though a marketing requirements document was approved when the project was funded; and competing technical solutions are pursued in parallel because the initial concept may not work as planned. Though some of these “reactive” adaptations result from poor initial planning—in many cases, because of insufficient resources for more detailed up-front planning—they are not all avoidable. Many of the episodic interviews in this study point to the prevalence of unknown unknowns as the root cause. In addition to these (at least initially) unplanned adaptive practices, we also found ample evidence of planned, ex ante adaptation. However, these adaptations follow, as outlined above, the fundamentally linear, planning-based philosophy of the long-established new product SG and do not explicitly incorporate learning-based strategies.

Effectiveness of the SG Process

The SG provides a widely accepted way for managing new product development and its dominance “crowds out” practices that originate in the project management literature, in particular approaches for project monitoring and control. Moreover, the SG is still mostly associated with new product SG, which, by its very nature, is designed to be a linear process that—step-by-step—reduces risks as resource commitments increase. We were, therefore, interested if the reliance on SG as the de facto “gold standard” was justified. The respondents in our study see mixed results.

The SG is intended to support management in making portfolio decisions (including the cancellation of projects) and to introduce market focus, rigor, and cross-functionality to development projects. The study participants agree that the process increases execution quality by aligning different functions and activities behind the project and systematically checking off items that can cause problems down the line. They are less convinced that it is powerful for improving portfolio decisions: In practice, gate reviews are means to start projects, communicate the project status, and make minor adjustments, rather than a mechanism to terminate projects. One respondent from study 2 pointed out that the very fact that upper management had approved the project in earlier gates can make it difficult to cancel it down the road because it means that “management got it wrong.” Another respondent, from study 3, stated: “For there was an expectation that if you presented it, it was going to get approved and you needed to do it.”

Several respondents recounted cases where they had made the decision to continue work beyond what was within the scope of the phase, without announcing this to all the project stakeholders or even making it clear at the review gate. A statement by a product manager illustrates this well: “Honestly, if I’m sitting in the room as the project manager, and I’m sitting there with our CEO and the engineering managers, and we’re like, yes, we need to do this, but we need to get this sent out to the field right now. We will make the call and get to the gate, get into the field and follow up later.” These exceptions typically occur because timing is urgent and the decision makers have a good knowledge of which way the gate review will go, though one manager characterized this as a big bet that can put his career on the line. Incidentally, our study found frequent concerns about a lack of discipline, including management sidelining the agreed-upon process and project offices that struggle with “under the radar” projects.

The problem of “gates with no teeth” is addressed in the SG literature through various recommendations: Gate-review meetings need to be held on the appropriate management level so that decisions are linked to the commitment of resources, termination criteria need to be transparent, and discussions about project readiness (i.e., did the team do everything required for the gate?) need to be clearly separated from discussions about the business value of the project. Moreover, data need to be sufficiently complete and reliable because tough decisions aren’t easily made without undisputable facts (Cooper, 2011). Many companies in our study struggle with these recommendations. In particular, they often lack complete data because the little project management that does occur does not track what matters for decisions about the future business value of the project. For example, a budget overrun or missed milestone says little about future projects’ desirability in the market.

Another problem is that gate deliverables are crossed off because it is something that needs to be done, without much added value: “You can check off your checklist sometimes by saying, we put part A into part B. It’s not useful, but you’ve at least done the steps.” On some occasions, there appears to be an implicit consent that the gate documents may not tell the full story. One respondent recounted a project (a relatively low-tech consumer product) that arose out of a very large market opportunity, but required an aggressively compressed time line to meet a shipping date before Christmas. The project followed the company’s standard process and all required deliverables were provided, but the premise of the reviews was different from that for other projects. For example, the manufacturing validation occurred at a time when any change would have forced the company to scrap expensive tooling. Also, samples provided at a particular review were lab samples, not the usual manufacturing samples. These differences were not fully visible to all project stakeholders, who were under the impression that the project was similar to others.

Although recent modifications of the SG framework (Cooper, 2011) explicitly emphasize the possibility of agile, quick learning cycles, the prevailing mind-set in SG application is still one of proper up-front planning and plan execution. For one case, our study even confirmed that project execution “to plan” may trump project success, as Smith (2007) and MacCormack, Verganti, and Iansiti (2001) report in the literature. In one interview, a respondent mentioned participating in a commercially successful project that, despite some difficulties, ultimately succeeding in exploiting a 20 to 30 times “bigger than usual” market opportunity with very high profit margins. Yet the project was internally perceived to be a bad one because it did not follow the standard approach and suffered from plan changes and surprises. The respondent noted that the careers of some of the people on the project suffered as a result and that the company has recently passed on a similarly large opportunity that, again, would have required a more adaptive management approach.

Summary and Discussion

This research set out to answer four research questions. Research question one asked how project-specific “tailoring” of SG project management occurs. Our studies found two practices: The more common approach is to define a general SG process that includes all gate-review documents that could be relevant for any project and drops or modifies those that do not apply. A second approach is the definition of alternative processes, such as one for a “typical” (new product) SG and one for technology validation projects. In our study, neither the decision about which review documents to require nor the decision about which project process to choose is made with analytical techniques, such as project profiles or matching criteria. Accordingly, individual project stakeholders have strong influence on this decision.

Research questions two and three investigated two closely related topics: How do projects move from early SG stages—the fuzzy front end—to product development? And how are projects with high uncertainty managed? The respondents in our studies describe the first stages of the SG process, leading up to and including the building of a business case, as unstructured and based on up-front learning. They are focused on gaining a fundamental understanding of what will determine the success of the future product and result in key project definitions, including markets, product concept, key features, and technologies in order to select the “right” project. The companies in our study, however, frequently experience projects entering later stages with what turns out to be insufficient clarity around these parameters. Nevertheless, the new product SG is not systematically used to broaden the search for undiscovered unknowns in the front end nor to implement more flexible approaches downstream. When defining gates and gate deliverables, project approaches such as selectionism or trial-and-error learning are rarely used systematically and proactively but only in response to downstream problems with earlier plans. This means that projects that would lend themselves to learning-based strategies are frequently forced to provide extensive up-front homework and relatively detailed plans. This makes it less likely for radical innovation to be pursued and extends the length of the front end, without solving the fundamental problem that many projects experience rather large changes and budget and schedule overruns. However, despite these problems, there is a sense that the SG process eventually enables companies to do the right thing (i.e., develop good products), and many companies in our sample aim to expand their SG use.

The fourth research question focuses on how complementarity between SG and project management practices is achieved. Our study found that the SG process provides a broad framework that integrates specific project management tools and practices so seamlessly that, to many product development practitioners, project management *is* SG. This can lead to inefficiencies because some projects do not need to be looked at from the portfolio perspective that SG aims to provide. For example, design changes to address a quality problem in the field or to upgrade to a vendor’s newest component arise from necessity and can be assessed by engineering without considering the portfolio or projects. Accordingly, they are typically managed outside the SG system. However, these projects still need some kind of project management to organize and schedule work, to track progress and expenses, and to build a knowledge base that increases planning quality. If SG is the only project management approach, the projects remain invisible to the organization and cannot benefit from the experience gained in prior projects of a similar nature. In response, there is a tendency to bring more projects under the umbrella of the SG framework, resulting in high management overhead for these projects. Moreover, the SG is designed to be a relatively flexible process that leaves a lot of room for project-specific adaptations. If SG and project management are not clearly differentiated, this can either lead to an overly rigid SG that is too strongly influenced by the notion of project monitoring and control, leading to unwanted rigidities and overheads, or it can result in projects that are less rigorously managed and documented than is beneficial. We found ample

evidence that companies struggle with both problems, often within the same organization, as the company in Phase 2 of this study illustrates.

A second challenge, which may help explain the almost complete absence of advanced project management practices in product development, is the prevalence of uncertainty in new product development. Current project management approaches need a relatively stable baseline against which actuals and forecasts are compared in order to steer the project “back on track.” The perception is that a well-planned project should have relatively low variance; practitioner literature considers anything above 10% a high risk that should spur immediate action (Dayal, 2008). A textbook on product development, on the other hand, states that early forecasts of timing and costs “may only be accurate within 30 to 50 percent” (Ulrich & Eppinger, 2008, p. 389), forcing major adjustments to project plans. High project variance is thus the norm, not the exception, and triggers ongoing adjustment and corrective action, resulting in high overhead.

Moreover, project management currently does not have frameworks or methods for helping teams articulate and understand the strategic implications of a project, though the concept of project strategy is currently evolving (Patanakul, Shenhar, & Milosevic, 2012; Patanakul & Shenhar, 2012). Without this link to strategy, project management can help decision makers understand the implications of tactical decisions (e.g., emphasizing time over cost), but leaves the more fundamental questions, such as “Should this project be pursued further, even though the market opportunity is smaller than anticipated or development costs are skyrocketing?”, poorly supported. To improve the situation, project management research has to reconsider the metrics that project management typically tracks: Time or budget spent does not mean much if there isn’t reliable information about how much effort it will take to get to results. And task completion levels and earned value approaches are equally problematic: Is new software 99% complete when it is fully coded but not yet integrated with a device? Or 70%, because last time it took three days for debugging? Or 0%, because we are integrating new software with a new device and anything can happen? And how much value does the software contribute from a customer perspective, given how difficult it is to forecast what customers truly value? A more meaningful measure would reflect how much of the development effort is a well-structured problem with clear risks, and how much of it is still ambiguous and may be suffering from unknown unknowns. Current project management practices, as they are used in R&D organizations, however, do not provide insights of this nature. Consequently, project management finds itself struggling for relevance in product development, where fundamental project decisions and coordination needs are addressed by the SG framework and tactical decisions are made with only basic project management tools. This is, however, not a desirable situation, as frequent reports about later-stage unk unks and resulting schedule and budget overruns indicate.

Limitations, Implications, and Future Research

Initially, this work was planned to identify *best* practices for project adaptation in R&D organizations. Instead, the study found inconsistent practices, gaps between the prescribed and the actual process, challenges with late-stage “unk unks” that lead to frequent budget and schedule overruns, and limited data on what practices (if any) systematically lead to better outcomes. Study participants described product development as a messy process that is characterized by surprises, reoccurring problems, and improvisations. These findings could be a result of the study’s deliberate focus on small and medium-sized companies with manufactured products, which may have less sophisticated project management and SG practices than larger companies and companies in other industries, yet this is unlikely for two reasons. First, we found similar patterns in the contrasting cases that were sampled because of their much larger size and higher project management sophistication. Moreover, statistics show that the companies in our sample—innovative small and medium companies—tend to outperform innovative large companies in per-capita innovation⁵, so, if anything, one would expect better practices that allow engineers and scientists to be more productive. It is, therefore, probable that this study truly reflects the nature of adaptive project management in R&D organizations, which continue to struggle with up to 50% failure rates for new product launches (Barczak et al., 2009) and delays that cause only about 50% of all new products to be launched on time (Cooper, 2011).

Our study found several explanations for the observed problems: Most R&D organizations in our sample fail to clearly delineate the two frameworks of project management and SG and consequently use neither concept to its full potential. SG is often strained with too much bulk and formalism or so overly adaptable that “anything goes” and gate reviews lose their teeth. Project management is typically reduced to simple up-front scheduling and budgeting, tracking, and engineering change management without providing much insight into how to adjust the project to changing needs. At the same time, up-front planning and plan execution are the focus of attention. Approaches like tight-loose planning and rolling-wave planning (Smith, 2007) and learning-based approaches, such as selectionism and trial-and-error learning, are rarely embedded in the SG framework up front but only occur in response to downstream problems. Future research needs to investigate how both SG and project management can shift the mind-set toward more flexibility, so that the (still very limited) good practices identified in the literature and by some of the respondents in this study can come into play. In addition, research needs to systematically investigate which practices lead to improved success. This, however, should occur with caution. This research found that specific practices, though similar on a high level, differ from company to company and—in many cases—from project to project. Moreover, the “official” practices on record often do not fully reflect the reality on the ground. Future research on project management and on project success should take this into account and capture the actual practices that apply to the particular projects under investigation, rather than asking if particular SG or project management methods are generally used in the organization. This can help explain the inconclusive results on the success factors of new product development and broaden the still limited insights into the drivers of project management and project success (Cooke-Davies, 2002).

Adaptive project management is currently limited by a “planning and execution” mind-set that dominates the project management and the product innovation literature. Moreover, though both literature streams cover similar topics, they have little overlap and cross-referencing. Product development research, in particular, has developed a variety of project management approaches and tools that are adapted to the challenges of

⁵ Small companies produce 16 times more patents per employee than larger companies: https://www.sba.gov/sites/default/files/FAQ_March_2014_0.pdf (The study compares patenting and non-patenting firms.)

innovation projects. Examples include the Design Structure Matrix (Steward, 1981; Ulrich & Eppinger, 2008), which was first published in 1981 and is frequently referred to in product development publications, but has only gained very limited traction in project management. Another example is the risk-value method (Browning, 2003; Browning, Deyst, Eppinger, & Whitney, 2002), which was developed as an alternative to earned value approaches, but is almost exclusively referenced in engineering management journals. To improve the relevance of project management in new product development, future research needs to build more strongly upon the contributions in other fields and investigate them from a project management perspective. This can support the evolution of improved practices and implementation of adaptive project management beyond its current infancy. The product innovation literature, on the other hand, is currently largely focused on creating a strategic portfolio of successful new products and thus supports decisions on *what* project to select and develop. However, as this study shows, R&D organizations have additional challenges with regard to budgeting, scheduling, and managing changes that product innovation research can help address. Though they are tactical in nature and focused on *how* to develop a project, they can have tremendous impacts on a company's ability to bring portfolio planning to life. They are worthy of increased attention in product innovation research.

Because of this lack of demonstrated best practices, managerial recommendations have to be given with some caution: We propose to decouple maintenance and technology products from the Stage-Gate system, rather than to manage them with tailored SG processes, as the literature proposes. To this end, a percentage of engineering resources can be allocated for ongoing product improvements and technology explorations. For these budgets, project selection occurs within the R&D organization. Project management approaches are kept simple and focused on informing the team about responsibilities and time lines, rather than management control and/or documentation. In most cases, a simple task list with dates and responsibilities is sufficient. This approach takes into account that these types of project rarely require an alignment of schedules and tasks in different areas, nor do future projects benefit from detailed documentation of resource needs. The recommendation further responds to the fact that many of the organizations in our study have limited capacity for project adaptation and operate without a project office that could help with process design and selection. Moreover, they often struggle to create sufficient discipline around the management practices of "normal" product development projects and, therefore, should focus their processes on the type of projects that are known to benefit most from a disciplined approach—namely, new product projects with normal levels of uncertainty.

There also needs to be a clear differentiation of roles: Technical project management activities, such as scheduling and tracking, may be best put in the hands of a project management practitioner, such as an analyst, who informs project managers (typically engineers or scientists with limited knowledge of project management tools) about the state of the project so that everyday decision making is supported by data. SG, however, is the responsibility of the project managers and focuses on go/no-go decisions and cross-functional handoffs at pivotal project moments.

Given how prevalent late-stage "unknown unknowns" are, much more consideration needs to be given to how projects can move forward while still maintaining flexibility to minimize risks. This will require parallel trials, quick build-and-test cycles, and agile contractual arrangements for internal budgets and external customers of custom projects. Project outcomes should not only be monitored based on task completion, but—more important—based on learning. This can occur by tracking a list of assumptions to see how many of them have turned into tested knowledge and how many are still uncertain.

Finally, this study shows that the implementation of the currently existing project management body of knowledge is extremely limited. Also, SG practice is far behind the recommendations in the current literature, let alone the envisioned project "canvasses" for implementing learning-based strategies (Cooper, 2014b). R&D practitioners need to address this discrepancy if they want to improve efficiency and new product success.

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