Managing the Front End of Innovation—Part II

Results from a Three-Year Study

Effective front-end activities were found to be significantly different for incremental and radical projects.

Peter A. Koen, Heidi M. J. Bertels, and Elko J. Kleinschmidt

OVERVIEW: Based on data collected from 197 large, US-based companies, we analyzed the elements important for success in the front end of innovation. A previous article explored the role of organizational attributes, which account for 53 percent of front-end performance. A second set of organizational attributes—including effective teams, team leadership, and communities of practice—explain 24 percent of the variance in front-end performance. Specific activity elements were also identified as being important to success in the front end for incremental and radical innovation. Opportunity identification and analysis, idea enrichment, and concept definition were found to be the most important activity elements for front-end success for incremental innovation. In contrast, effective activity elements for radical innovation were related to understanding both existing and disruptive markets and leveraging new and emerging technologies. We were able to explain 29 percent and 32 percent of the variance in front-end performance for incremental and radical innovation based on these activity elements.

KEYWORDS: Fuzzy front end, Front end of innovation, Radical innovation, Incremental innovation, Communities of practice

The innovation process in large companies may be divided into three parts: the front end, new product development, and commercialization. The front end of innovation forms the foundation for future product development activities since the decisions made in this early stage determine the innovation options available for later development and commercialization. Yet, the front end has been vastly underexamined, with only eight empirical publications linking specific activities in the front end to the outcomes of front-end projects or overall innovation success. The majority of these studies have been done in small companies (those with less than $100 million in revenue) and have focused on incremental project outcomes, offering very little data about front-end performance for radical or disruptive innovation (see Koen, Bertels, and Kleinschmidt 2014 for a detailed review).

Since 1998, the Industrial Research Institute (IRI) has supported a series of studies to determine best practices in the front end for large companies. This work began with a Process Effectiveness Network (PEN) group that studied front-end practices from both an organizational and a

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ROR Profile

Front End of Innovation—Survey, Probe, and Intervention of Effective Practices

Identifying effective practices in the front end of innovation for sustained growth and profitability

Goal: To determine the key front-end skills and activities that a company needs to be proficient in order to achieve robust growth and sustained profitability

Chair: Drew Kugler (Welch Allyn)
Subject Matter Experts: Elko J. Kleinschmidt (McMaster University), and Peter A. Koen (Stevens Institute of Technology)

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project-specific standpoint; that work resulted in a new framework for front-end practices, called the New Concept Development (NCD) model (Koen, Ajamian, Burkart, et al. 2001), which provided a much-needed common language for the field. In 2002, another Research on Research (ROR) group was formed to continue the work of the PEN group; this ROR developed and administered a survey using the NCD model as a lens. (A detailed discussion of the survey design process can be found in Koen, Bertels, and Kleinschmidt 2014.) This work, which is ongoing, represents one of the largest studies ever done on the front end; data has been collected from 197 large, US-based companies with median annual revenues of $1.05 billion.

Analysis of that data has identified both organizational attributes and innovation activities essential to front-end success. Essential organizational attributes—senior management involvement, vision, strategy, resources, and culture—were discussed in an earlier article (Koen, Bertels, and Kleinschmidt 2014). In this second article, we focus on the role of teams and collaboration and the importance of activity elements for incremental and radical projects in front-end success.

The New Concept Development Model

The NCD model breaks the front end into three parts (Figure 1): the engine, the wheel, and the rim (Koen, Ajamian, Burkart et al. 2001; Koen, Ajamian, Boyce et al. 2002). The engine consists of the core elements that provide power to the front-end process—organizational attributes, such as senior management involvement in the front end, vision, strategy, resources, culture, and teams and collaboration. The wheel, the inner part of the model, comprises five activity elements: 1) opportunity identification, 2) opportunity analysis, 3) idea generation, 4) idea selection, and 5) concept definition. The third element of the NCD model, the rim, consists of the external environmental factors that influence the engine and the activity elements.

The model is circular in shape to indicate that ideas flow, circulate, and iterate among the five elements. This is in

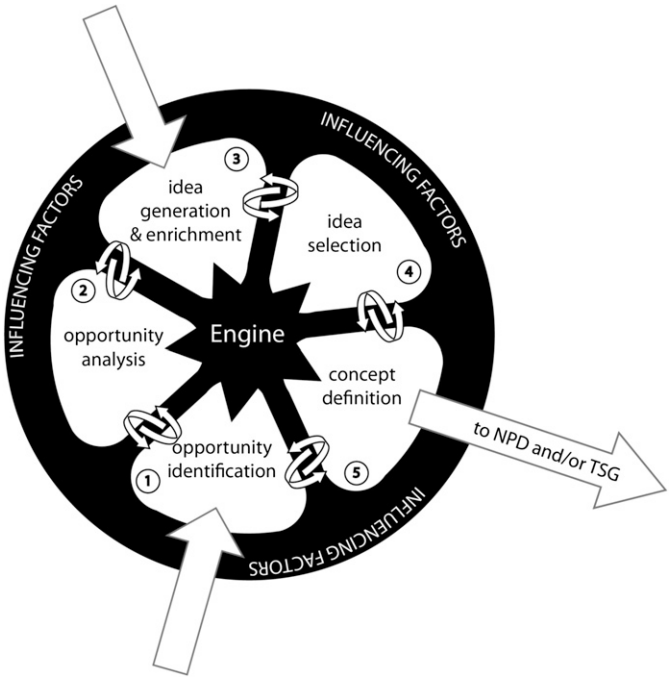

FIGURE 1. The NCD model. Adapted from Koen, Ajamian, Boyce et al. 2002; used with permission

contrast to the Stage-Gate process, which is sequential. The arrows pointing into the model represent the starting points for projects, which may begin in either opportunity identification or idea generation and enrichment. Projects leave the front-end process by entering into the new product development (NPD) or Technology Stage-Gate (TSG) process (Ajamian and Koen 2002).

The language of the NCD model provides a vocabulary for understanding the activities that occur in the front end. In this model, an *opportunity* is a business or technology gap that exists between the current situation and an envisioned future. For instance, a food company may identify a growing need for low-fat products arising from increased consumer interest in healthful eating but have no ideas and few products that can be sold in this segment. An *idea* is the most embryonic form of a new product or service, such as an idea for a new food category—for instance, nonfat potato chips. The food company's research group may envision several ideas for molecules that provide the same flavor as traditional frying fats but are not absorbed in the body like fat molecules. A *concept* refers to a well-defined product or service with principal features and customer benefits clearly identified. For our food company, the outcome of the R&D program arising from the idea could be a scientific program to create nonfat molecules, resulting in a new product that has the same taste as the original product but contains no fat.

These expanded definitions provide a vocabulary to explain the activities that occur in the front end. Without them, opportunity identification and ideation are frequently confused. Opportunity identification refers to the process of identifying new markets with unmet needs and emerging trends, while ideation is concerned with finding embryonic

solutions to the problems identified in the opportunity space. Why does this matter? Many companies begin a new innovation initiative by asking for new ideas. By doing so they are making the implicit assumption that the biggest growth and profit will come from unmet needs in the existing market (an opportunity space the company is familiar with). Instead, companies should start by identifying the largest opportunities, then develop ideas that can fill that opportunity space. For example, when IBM was looking for new growth, the company explored the healthcare opportunity space, although it was at the time a new opportunity for IBM, because it had large growth potential (Garvin and Levesquel 2005).

The Engine of Front-End Innovation: Teams and Collaboration

The engine of the front end consists of two elements: organizational attributes and teams and collaborations (Table 1). Organizational attributes, which account for 53 percent of the variance in front-end performance, were discussed in detail in a previous article (Koen, Bertels, and Kleinschmidt 2014).

The other element of the engine is effective teams and collaboration structures. In the survey design, attributes for teams and collaboration were captured in three constructs (Table 2):

- **Effective Teams:** Team members are passionately committed to their front-end projects and spend time and effort on them beyond that required by their job.
- **Team Leadership:** Team leaders have established credibility and recognized leadership experience.
- **Communities of Practice (CoPs):** The company supports CoPs, provides them with a budget, and has a coordinator who dedicates at least 25 percent of his or her time to the community. Our measurement for CoPs was based on the work of McDermott (2000).

Over three decades of research support the importance of effective teams and team leaders in successful innovation. Less obvious was the inclusion of communities of practice (CoPs), which are groups of individuals who share information, insight, experience, and tools around a common interest (Wenger 1998). We included this construct for two reasons. First, we saw the usage of CoPs increasing in many IRI companies. Second, CoPs enable tacit knowledge exchange, which is critical to effective collaboration, both within and external to the organization. (See "How the Study Was Done, p. 33, for a complete description of the survey design and analysis process.)

CoPs are as important as teams to a company's front-end success, accounting for nearly as much of a business's front-end performance as team effectiveness.

Regression analyses indicate that, taken together, these three constructs explain 24 percent of the variance in performance in the front end (Figure 2).[1] All of the constructs were significantly and positively related to front-end performance at about the same order of magnitude (20 percent, $p<0.01$, for CoPs; 23 percent, $p<0.05$, for effective teams; and 27 percent, $p<0.01$, for team leadership).

The importance of the team and its leader to success in the front end is a finding we expected. Two meta-analyses of new product teams, by Hulsheger, Anderson, and Salgado (2009) and by Sivasubramaniam, Liebowitz, and Lackman (2012), showed that the effectiveness of the team leader, the team's overall cognitive ability and experience, and how well the team worked together had a strong significant relationship to the innovation constructs of the studies surveyed in the analyses.

Our research showed that the development and support of CoPs was also related to success in the front end. CoPs can help bring together people who might not encounter each other in regular work life. For example, the Turbodudes group at Shell Oil is made up of people who are interested in a particular kind of geological structure called turbidites (McDermott 2000). The group meets regularly; group members engage in debates and share their knowledge and experience. Our analysis shows that that CoPs are as important as teams to a company's front-end success, accounting for nearly as much of a business's front-end performance as team effectiveness. This result points to the importance of effective collaborations outside the team, a finding supported by the work of Cross et al. (2008). Using network analysis tools to

[1] The terminology "explains 25 percent of the variance" means that that 75 percent of the variance in front-end performance in the sample is due to factors other than those captured by the constructs under consideration—effective teams, team leadership, and CoPs.

TABLE 1. Variables accounted for in the NCD model

NCD element	Variables found to be significant	Explanatory power of model
Engine	Organizational attributes (Senior management commitment, vision, strategy, resources, and culture)	53%
Engine	Effective teams, team leadership, communities of practice	25%
Incremental activities	Opportunity identification and analysis, idea enrichment and concept definition	29%
Radical activities	Opportunity identification (trends), opportunity identification (disruption), and idea enrichment (technology)	32%

Each row represents a separate regression analysis

TABLE 2. Constructs for teams and collaboration

Construct	Variables	Cronbach's Alpha*	AVE**
Performance in the Front End	The degree to which products in the front end are able to 1) generate sustainable competitive advantage, 2) deliver on front-end strategic objectives, and 3) deliver a front-end portfolio that is balanced—across types (product lines, technology platforms, new-to-the-world products), markets, and technologies, and with respect to long-term vs. short-term outcomes and risk. (3-item construct)	0.79	0.62
Effective Teams	The degree to which team members 1) are committed to their projects and 2) spend time and effort beyond job requirements. (2-item construct)	0.80	0.62
Team Leadership	The degree to which team leaders 1) have recognized leadership experience and credibility throughout the organization, 2) assure team performance exceeds expectations, and 3) enable and support commitment of all team members. (3-item construct)	0.82	0.68
Communities of Practice (CoPs)	The degree to which the organization 1) encourages and supports CoPs, providing each community 2) a budget and 3) a coordinator who dedicates at least 25 percent of his or her time to the CoP. (3-item construct)	0.79	0.66

* Cronbach's alpha is a measure of the internal consistency of a multi-item scale.
** Average variance extracted (AVE) measures the amount of variance captured by the construct in relation to the amount of variance due to measurement error.

compare low- and high-performing teams, Cross and colleagues found that high-performing teams were better networked both within the organization and externally. This mirrors a growing understanding that, as Sawyer (2007) argues compellingly, "the lone genius is a myth: instead it is group genius that generates breakthrough innovation" (7).

Activity Elements of the Front End

We distinguished between incremental and radical projects using the popular Booz, Allen & Hamilton (1982) designations. Incremental innovation included cost reductions, improvements to existing product lines, and repositioning efforts. Radical innovations were additions to existing product lines, new product lines, and new-to-the-world products.

Incremental Innovation

The five constructs we developed for incremental innovation (Table 3) were closely aligned with the five activity elements of the NCD model:

- **Opportunity Identification and Analysis:** The degree to which the company spends time evaluating the external environment with a formal process. Because the two original constructs statistically had no discriminate validity, the questions developed for activity elements 1) opportunity identification and 2) opportunity analysis were combined into one construct, producing this combined variable.
- **Idea Generation:** The degree to which the business unit has a systematic way to capture, share, record, and provide feedback on ideas.
- **Idea Enrichment:** The degree to which the business unit has an IT-based system for sharing, capturing, and assessing ideas, as well as the ability to identify R&D people and find out what they are doing.
- **Idea Selection:** The degree to which the business unit has an idea review board, a comprehensive method for idea evaluation, and a defined set of selection criteria.
- **Concept Definition:** The degree to which the business unit assesses the feasibility of manufacturing processes, the marketing and sales effort, technical requirements, and economic factors connected with a project. This construct can be considered synonymous with development of a business plan.

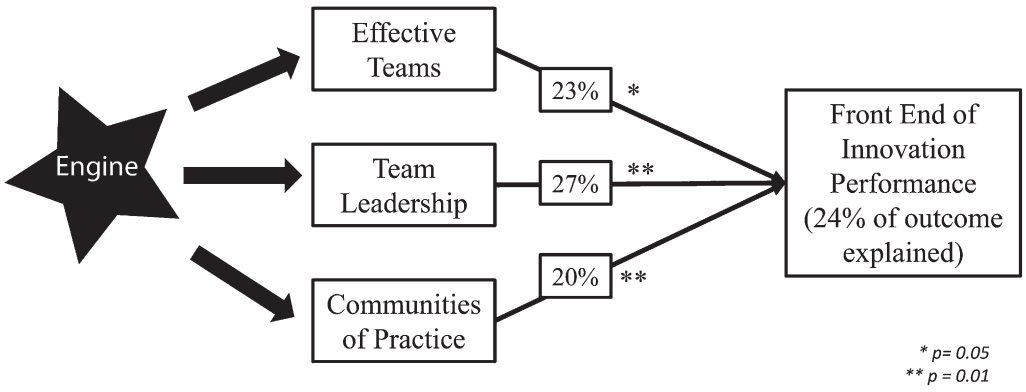

FIGURE 2. Results of the regression analysis for teams, team leaders, and CoPs

The regression analysis shows that these constructs taken together explain 29 percent of the variance in performance in the front end (Figure 3). However, there was a wide variation in the importance

TABLE 3. Constructs for incremental project activities

Construct	Variables	Cronbach's Alpha*	AVE**
Performance in the Front End	The degree to which products in the front end are able to 1) generate sustainable competitive advantage, 2) deliver on front-end strategic objectives, and 3) deliver a front-end portfolio that is balanced—across types (product lines, technology platforms, new-to-the-world products), markets, and technologies, and with respect to long-term vs. short-term outcomes and risk. (3-item construct)	0.79	0.62
Opportunity Identification and Analysis	The degree to which the organization 1) performs a thorough analysis of the external environment 2) using a formal documented process review that is 3) consistently applied to all incremental projects, combined with 4) a formal process to screen opportunities for incremental projects. (4-item construct)	0.85	0.59
Idea Generation	The degree to which the organization has systematic methods for 1) capturing and sharing ideas, 2) recoding ideas, and 3) providing feedback on ideas received. (3-item construct)	0.91	0.75
Idea Enrichment	The degree to which the organization has IT-based systems for 1) sharing, capturing, and assessing R&D project information and 2) allowing people to find R&D people and what they are doing. (2-item construct)	0.84	0.59
Idea Selection	The degree to which the organization 1) has an idea review board and 2) a comprehensive idea selection and evaluation method with 3) a defined set of selection criteria. (3-item construct)	0.88	0.74
Concept Definition	The degree to which the organization seeks to understand the feasibility of projects with regard to 1) manufacturing, 2) marketing and sales, 3) technical requirements, and 4) economics. (4-item construct)	0.86	0.61

* Cronbach's alpha is a measure of the internal consistency of a multi-item scale.
** Average variance extracted (AVE) measures the amount of variance captured by the construct in relation to the amount of variance due to measurement error.

of the constructs individually. The variance in front-end performance explained by the significant constructs ranged from 13 percent ($p<0.10$) for idea enrichment to 20 percent ($p<0.05$) for concept definition and 21 percent ($p<0.05$) for opportunity identification and analysis. No significant relationship was found in our sample between idea generation or idea selection and front-end performance. These results imply that opportunity identification, idea enrichment, and concept definition are done better by companies that are successful in the front end. The lack of a significant relation between idea generation and idea selection and front-end performance in our sample implies that these factors are less important to success.

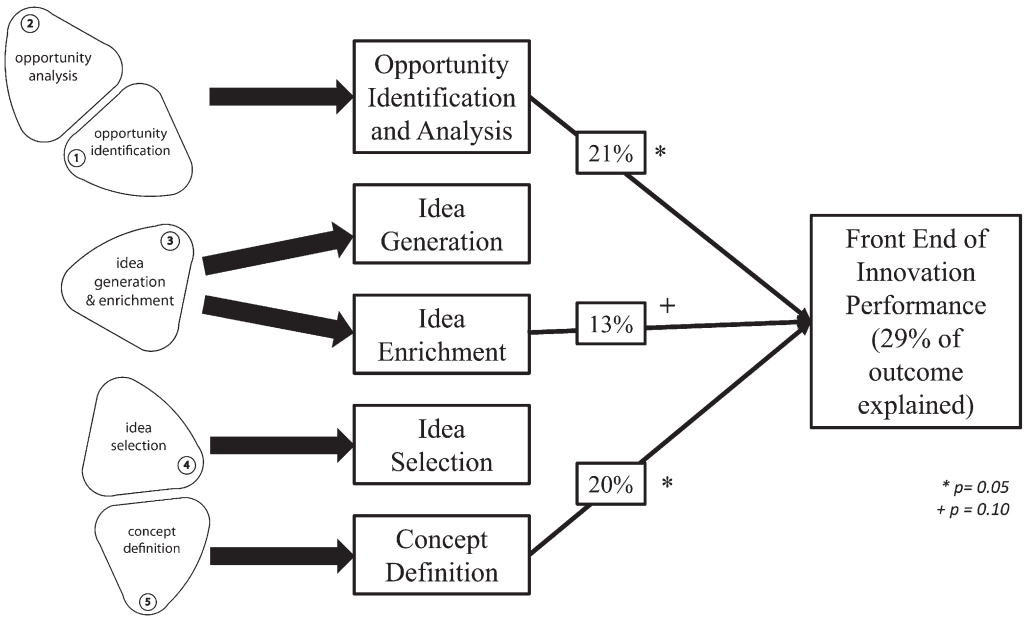

FIGURE 3. Results of the regression analysis for incremental project activity elements

We could not directly compare these results to previously published front-end studies since those studies used significantly different constructs than we did. Furthermore, previous work combined results for incremental and radical innovation or focused on factors other than activity elements. Instead, to validate our findings, we looked at the results of meta-analyses done by Henard and Szymanski (2001) and

Although we do not find that proficiency in idea generation is related to front-end performance, new methodologies such as crowdsourcing and idea markets could change that.

Evanschitzky et al. (2012), which together reviewed success factors in product innovation from 293 studies, the majority of which were incremental products. Many of the studies included in the meta-analyses examined variables that are applicable to the front end. These studies identified market potential and market orientation—constructs similar to our opportunity identification and analysis construct—as having strong positive effects. In addition, the meta-analyses also found strong, positive effects for proficiency in predevelopment activities as well as business and financial analysis, variables that align with our concept definition construct. Thus, our results, which document a significant relation between opportunity identification and analysis and front-end performance and concept definition and front-end performance, support findings by others.

We could not find similar studies that confirmed our finding that idea generation was not significantly related to front-end performance, although this result does echo the prevailing wisdom that most companies have too many ideas. Hammedi et al. (2011) produced results that contradicted our finding that there was no significant relationship between idea selection and front-end performance. Evaluating the idea screening process in the front end in 126 companies in Belgium, The Netherlands, and Luxembourg, they found support for the importance of successful idea decision making based on effective leadership of the screening team and a well-developed rationale for decision making. The difference in results between Hammedi and colleagues' results and our own might be explained by the difference in the dependent variable—Hammedi and team measured the effectiveness of the idea decision, while we looked more broadly at success measures for the front end. However, the importance of idea selection remains controversial.

Our results for incremental innovation are consistent with Cooper's (2001) results. Of the nine factors Cooper identified for success in new product development, two related to opportunity identification and analysis (strong market orientation and market attractiveness) and one related to concept definition: "sharp, early, fact-based product definition before development begins" (Cooper 2001, 59). In addition, our results indicate that companies that perform well in the front end tend to have robust IT platforms for capturing and enriching ideas. Although we do not find that proficiency in idea generation and selection is related to front-end performance, the spread of new methodologies, such as crowdsourcing and idea markets (see, for instance, Lauto, Valentin, and Carlsen, 2013), could change that. These new tools represent improved methods for selecting ideas and could supplement the traditional idea selection committee in a way that makes idea selection a significant factor in front-end success.

Radical Innovation

The eight constructs we developed for activities associated with radical innovation are also aligned with most of the activity elements in the NCD model (Table 4):

- **Opportunity Identification (Trends):** The degree to which the business evaluates economic, demographic, consumer, and cultural trends as well as regulatory shifts.
- **Opportunity Identification (Disruption):** The degree to which the business evaluates opportunities that are potentially disruptive to their current businesses.
- **Opportunity Analysis (Tools):** The degree to which the business unit uses tools such as technology roadmapping, scenario planning, and product generation mapping in their radical innovation activities.
- **Opportunity Analysis (Selection):** The degree to which the business unit evaluates the probability of market and technical success and does a competitive analysis and assessment of the advantage.
- **Idea Generation (Ethnography):** The degree to which the business uses ethnographic methodology to identify new ideas in order to understand unarticulated reasons customers make product choices.
- **Idea Generation (Technology):** The degree to which the business unit obtains new ideas from new technologies or technology-driven inventions.
- **Concept Definition:** The degree to which the business unit determines the feasibility of the radical innovation concept from market, customer, and commercial risk perspectives. This construct can be considered synonymous with the development of a business plan.

The activity elements of opportunity identification, opportunity analysis, and idea generation and enrichment were all associated with two constructs. The remaining activity element, idea selection, did not yield a valid construct—our analysis produced values for Cronbach's alpha and AVE below acceptable thresholds—and as a result was excluded from further consideration.

The regression analysis reveals that these constructs, taken together, explain 32 percent of the variance in performance in the front end (Figure 4). We found no significant relationship to front-end performance for four of the seven remaining constructs. Significant relationships with front-end performance were found for opportunity identification focused on trends (17 percent, $p<0.10$), opportunity identification focused on disruptive businesses (20 percent, $p<0.01$), and idea generation from technology (23 percent, $p<0.01$).

TABLE 4. Constructs for radical project activities

Construct	Variables	Cronbach's Alpha*	AVE**
Performance in the Front End	The degree to which products in the front end are able to 1) generate sustainable competitive advantage, 2) deliver on front-end strategic objectives, and 3) deliver a front-end portfolio that is balanced—across types (product lines, technology platforms, new-to-the-world products), markets, and technologies, and with respect to long-term vs. short-term outcomes and risk. (3-item construct)	0.79	0.61
Opportunity Identification —Trends	The degree to which the organization assesses new opportunities by evaluating 1) economic and demographic trends, 2) regulatory shifts and developments, 3) new business models, and 4) consumer and cultural trends. (4-item construct)	0.79	0.52
Opportunity Identification —Disruption	The degree to which the organization 1) actively looks for disruptive opportunities, 2) will accept margins for the disruptive business that are lower than those of the current business, and 3) systematically reviews high-potential areas for disruptive products and technologies. (3-item construct)	0.71	0.56
Opportunity Analysis—Tools	The degree to which the organization uses 1) technology roadmapping, 2) scenario planning, and 3) product generation mapping. (3-item construct)	0.83	0.59
Opportunity Analysis—Selection	The degree to which the organization uses an opportunity selection process that includes the probability of 1) market success and 2) technical success as well as 3) a competitive analysis. (3-item construct)	0.71	0.50
Idea Generation—Ethnography	The degree to which the organization uses ethnographic methodology to identify new ideas by observing 1) current and 2) potential customers in their own environment and 3) works to understand the unarticulated reasons customers make product choices. (3-item construct)	0.84	0.70
Idea Generation—Technology	The degree to which the organization identifies and obtains new ideas by assessing 1) emerging new technologies and 2) technology-driven inventions. (2-item construct)	0.88	0.78
Concept Definition	The degree to which the organization seeks to understand the feasibility of a project with regard to 1) markets, 2) customers, and 3) commercial risks. (3-item construct)	0.79	0.64

* Cronbach's alpha is a measure of the internal consistency of a multi-item scale.
** Average variance extracted (AVE) measures the amount of variance captured by the construct in relation to the amount of variance due to measurement error.

Comparing these results with existing literature is difficult, since the majority of the studies that evaluated radical innovation focused on organizational challenges rather than on activities. The lack of a significant relationship between idea generation using ethnographic techniques and front-end performance can be related to the results of a study by Govindarajan, Kopalle, and Danneels (2011) in which the investigators found that an orientation to mainstream customers was significantly and negatively related with radical innovation and that an orientation to small, emerging customer segments was positively related to radical innovation success. Similarly, the absence of a significant relationship between concept definition and success in radical front-end innovation is consonant with Christensen and Raynor's (2003) suggestion that the kind of deliberate, rigorously documented strategy that is appropriate for incremental innovation will not work for radical innovation. Rather, they argue, when "the future is hard to read and . . . it is not clear what the right strategy should be," as in radical innovation, an "emergent strategy" is required (Christensen and Raynor 2003, 216). In other words, a well-formulated business plan (or concept definition) is not only unnecessary for radical innovation; it may hinder the project's development.

We did find that three factors were significantly related to front-end performance: opportunity generation focused on understanding trends, opportunity generation focused on identifying disruptive businesses, and idea generation focused on new technology. The first two of these factors capture a process for identifying radical innovation opportunities that is fundamentally different from that required for incremental innovation. The approach these constructs map is consistent with findings in the literature. In a study of radical innovation projects, including Corning's optical fiber program, General Electric's development of computerized

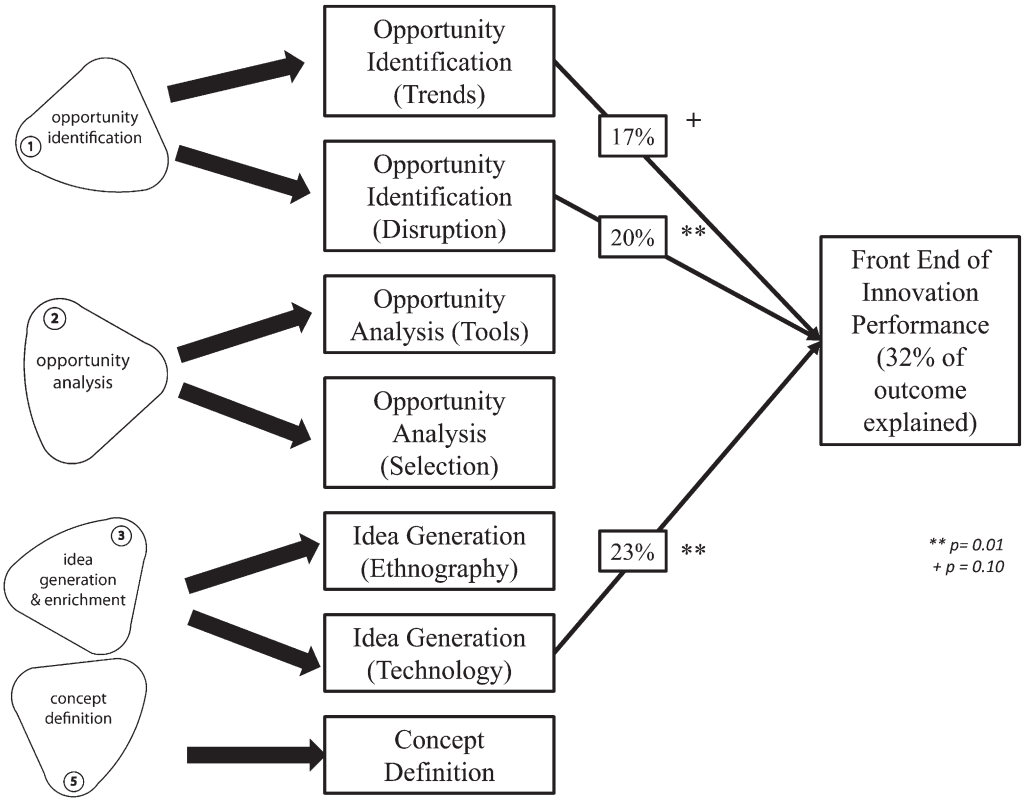

FIGURE 4. Results of the regression analysis for radical project activity elements

axial tomography, Motorola's development of the cell phone and Searle's development of NutraSweet, conventional marketing techniques were found "to be of limited value, were often ignored, and in hindsight were sometimes strikingly inaccurate" (Lynn, Morone and Paulson 1996, 15). The research team found that these projects followed a much more iterative, experimental process, which the authors called "probe and learn." Early versions of the product were tested in the market, redesigned, and then tested again. These market probes allowed the company to better understand the features and benefits valued by the emerging market. A similar approach is advocated by Christensen and Raynor (2003) and O'Connor et al. (2008).

The third factor that we found to be positively and significantly related to front-end performance was the development of new ideas by assessing emerging technology or technology-driven inventions. While there are many examples in the literature of companies succeeding with a "probe and learn" process combined with a deep conviction that the market will emerge, the role of emerging technologies in radical innovation is less well studied. Shane (2000) studied one technology invented at MIT, applied by eight entrepreneurs to eight completely different markets. While the technology was applicable to multiple markets, the entrepreneurs applied it only to market opportunities of which they already possessed intimate knowledge. On a related note, Danneels (2007) found that the lack of marketing competence in identifying new markets prevented a $26 million company from using new technology to move beyond its existing customers and markets, an analysis that supports our finding that identifying new markets is significantly related to front-end success in radical innovation. Our finding of significant relationships between both trends-focused and disruption-focused opportunity identification and front-end performance indicates that companies who are successful in radical innovation have competences in understanding both current and new markets. In addition, companies that are successful in radical innovation are adept at leveraging technology competence, as indicated by the significant relationship between idea generation using technology and FEI performance.

Three factors were significantly related to front-end performance: opportunity generation focused on understanding trends, opportunity generation focused on identifying disruptive businesses, and idea generation focused on new technology.

Our results for radical innovation are distinctly different from those for incremental innovation. A number of studies have established that radical innovation requires a substantially different process from incremental innovation and several well-regarded books on radical innovation advocate iterative or experimental approaches (Christensen and Raynor 2003; O'Connor et al. 2008). In one of the better-documented cases, Garvin and Levesque (2005) describe how IBM's emerging business opportunity (EBO) unit explored new white space opportunities using an iterative process that could sometimes "take a year and a half to get the strategy we were happy with. It would change three or four times" (Garvin and Levesque 2005, 10). Monthly review meetings with the EBO teams focused on achieving strategic clarity and understanding significant unmet

How the Study Was Done

The three-year project, launched in 2004 with support from the National Science Foundation, used the NCD model as a lens to identify the most effective practices in managing the front end of innovation.

This large-scale survey proceeded in three major steps:

1. *Developing survey questions.* The survey was developed by an ROR team consisting of R&D managers from 10 companies who all had intimate knowledge of the front end. In considering the construction of the survey, the team was guided by a number of key ideas:
   - *Incremental vs. radical innovation.* Classic studies by Lynn, Morone, and Paulson (1996) and O'Connor and DeMartino (2006) have shown that the innovation processes for incremental and radical projects are different. As a result, the group developed separate constructs and question sets for incremental and radical projects, using the well-known designations from Booz, Allen & Hamilton (1982) to distinguish between incremental and radical projects.
   - *Defining success.* Financial expectations for the front end are unreliable and difficult to obtain. Instead of financial measures, the group defined front-end success as 1) the degree to which the products in the front end are able to generate competitive advantage, 2) the extent to which the business unit delivers on its front-end objectives, and 3) the degree to which the business unit's portfolio is balanced across products, technologies, and risk levels. This construct was significantly correlated (r=0.62) with the well-accepted 13-item construct developed by Cooper and Kleinschmidt (1993), which measures overall new product development success (Bertels, Kleinschmidt, and Koen 2011).
   - *Multi-item constructs.* Because multiple-item scales are psychometrically superior to single-item scales—"other things being equal, a long test is a good test" (Nunnally 1978, 243)—all constructs were measured using multiple items.*

When the survey was completed, members of the ROR team took it and provided feedback. The survey was then revised and administered to colleagues at team members' companies. After a further revision, the survey instrument was reviewed by three academics knowledgeable in front-end research.**

2. *Data collection.* The unit of analysis for this study was the business unit. Data were gathered over a two-year period. Participants included 197 business units in a range of industries with median annual sales of $1.05 billion and an average R&D investment of 4.0 percent of revenues. Surveys were collected from multiple respondents in each business unit, to increase the reliability of the data.
3. *Data Analysis.* Data analysis was carried out both to verify the validity of the constructs and to measure statistical relationships between the dependent variable (front-end performance) and independent variables.

The validity of the constructs was verified using two accepted statistical measures. Cronbach's alpha is a measure of the internal consistency of a multi-item scale and estimates the degree to which multiple items on a test all measure the same construct (Henson 2001; Cronbach 1951.) A Cronbach's alpha greater than 0.6 is considered acceptable, 0.7 is considered adequate, and 0.8 is considered good. All of the constructs were above the 0.7 threshold for adequacy. The average variance extracted (AVE) measures the amount of variance captured by the construct in relation to the amount of variance due to measurement error (Fornell and Larcker 1981). All constructs had an AVE higher than the threshold of 0.5. We also measured inter-rater reliability to determine whether answers of primary and secondary respondents from the same business unit were more similar than could be expected by chance. Again, these tests confirmed adequate inter-rater reliability.

The relation between front-end performance and the various constructs, both individually and collectively, was determined through regression analysis, using firm size (in the number of employees) and percentage of R&D spending as controls.

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* A construct is a collection of questions that measure the same topic and are designed to elicit the same response. This is the preferred way of enhancing response reliability and minimizing random measurement error inherent in individual questions. Constructs may measure either dependent or independent variables. Dependent variables, in this study, are the front-end outcomes. Independent variables are things that the company can change—for example, effective teams and team leadership—that affect the dependent construct.

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customer needs. As of 2006 the EBO unit was responsible for generating 26 percent of total IBM revenue or $22 billion in new revenue (O'Reilly, Harreld, and Tushman 2009). Similar approaches are discussed by Koen, Holcombe, and Gehres (2006) and Edwards (2012). This process is in sharp contrast to traditional Stage-Gate processes, in which a deliberate sequential strategy defines specific deliverables required at each gate.

Conclusion

In the second part of this three-year field research project, we identified the most effective practices in the front end. One part of the engine, organizational attributes such as senior management commitment, vision, strategy, resources, and culture, explains 53 percent of variance in front-end performance in companies participating in our study (reported in Koen, Bertels, and Kleinschmidt 2014). In the work reported

in this article, we evaluated the second part of the engine along with the activity elements of the NCD model for both incremental and radical innovation. These variables separately explained about one-quarter of the variance in the front end and were all similar in magnitude (25 percent for effective teams and team leadership, 29 percent for incremental activity elements, and 32 percent for radical innovation activity elements).

While our findings with regard to the importance of team and team leadership are consistent with over three decades of research, the importance of CoPs in front-end success was an unanticipated finding. CoPs provide venues for rich, often face-to-face communication between members, which supports tacit knowledge transfer. Our results suggest that opportunities for tacit knowledge transfer both within the organization and externally, like that provided by CoPs, are as important as effective teams and team leadership to front-end success.

The results for incremental and radical innovation activities are also broadly consistent with previous research. The regression model for radical innovation is quite different from the one for incremental innovation. This reflects the very different requirements for incremental and radical success. Successful incremental innovation builds from a thorough understanding of the market and proceeds to the development of a solid business case (steps captured in our opportunity identification and analysis and concept definition constructs).

By contrast, the traditional, sequential process typical of incremental innovation efforts will not work for radical innovation. Rather, our study found that a deliberate sequential strategy leading to a business plan is appropriate when the future is known, as in incremental innovations, but may actually hinder the iterative nature of the activity associated with radical innovation. Our results also stress the importance of having both market and technology competence embedded in radical innovation activity efforts. This is because radical innovation may require both defining a new or emerging market and identifying technology that can provide solutions for that new market, often simultaneously. Thus, successful radical innovation requires a deep understanding of both emerging markets and relevant technology; therefore, radical innovation teams must include technology people as well as marketing expertise.

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