Performance Assessment of the Lead User Idea-Generation Process for New Product Development

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Traditional idea generation techniques based on customer input usually collect information on new product needs from a random or typical set of customers. The "lead user process" takes a different approach. It collects information about both needs and solutions from users at the leading edges of the target market, as well as from users in other markets that face similar problems in a more extreme form. This paper reports on a natural experiment conducted within the 3M Company on the effect of the lead user (LU) idea-generation process relative to more traditional methods. 3M is known for its innovation capabilities—and we find that the LU process appears to improve upon those capabilities. Annual sales of LU product ideas generated by the average LU project at 3M are conservatively projected to be $146 million after five years—more than eight times higher than forecast sales for the average contemporaneously conducted "traditional" project. Each funded LU project is projected to create a new major product line for a 3M division. As a direct result, divisions funding LU project ideas are projecting their highest rate of major product line generation in the past 50 years.
(*New Product Development; Lead Users; Idea Generation*)

1. Introduction

Many firms generate new product ideas based on information collected from current or potential users. What distinguishes such "customer-focused" processes across companies is the kind of information they collect and the respondents from whom they collect it. Traditional market research techniques collect information from users at the center of the target market. The "lead user" (LU) process takes a different approach, collecting information about both needs and solutions from the leading edges of the target market and from markets facing similar problems in a more extreme form.

The research question we address in this paper is: How does the LU process actually perform relative to more traditionally used methods? We are motivated to explore this matter by accumulating evidence that ideas generated by traditionally used processes are rarely breakthroughs, tending instead to be marginal contributors to firms' product portfolios

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(Eliashberg et al. 1997). This evidence has heightened interest in nontraditional techniques in general, and in novel idea-generation techniques in particular (Goldenberg et al. 2001). Our research involves a natural experiment conducted within 3M divisions to quantitatively compare outcomes produced by LU idea-generation projects with those of projects using more conventional approaches.

The LU method as conducted at 3M involves identifying and learning from lead users both within the target market *and* in "advanced analog" markets that have similar needs in a more extreme form. We find that this method generates breakthrough new products at a higher rate than methods traditionally used at 3M. Annual sales for the average funded LU project idea was forecast by management to be $146 million in year five—more than eight times higher than projected sales for contemporaneous traditional projects. Funded ideas from a total of only five LU idea-generation projects were conservatively projected to yield $730 M in incremental annual sales for 3M.

In §2 of this paper, we review the literature on idea generation and the LU method. In §3 we present our research setting, qualitative pilot research, and our research hypotheses. In §4, we describe our quantitative research methods. In §5 we present our findings. In §6 we discuss the implications of the study, and in §7 we offer suggestions for further research.

2. Background and Literature Review

Despite the strategic importance of effective new product development as a source of competitive advantage, most new product development activities fail to achieve their anticipated level of market success. Thus, Eliashberg et al. (1997) report on a survey of 154 senior marketing officers of U.S. corporations, 79% of whom believe their new product development process could be significantly improved. A major complaint they identified was that most of the products developed tended to be marginal contributors to the firm's portfolio, rarely involving very new or "breakthrough" ideas. Eliasberg et al. then assess the range of market research methods that might enhance the output of new product development processes, classifying them by type of product sought (radically new vs. marginally new) and nature of the research method (traditional vs. nontraditional). They point out that traditional marketing research methods obtain information from respondents at the center of the market—respondents whose thinking is limited by their current experience and environment. They also note that these traditional methods have generally failed to produce radical new product breakthroughs, leading to interest in nontraditional methods.

A review of marketing literature on techniques and tools used to generate ideas for new products and services makes clear two major points of difference between methods traditionally used and the LU idea-generation method: the kind of respondents from whom information is collected and the type of information that is collected. What we will term "traditional" idea-generation methods have two characteristics in common. First, traditional methods obtain data from representative users or customers at or near the center of the intended target market. Second, they obtain need information only, and assign the task of generating ideas for solutions leading to new products to manufacturers (Griffin 1997, Haman 1996, Rangaswamy and Lilien 1997, Eliashberg et al. 1997, Lonsdale et al. 1996). In contrast, LU idea-generation methods collect information on *both* needs and ideas for solutions from "lead users." Lead users are defined as users of a given product or service type that combine two characteristics: (1) They expect attractive innovation-related benefits from a solution to their needs and so are motivated to innovate, and (2) they experience needs for a given innovation earlier than the majority of the target market (von Hippel 1986).

It is possible that traditional methods' focus on representative users is a cause of their apparently poor ability to generate ideas for "breakthroughs"—defined here as new product ideas that form the basis for an entire new line of products or services. Classical research on problem solving shows that subjects are strongly constrained by their real-world experience, an effect called "functional fixedness." Thus, those who use an object or see it used in a familiar way are blocked from using that object in a novel way (Dunker 1945, Birch and Rabinowitz 1951, Adamson 1952). Furthermore, the more recently objects or problem-solving strategies have been used in a familiar way, the more difficult subjects find it to employ them in a novel way (Adamson and Taylor 1954). This fixedness effect is also displayed in innovation practice (Allen and Marquis 1964).

If familiarity with existing product attributes and uses interferes with the ability to conceive of novel attributes and uses, then representative target-market customers, users of today's products, would seem to be poorly situated to envision novel needs or solutions. In contrast, lead users would seem to be better situated in this regard—they "live in the future" relative to representative target-market users, experiencing today what representative users will experience months or years later.

As was proposed by von Hippel (1986), LU idea-generation studies can identify and learn from lead users, both within and well beyond intended target markets. Lead users found outside of a target market often encounter even more extreme conditions on a trend relevant to that target market. They may, therefore, be forced to develop solutions that are novel enough to represent "breakthroughs" when applied to the target market. For example, auto manufacturers seeking to improve auto efficiency by reducing weight with lighter, stronger materials might find breakthroughs in the aerospace industry, which faces a very similar problem in an even more extreme form.

The second major difference between traditional marketing research idea-generation methods and lead users' methods is that the former only collect data on *needs* from users or customers. Manufacturer-based product developers then have the task of creating ideas for new products and services based upon that need data. Tools used to support ideation include brainstorming (Rossiter and Lilien 1994, Hargadon 1996) focus groups, customer visits (McQuarrie 1998), conjoint analysis and "channeled ideation" (Goldenberg et al. 1999).

The value of assigning idea generation to manufacturers, as is traditionally done, is not supported by research. As Goldenberg et al. (2001) point out, "...the marketing literature has paid little attention to the way an idea is generated as a possible predictor of its success." (p. 71). They themselves find that ideas based on solution spotting (where the solution either precedes traditional market research or where the solution and the need are spotted simultaneously) are superior to those associated with prior need assessment (need spotting). Similar results are reported by Finke et al. (1992).

Two findings from innovation research also support the potential utility of the LU approach. The first shows that users rather than manufacturers are often the initial developers of—the "idea generators" for—what later become commercially significant new products and processes (e.g., Enos 1962, Freeman 1968, von Hippel 1988, and Shaw 1985). The second finding shows that innovation by users tends to be concentrated among lead users of those products and processes (Urban and von Hippel 1988, Morrison et al. 2000, Shah 1999, Luthje 2000).

2.1. The LU Idea-Generation Process

In general overview, the LU process involves four major phases.

Phase 1: Goal Generation and Team Formation. A firm provides an ideation-goal for the project and forms a LU project team. Teams typically are composed of three to five experienced people from marketing and technical departments, with one member serving as project leader. Team members typically spend 12 to 20 hours per week on a project. Typical project duration is four to six months. During the initial project phase, the LU project team works with relevant key company stakeholders to select the general market it will target and the type and level of innovation desired.

Phase 2: Trend Research. During Phase 2, LU teams focus on identifying and deeply understanding important market and technical trends in the field being explored. Team members begin by reviewing conventional information sources. Next, they systematically identify and interview leading experts in the marketplace that they are exploring—people who have a broad view of emerging technologies and leading-edge applications in that field or fields. They then select an important trend or trends as the central focus of further project work.

Phase 3: LU Pyramid Networking. In Phase 3, unique to the LU process, the project team engages in a "pyramid" networking exercise to identify and learn from users at the leading edge of the important trends selected for as a study focus. They identify lead users both in the target market *and* in other markets that face similar needs in an even more extreme form, and learn from those lead users about needs and solutions they are encountering at the leading edge. The pyramid networking technique, a modified version of the "snowballing" technique, relies on the fact that people with a strong interest in a topic or field tend to know people *more* expert than themselves: For example, good computer science professionals tend to know the identity of computer scientists who are even more skilled than they are (von Hippel et al. 1999).

Phase 4: LU Workshop and Idea Improvement. In the fourth and final phase of a LU project, activity centers around a LU workshop in which invited lead users work with company personnel to improve the preliminary concepts generated in Phase 3—and sometimes to generate entirely new concepts. Typically, 10 to 15 people attend this workshop, of which a third may come from the firm sponsoring the study. Participants first work in small groups, then work as a whole to design final concepts that fit the company's needs. Thereafter, the entire group evaluates the concepts in terms of technical feasibility, market appeal, and management priorities.

2.2. The LU Method Track Record

The three empirical studies of LU idea-generation processes published to date all utilized inputs from users at the leading edge of the *target* market, and all reported developing concepts for valuable, "next generation" products. Thus, Urban and von Hippel (1988) evaluated the LU idea-generation method in a laboratory setting in the field of computer-aided systems for the design of printed circuit boards—PC-CAD. They followed the four-phase LU process described earlier, drawing information from a sample of 136 lead and representative users identified within the PC-CAD market. The new products that emerged from LU need and solution data were greatly preferred by potential users compared to product concepts generated by more traditional methods.

Herstatt and von Hippel (1992) documented a LU project seeking to develop a new line of pipehangers—hardware used to attach pipes to the ceilings of commercial buildings. Hilti, a major global manufacturer of construction-related equipment and products, conducted the project. The firm introduced a new line of pipehanger products based on the LU concept, and a poststudy evaluation has shown that this line has become a major commercial success for Hilti, according to private communication from the first author.

Olson and Bakke (2001) report upon two LU studies carried out by Cinet, a leading IT systems integrator in Norway, for the firm's two major product areas—desktop PCs, and Symfoni application GroupWare. In both studies, data collection focused on lead users in the target markets. These projects were very successful, providing most of the ideas incorporated into next-generation products. However, one year after their LU method trial, the firm had reverted to its traditional pattern of learning from suppliers rather than customers, indicating the difficulties of changing traditional practices within firms.

3. Research Goals, Setting, Pilot Research, and Hypotheses

Past evaluations of the LU process assessed projects utilizing input from lead users at the leading edge of target markets and reportedly produced concepts for valuable "next-generation" products. Our research seeks to extend these findings in two ways. First, we investigate whether LU projects that identify and learn from lead users from fields *in advance of* the leading edge of target markets develop concepts for new products that are more valuable—i.e., are more likely to produce "breakthroughs" that set the basis for new product lines. Second, we want to compare the effectiveness of the LU procedure in a field setting against procedures used by non-LU teams in the same setting.

3.1. Research Setting

Following Cook and Campbell (1979), we sought a field situation that could closely approximate a pre-post/test-control situation, with at least quasi-random assignments to treatment cells, satisfying three conditions. First, the site should be one for which innovation has historically been strategically important. This condition would ensure that the LU intervention would not signal a concurrent increase in the strategic incentive to innovate, a change that might improve innovation performance independent of any effect caused by the method itself. Second, the site must be using *both* LU methods seeking lead users beyond the target market *and* traditional idea-generation methods, which could act as a control within the same organizational units in parallel with the LU method. Third, the site must have data on a sufficient number of projects utilizing both LU and traditional idea-generation processes to permit statistical distinction between the effect of the methods from other firm-or industry-specific characteristics. (Henceforth, we will use the term "non-LU" methods to refer to the range of more mainstream methods 3M has traditionally employed for idea generation.)

At the time of our study, we found that 3M satisfied these three requirements as follows:

(1) 3M has historically been known for, and has always placed major emphasis on, innovation. As they note in their 1999 Annual Report, "For nearly 100 years, 3M has grown by pioneering innovative technologies and products.... Innovation remains *the* driving force of 3M culture and growth." (3M, Annual Report, 1999. p. 12.)

(2) 3M first began using the LU method in one division in 1996. All 3M LU projects involved searches for lead users both within and beyond intended target markets. By May 2000, idea-generation projects using the LU method had been carried out in several divisions, each of which was at the same time also employing more traditional idea-generation methods. These divisions therefore could play the role of experimental units.

(3) By May 2000, 3M had completed seven LU projects and had funded further development of the ideas generated by five of these. The divisions carrying out LU projects also had 42 contemporaneously funded projects available for study. These comparison projects used a range of non-LU idea-generation processes, described later.

While 3M cooperated in our study and permitted access to company records and to new product development team members, the firm did not offer us a controlled experimental setting. Rather, the organization agreed to serve as an environment for a natural experiment where we as researchers would have to account for any naturally occurring differences after the fact.

3.2. Pilot Research and Hypotheses

We conducted an inductive, qualitative research phase at 3M to generate more specific research hypotheses and associated measurements. Our approach utilizes a research tradition informed by both ethnographic (Douglas 1986, Willis 1981, Lave 1988, Van Maanen 1988, and Workman 1993) and grounded theory (Glaser and Strauss 1967) perspectives, and incorporated three goals:

(1) *Develop trust-based relationships between 3M new product development professionals and researchers.* To implement this goal, we began our grounded research activities only after obtaining strong top management support and permissions for access to confidential company data. These permissions enabled our research team to develop unguarded and informal relationships with 3M product development teams.

(2) *Allow data and the field to drive theory creation.* Product developers throughout the firm shared their time and helped us understand how innovative product concept generation is practiced, understood, and communicated at 3M. Their insights were an important input into hypothesis formulation (Wenger 1998).

(3) *Use fieldwork to drive measurement development.* We studied the variables and scales used internally by 3M related to new product development and resourcing decisions and integrated them with those we acquired from the academic literature. To the extent possible, our measures incorporated the types of data customarily collected by 3M.

In the course of our grounded research at 3M, we specifically sought balance between LU and non-LU participants. We interviewed more than 20 managers and related new product development professionals in several 3M divisions. These internal experts represented the technical/scientific side of new product development (the professional group historically most credited as being the source of the company's innovative product offerings) and the business side (including marketing professionals). Research team members also observed and participated in LU training sessions and studied relevant internal company documentation.

Our fieldwork showed that all LU teams were taught the same process by the same small group of coaches working from the same set of written training materials. We also found that both instruction and project team practice drove 3M teams to and then beyond the leading edges of the target market to identify and learn from lead users in "advanced analog" markets.

Three clear concerns about the LU process emerged during the course of our interviews. First, some interviewees expressed concern that ideas developed via the LU process might have low "organizational fit" with the 3M technical, production, and market environment, and hence, be less likely to be judged worthy of funding by 3M management. If this concern proved correct, it would represent a major barrier to gaining actual marketplace benefit from any breakthrough ideas generated by the LU method. Second, some managers expressed a concern that a process built upon distilling new ideas from LU needs and prototype solutions would result in ideas that could not be effectively patented by 3M, a major drawback to the method if true. Third, many LU participants expressed concern about the greater time and effort involved in the LU idea generation method relative to alternative approaches, and the impact of that time and effort on managers' willingness to use the method.

Following our grounded research, we generated five hypotheses. Hypotheses 1 and 2 measure basic outputs, and their motivation derives from the literature cited earlier. Hypotheses 3–5, derived from our grounded theory approach, express the three major concerns of interviewees, described above, in hypothesis form.

HYPOTHESIS H1. *LU methods will generate ideas with greater commercial potential than will non-LU methods.*

HYPOTHESIS H2. *LU methods identifying and learning from lead users outside of the target market will increase the overall rate at which the organization generates major new product lines.*

HYPOTHESIS H3. *Projects from LU methods will exhibit a lower level of organizational "fit" than will non-LU projects.*

HYPOTHESIS H4. *Ideas generated by LU methods will be less protectable by patent or other means of intellectual property protection than will ideas generated by non-LU methods.*

HYPOTHESIS H5. *LU methods will cost more in money and time than non-LU methods to generate ideas forming the basis for funded projects.*

4. Research Samples, Data Collection Instruments, and Methods

4.1. Research Samples

We sought samples of development projects in 3M divisions that differed with respect to their use of the LU process, but that were in other respects as similar as possible to those from the LU process. Where unavoidable differences did exist between our samples, we attempt to err in the conservative direction to ensure that we do not overly favor the outcomes of the LU process. We control for the impact of division-related variables by selecting projects only from divisions that were carrying out both LU and non-LU projects. Within these divisions, we selected two types of samples.

Cross-Sectional Sample. Our first sample consists of "funded ideas." The earliest stage involving 3M critical management review is the initial request for funding; a "funded idea," therefore, has received careful review and positive evaluations from 3M divisional managers and has received, at a minimum, initial funding within the 3M product development system. Our sample of funded ideas was a complete census of all ideas receiving funding in the 3M divisions that funded both LU and non-LU project ideas during our data collection period of February 1999–May 2000. We identified funded ideas via divisional records and generated a sample of five funded ideas developed by LU studies ("LU ideas") and 42 funded ideas developed by other, more traditional, divisional processes ("non-LU ideas). This process controls for variation over time in criteria that management might apply to the funding decision.

We next had to address the issue of possible differences between project staffing and performance incentives. To explore possible staff differences, we compared the backgrounds, personalities, and skills of LU project participants with those in non-LU groups via a survey. We found that those staffing LU and non-LU groups were not significantly different in terms of job level, years employed at 3M, rate of career advancement, and other background variables. However, they did differ significantly on two self-reported skill dimensions. LU project participants gave themselves significantly higher ratings with respect to general marketing/sales skills (the means differed by 0.72 points on a 5-point scale, $p < 0.03$). Also, non-LU project participants gave themselves significantly higher ratings on technology skills (the means differed by 0.62 points on a 5-point scale, $p < 0.05$). In addition, LU group participants differed significantly from non-LU group participants on one of four Myers Briggs scales: They rated significantly higher on the extrovert/introvert dimension (the means differed by 11 points on a 100-point scale, $p < 0.08$).

The differences noted are a potential source of concern with respect to the validity of our natural experiment on the impact of the LU idea-generation process. Perhaps 3M LU project teams could generate better ideas simply because they contained more skilled (and extroverted) marketing researchers. However, a more detailed look suggests that this is unlikely. Although the difference was statistically significant, LU team members ranked themselves on average only 15% higher on the marketing/sales skills scale than did non-LU team members. In addition, the overlap between conventional marketing research skills and the activities prescribed for LU teams is low—and the skill level differences reported did not correlate significantly with differences in the activities the team members reported carrying out during their projects.[1]

We next sought differences in the motivation of LU and non-LU team members to achieve a breakthrough and found none. Our interviews with 3M management revealed that concerns about corporate growth and margins had led to intense pressure being put on *all* personnel at the levels of LU and non-LU team members to achieve new "breakthrough" products and product lines. We could find no evidence that there was any difference in a priori attractiveness of the areas of focus between LU and non-LU teams. Managers said that there was no difference, and a content analysis of formal annual performance goals set for the individual LU and non-LU team members in the one division that allowed us access to this data, supported their views that equivalent opportunities for and pressure for breakthroughs existed for all.

Even given equivalent incentives being applied to LU and non-LU project teams, it is possible that Hawthorne or placebo effects were impacting these teams differentially. (For our purposes here, the Hawthorne effect can be described as "I do better because extra attention is being paid to me or to my performance." The placebo effect can be described as "I expect this process will work and so I will strive to get the results that have been described to me.") While such effects are possible, our fieldwork suggests that neither effect was likely to positively and differentially affect the performance of teams using the LU method. At 3M, as at most companies, high-profile activities are burdened by high management attention paid to those activities, resulting in more

[1] To explore this matter, we first ran a principal component analysis on a battery of 21 product development activities. We then used the first principal component (representing twice the variance of the second principal component) as a summary measure of critical product development capabilities, and regressed it against LU vs. non-LU training, using background, personality, and skills as covariates. We found that the LU vs. non-LU training explained the bulk of the variance on this factor, with none of the covariates noted above statistically significant. While some of these covariates did explain significant variance in the other principal components, as those components are of much less importance than the first component, the impact of those covariates can be regarded as minor overall.

frequent reporting and restricted horizons. Also, our qualitative research showed that at 3M, employees generally view new processes introduced to the company with skepticism rather than with the expectation that they will perform well.

With respect to the intended difference under study—use of LU methods within projects—all LU teams employed an identical LU process taught to them with identical coaching materials and with coaching provided by members of the same small set of internal 3M coaches. In accordance with traditional 3M practice, idea generation leading to funded non-LU projects was an internal process using informal methods and carried out by marketing and lab personnel. Non-LU teams used data sources for idea generation that varied from project to project and included market data collected by outside organizations, data from focus groups with major customers and from customer panels, and information from lab personnel. Non-LU teams never reported collecting information from lead users—they collected market information only from target markets. We refer to these traditional 3M idea-generation practices as non-LU idea-generation practices.

In sum, while not satisfying the random assignment criterion for experimental design, these samples appear to satisfy the "rough equivalence" criteria in test and control conditions associated with natural or quasi experimentation.

Longitudinal Sample. Preliminary analysis of the outcomes of the LU process showed that LU teams were generally developing ideas for major new product lines, suggesting that it was important to generate an additional sample of non-LU comparison projects. As major new product lines generally emerge rarely, we chose this second sample to consist of all major new product lines introduced to the marketplace between 1950–2000 by the 3M divisions that had executed one or more LU studies. (1950 was as far back as we could go and still find company employees who could provide some data about the innovation histories of these major product lines.) Following the advice of 3M controllers (and in line with Stalk et al. 1996), we operationalized the concept of major product lines as those that were separately reported upon in divisional financial statements. In 1999 in the 3M divisions we studied, sales of individual major product lines ranged from 7% to 73% of total divisional sales. Major product lines at 3M tend to be long lived: We were able to identify only two in our sampled divisions that had been discontinued after being initiated in the period 1950–2000. Each major product line showed similar patterns of strong growth and good profit margins.

Our sample of major product lines developed via non-LU methods contains 21 cases that met our criteria and that had been developed and funded by the divisions executing LU studies during the 1950–2000 period. We will compare data on these non-LU major product lines with data related to the five funded ideas developed by LU methods that produced outcomes meeting the criteria for major product lines.

The data for our longitudinal sample of major product lines is neither as complete nor likely to be as accurate as were the data collected for our cross-sectional sample. Specifically, we have no data on the characteristics of the personnel involved in major product line developments prior to 1997, nor do we have data on incentives applied to or any specifics regarding idea-generation methods used by these personnel. The data collected for our longitudinal samples depends upon the recall of a small number of informants (usually one or two) for each case. While these informants had been actual participants in the projects they were describing, the accuracy of the reports is questionable (and might even involve upwardly biased recall of the degree of past innovation successes), as, in many cases, the innovations they described were made decades earlier. An additional concern is that conditions within 3M and also within the general U.S. and world economies have varied significantly over the 50-year analysis time frame.

In sum, the quasi-experimental field setting for this research involves several potential threats to validity and generalizability of findings. While we believe that these threats are small in the case of our cross-sectional sample, they are more significant in the case of our longitudinal sample.

4.2. Data Collection Instruments

We developed two data collection instruments for use during our study, as follows:

Outcomes Survey. We developed a New Product Idea Description Form from measures used in previous academic research: *novelty of ideas, originality/newness of customer needs,* and *potential for proliferating into an entire product line* from the New Product Creativity scale (Moorman and Miner 1997); *company sales/market share from the new idea in year 5,* and *probability of business success* from NPD Success Criteria (Griffin and Page 1996); and *global market potential for all competitors* from Cooper (1993). We supplemented these measures with items revealed during the exploratory phase of the research, including several in general use within 3M, as part of their internal new product idea-assessment procedure. We carefully pretested all items and refined them during preliminary instrument development meetings with participating staff at 3M. (The Appendix lists the data items collected for each idea.)

Process Survey. We developed a process instrument to measure individual skills in idea-generation activities, personality traits, and individual characteristics such as job level, time in the job, and R&D/marketing/accounting/manufacturing expertise. We developed items for the individual skills identified in the literature to be associated with generating new product ideas (Thomas 1993) and supplemented those items with skills identified from interviews with LU team leaders and their primary LU trainer. We measured personality traits using a Web-based version of Myers-Brigg's Personality Inventory (www.personalitypage.com).

4.3. Data Collection Methods

We began our quantitative data collection with face-to-face meetings with each LU project team leader. In these meetings we asked each project leader to: (a) identify and recruit the members of their team as respondents; (b) identify and recruit appropriate respondents within the same division to provide non-LU idea method data; and (c) describe the new product development goals and outputs from the LU project, provide organizational information about their division, and provide process information. We then contacted the respondents identified in (a) and (b) above. The respondents from non-LU idea-generation methods provided detailed information both on funded ideas as well as on process data. Respondents returned all (100%) of the Idea Description Forms for LU projects and 79% for non-LU projects, and 94% of the process instruments for LU projects and 86% for non-LU projects. These response rates are sufficiently high to suggest that validity checks for nonresponse bias are not needed (Malhotra 1996).

We collected data on major new product ideas developed early in the 1950–2000 period through in-depth interviews conducted with long-tenure employees in each of the LU study divisions who had a good knowledge of their division's and product line histories. We converted all historical dollar figures to 1999 dollar equivalents using U.S. consumer price index data (Council of Economic Advisors 2000).

5. Analysis and Results

We performed two sets of analysis: a cross-sectional analysis of the census of all contemporaneous funded ideas (that is, currently funded ideas in the data collection period February 1999–May 2000), and an intertemporal analysis of major product lines, for which we will compare the LU results with a 50-year history of major product line development at 3M.

In several of our analyses, we compare forecast data (projected sales for a line of products not yet launched) with actual, historical sales. To develop a conservative basis for these comparisons, we explored both the general literature and 3M historical data. In the general literature, Armstrong's (2001) review on forecast bias for new product introduction indicates that forecasts for new product sales are generally optimistic, but that upward bias decreases as the magnitude of the sales forecast increases. Coller and Yoln (1998) review the literature on bias in accuracy of management earnings forecasts and find that little systematic bias occurs. Tull's (1967) model calculates $15 million in revenue as a level above which forecasts actually become pessimistic on average.

We collected data from five 3M division controllers responsible for authorizing investment expenditure for developing new ideas into products and also obtained data from a 1995 internal study that compared such forecasts with actual sales. We combined this information to develop a distribution of forecast errors for a number of 3M divisions, as well as overall forecast errors across the full corporation. Those errors range from forecast/actual of +30% (overforecast) to −13% (underforecast). Based on the information just described, and in consultation with 3M management, we chose a 25% sales-forecast deflator to apply to all projected sales data in the analysis that follows. That deflator is consistent with 3M's historical experience and, given Tull's (1967) findings, should provide conservative sales projection figures.[2]

5.1. Cross-Sectional Findings: Comparison of Contemporaneously Funded Ideas Generated by LU and Non-LU Methods

We compared all "funded ideas" generated by LU and non-LU methods during the time period of our data collection (February 1999 to May 2000). Table 1 provides a census of all funded ideas during the noted period in the five divisions that funded LU ideas. During that time, five ideas generated by LU projects were being funded along with 42 ideas generated by non-LU idea-generation methods.

From Table 1, we see that LU ideas are significantly more novel than are ideas generated by non-LU methods, they address more original/newer customer needs, have significantly higher market share, have greater potential to develop into an entire product line, and are more strategically important. We also find that the LU ideas have projected annual sales in Year 5 that are eight times higher than those of ideas generated by non-LU methods—an average of $146 million versus an average of $18 million in forecast annual sales. Thus, we find support for Hypothesis 1: LU methods do appear to generate ideas with greater commercial potential than do non-LU methods in this sample ($p < 0.005$).

Table 1 LU vs. Non-LU Funded Ideas (Census)

	LU ideas ($n = 5$)[2]	Non-LU ideas ($n = 42$)[3]	Sig.
Factors related to value of idea			
Novelty compared with competition[1]	9.6	6.8	0.01
Originality/newness of customer needs addressed[1]	8.3	5.3	0.09
% market share in Year 5	68%	33%	0.01
Estimated sales in Year 5 (deflated for forecast error)	$146m	$18m	0.00
Potential for entire product family[1]	10.0	7.5	0.03
Operating profit	22%	24.0%	0.70
Probability of success	80%	66%	0.24
Strategic importance[1]	9.6	7.3	0.08
Intellectual property protection[1]	7.1	6.7	0.80
Factors related to organizational fit of idea			
Fit with existing distribution channels[1]	8.8	8.0	0.61
Fit with existing manufacturing capabilities[1]	7.8	6.7	0.92
Fit with existing Strategic Plan[1]	9.8	8.4	0.24

[1]These items were measured using a 10-point rating scale, where 10 = high, 1 = low.
[2]Funded LU ideas: all are for major product lines.
[3]Funded non-LU ideas: one is for a major product line, 41 are incremental ideas.

We also found that LU ideas differed in kind from those ideas produced by non-LU methods. Non-LU methods produced mainly funded ideas for product improvements and extensions to existing product lines, while the LU method produced funded ideas that fit 3M divisional criteria for major product lines. Those ideas produced projected sales that fell within (and sometimes exceeded) the proportion of divisional sales accounted for by existing individual divisional major product lines: projected sales five years after introduction for funded LU ideas, conservatively deflated as discussed above, ranged from 25% to over 300% of current total divisional sales. Table 2 shows the qualitative difference in the type of product (incremental vs. major product line/breakthrough) that the LU process has been generating. Using a chi-square

[2] We find no reason to apply a different deflator to LU vs. non-LU project sales projections. Even if LU project personnel were for some reason more likely to be optimistic with respect to such projections than non-LU project personnel, that would not significantly impact our findings. In addition, over 60% of the total dollar value of sales forecasts made for LU projects were actually made by personnel not associated with those projects (outside consulting firms or business analysts from other divisions).

Table 2 Idea Types Generated by LU and Non-LU Methods

	Incremental	Major product line
LU method	0	5
Non-LU method	41	1

test, the probability of this outcome occurring by chance is $p < 0.005$, supporting Hypothesis 2.

To illustrate what the "major product line" innovations that the LU process teams generated at 3M were like, we briefly describe four:

(1) A new approach to the prevention of infections associated with surgical operations. The new approach replaces the traditional "one size fits all" approach to infection prevention with a portfolio of patient-specific measures based upon each patient's individual biological susceptibilities. This innovation involves new product lines plus related business and strategy innovations made by the team to bring this new approach to market successfully and profitably.

(2) Electronic test and communication equipment that, for the first time, enables physically isolated workers such as telecommunication equipment repair people to carry out their problem-solving work as a team. Linked workgroup members can contribute to the solution of a problem being worked upon by a single, physically isolated worker in real time.

(3) A new approach (implemented via novel equipment) to the application of commercial graphics films that cuts the time of application from 48 hours to less than 1 hour. (Commercial graphics films are used, for example, to cover entire truck trailers, buses, and other vehicles with advertising or decorative graphics.) The LU team ideas involve technical innovations plus related channel and business model changes to help diffuse the innovation rapidly.

(4) A new approach to packaging fragile items in shipping cartons to replace current packaging materials such as foamed "plastic peanuts." The new product lines implementing the approach are more environmentally friendly and much faster and more convenient for both shippers and package recipients than are present products and methods.

Following Hypothesis 3, our qualitative interviewees proposed that the apparently more ambitious outcomes from the LU process would be less compatible with key organization-fit criteria than would non-LU ideas. The last three items in Table 1 address this issue: We find no statistical difference in quality of fit of LU and non-LU ideas with respect to existing divisional distribution channels, manufacturing capabilities, or divisional strategic plans. Hence, we cannot reject the Null Hypothesis H_3 that LU and non-LU major product lines are equal on these critical dimensions of organizational fit ($p > 0.10$).

In line with Hypothesis 4, interviewees proposed that ideas generated by the LU method would be less protectable by patents than would ideas generated by other methods. A single item in Table 3 tests this hypothesis and we cannot reject the Null Hypothesis H_4 that LU and non-LU major product lines are equal on intellectual property protection ($p > 0.10$).

Finally, we hypothesized (H_5) that LU idea-generation methods would cost more in time and money than would idea-generation methods used in our sample of comparison projects. This hypothesis is supported by our data. An audit of idea development time shows that the generation of a funded LU idea consumed 154 (sd. = 82) person days on average. In contrast, generation of an average non-LU idea consumed an average of 60 (sd. = 43) person days, rejecting the hypothesis of equality of these two means at the $p < 0.05$ level. Using internal 3M data for average costs of professional development personnel, we obtained a total cost of approximately $100,000 per funded LU project (including additional costs associated with the LU training) versus $30,000 for non-LU projects. After accounting for the different probability of success for LU projects (Table 1: 80% for LU projects vs. 66% for the census of non-LU projects), we determined that 3M pays about $80,000 more, on average, for a successful LU project than it does for a successful non-LU project.

5.2. Longitudinal Findings: Major Product Line Ideas Generated by LU and Non-LU Methods

We now compare the major product line ideas generated by the LU method with those generated earlier—during the period 1950–2000—by the 3M divisions in our study using non-LU methods. The 3M divisions we studied produced 21 major product lines during the 1950–2000 period. During the 1997–2000 period, they produced five of those major product lines using LU methods and two using non-LU methods. Examples of major product lines generated by *non*-LU methods in our 1950–2000 sample include:

(1) Scotch tape: A line of transparent mending tapes that was a major success in many household and commercial applications.

(2) Disposable patient drapes for operating room use: A pioneering line of disposable products for the medical field now sold in many variations.

(3) Box-sealing tapes: The first type of tape strong enough to reliably seal corrugated shipping boxes, it replaced stapling in most "corrugated shipper" applications.

(4) Commercial graphics films: Plastic films capable of withstanding outdoor environments that could be printed upon and adhered to vehicles. This product line changed the entire approach to outdoor signage.

Our sample of ideas for new major product lines provides additional tests of H_1 through H_4. However, that sample does not permit an alternative means to test Hypothesis 5, as we have no data on the costs of idea generation for major product lines developed prior to 1997. We begin with alternative tests for H_1, the hypothesis that LU methods will generate ideas with greater commercial potential than will non-LU methods. Here we consider an alternative to H_1, call it H_{1A}, that focuses on major new product lines only. H_{1A} proposes that ideas for *major product lines* developed by LU methods will have greater commercial potential than those generated by non-LU methods. To proceed, we make the following two assumptions:

ASSUMPTION 1. *Returns from all major product lines that have emerged at 3M using methods other than the* LU *method can be considered as draws from the same probability distribution.*

ASSUMPTION 2. *Revenue projections for* LU *major product lines are biased to the same degree on average as historical projections have been for other major product lines.*

Assumption 1 allows us to compare the major product lines from the LU method with all major product lines in these divisions during the prior four decades. Assumption 2 allows us to use historical 3M figures on major product line forecast error to adjust the forecasts from the LU data. Following Assumptions 1 and 2 for major product lines introduced to market in 1994 or earlier we used as a reference "actual sales five years after introduction (including loss/gain from sales of related products in the division)." 3M management maintains such records and the five-year sales goal is part of 3M's project justification process. To provide comparable data, we translated all sales data into 1999 dollars. Following Assumption 2 for the major product line ideas generated from the LU process (and for two major product line ideas recently generated by non-LU processes), we have forecasts of five-year sales vs. actual figures for the historical major product lines.

After deflation of the forecasts as discussed earlier, we find that the average "sales in Year 5" for LU major product lines ($n = 5$), is \$146m, while the similar figure for major product lines generated by non-LU methods ($n = 16$, as we were able to obtain detailed data on only 16 of the 21 non-LU major product lines) is \$62m. (Table 3).

We next test whether the mean LU major product line yields higher sales than those derived from non-LU sources. At the $p = 0.05$ level we reject the hypothesis that these values are equivalent (Table 4), providing support for H_{1A}, conditional on Assumptions 1 and 2. Table 4 also provides profiles of the 5 LU major product lines and the 16 non-LU major product lines for which we were able to collect data on the matters listed in that table. We find that the ideas for

Table 3 **What Is a Major (New) Product Line (MNPL) Worth?**

	LU MNPL five-year sales forecasts*	Non-LU MNPL five-year sales forecasts and actual*
	1997–2000 ($n = 5$)	1950–2000 ($n = 16$)
Mean	\$146m	\$62m
Median	\$124m	\$38m
Range	\$67.5m–\$232.5m	\$11.7m–\$276m

Note. Five-year sales forecasts for all major product lines commercialized in 1994 or later (five LU and two non-LU major product lines) have been deflated by 25% in line with 3M historical forecast error experience (see text). Five-year sales figures for major product lines commercialized *before* 1994 are actual historical sales data. This data has been converted to 1999 dollars using the Consumer Price Index from the Economic Report of the President (Council of Economic Advisors 2000).

Table 4 Dimensions of Difference Between LU Major (New) Product Lines (MNPL) and Non-LU Major Product Lines

	Lead User MNPLs ($n = 5$)	Non-LU MNPLs ($n = 16$)	Sig.
Novelty compared with competition*	9.6	8.0	0.21
Originality/newness of customer needs addressed*	8.3	7.9	0.78
% market share in Year 5	68%	61%	0.76
Estimated sales in Year 5 (deflated for forecast error)	$146m	$62m	0.04
Potential for entire product family*	10.0	9.4	0.38
Operating profit	22%	27%	0.41
Probability of success	80%	87%	0.35
Strategic importance*	9.6	8.5	0.39
Intellectual property protection*	7.1	7.4	0.81
Fit with distribution channels*	8.8	8.4	0.77
Fit with manufacturing capabilities*	7.8	6.7	0.53
Fit with Strategic Plan*	9.8	8.7	0.32

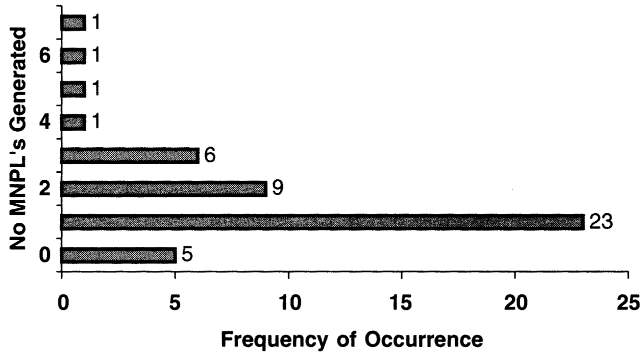
Note. These items noted with an asterisk were measured using a 10-point rating scale, where 10 = high, 1 = low.

major new product lines developed by LU and non-LU methods are relatively similar on most dimensions examined. However, as a comparison with the data in Table 1 shows, both are very different from our sample of currently funded ideas that were generated by non-LU methods.

To test the hypothesis that the LU method produces major new product line ideas at a higher *rate* than do non-LU methods (H_2) we look at the entire four-year period during which the LU process was implemented at 3M and compare it (on a rolling basis) with all other four-year periods during 1950–2000. The average rate of major product line development during this half-century for the divisions studied was 1.64 per four-year period. As Figure 1 shows, the highest rate achieved over a four-year period was seven major product lines, and this result was achieved during the 1997–2000 period during which the LU process was implemented by those divisions. During this period, five of the seven major product lines developed were generated by LU methods. Non-LU methods generated five or more major product lines in two of the 47, four-year rolling periods.

We next look at three comparisons: (1) LU output vs. pre-1997 output; (2) LU output vs. non-LU output,

Figure 1 Major Product Lines Generation Rate in 3M Divisions Under Study on a Four-Year Rolling Basis (1950–2000)



Note. Development of seven major (new) product lines (MNPLs) within a four-year period has occurred only once in the last half century—during the period corresponding to the use of the LU method.

1997–2000; and (3) pre-1997 output vs. all post-1997 output in the divisions studied. For Comparison (1), assume that 3M generates major product lines at a (constant) rate that represents the null hypothesis of no difference in rate of major product line generation over time. Using the four-year data in Figure 1, that rate is 1.64 major product lines per four-year period for non-LU methods. Then, a formal test of our Hypothesis H_2 is: "What is the likelihood that a process that generates $\lambda = 1.64$ events on average per study period could generate five (or more) in a period?" (1997–2000 for LU). Using an assumption of a Poisson generation process (Grassman 1981), we calculate that P(5 or more $|\lambda = 1.64) = 0.025$, providing support for H_2 (rejecting the null hypothesis at the 0.05 level).

For Comparison (2), if we compare the 1997–2000 period (five major product lines for LU methods vs. two major product lines for non-LU methods), we get P(5 or more $|\lambda = 4 \times 0.5 = 2.0) = 0.052$, again providing support for H_2. For Comparison (3), if we consider the LU method an organizational intervention (Mills 1999), we can compare the post-1997 period for 3M (blending both LU and non-LU ideas) with the results of the previous regime. These results give seven major product lines (five LUs and two non-LUs) in the four-year 1997–2000 period, versus the historical average (adjusted to account for four fewer intervals and two fewer major product lines) of 1.79, giving P(7 or more

$|\lambda = 1.79) = 0.003$. Thus, all three approaches provide support for H_2: We find that the rate of major new product line generation using the LU process is significantly higher than the rate historically seen at 3M in the 1950–2000 period using non-LU idea-generation processes.

Finally, we can perform additional tests of Hypotheses 3 and 4 by referring back to Table 4. We investigated earlier how major product line ideas generated by the LU method differed from those generated by non-LU methods. We reject the hypothesis (H_3) regarding a significant difference between LU and non-LU major product lines on dimensions of organizational "fit" (see the last three rows of Table 4). Also, we reject the hypothesis (H_4) that ideas generated by LU methods will be significantly less protectable by patent or other means of intellectual property protection than will ideas generated by non-LU methods.

6. Discussion

Our study of LU idea-generation projects at 3M has yielded several interesting empirical findings. From our cross-sectional sample, we have seen that ideas generated by LU processes had forecast sales in Year 5 that were more than eight times higher than the sales of the contemporaneously funded projects: $146 million annual sales on average versus $18 million. We also found that funded projects emerging from 3M LU studies had significantly higher novelty (usually being judged "new to the world"), addressed more original newer customer needs, and also had significantly higher forecasted market share in Year 5 (on average, 68% vs. 33% for non-LU ideas) than did those from more conventional methods.

With respect to findings from our longitudinal sample, we found both sets of ideas to be relatively similar in most respects, but forecast sales from major new product ideas generated by LU methods were significantly higher than sales forecasts for products generated by non-LU methods. We also found that the *rate* of introduction of products forecast to grow into a major new product line was significantly higher after use of the LU method began at 3M in 1997. The key finding here is not the rate itself: Clearly, the rate of major new product line ideas resulting from LU projects will go up or down depending upon the number of LU projects funded by management, but rather that ideas for major new product lines seem to be consistently produced by LU idea-generation projects—at least as 3M practices this method. This outcome differs from the outcomes of earlier studies of LU projects that reported generating ideas for valuable next-generation products rather than for breakthroughs. We speculate that this difference in outcomes is due to the 3M practice of identifying and learning from lead users outside and well in advance of the target market, a speculation that requires further investigation.

In the case of both the cross-sectional and longitudinal samples, we found that funded "breakthrough" ideas generated via the LU process offered as good a fit to existing divisional goals and competencies as did ideas generated by traditional methods. Insights from our grounded research leads us to suggest that this is because both LU and non-LU team developers at 3M know that ideas with "good fits" have a greater chance of acceptance and funding. They therefore work to select and shape the ideas they propose to achieve that fit.

We also found that LU ideas involved as high a level of intellectual property protection as did the ideas generated by non-LU methods. On the face of it, this finding seems puzzling: How can 3M expect to protect ideas that lead users have developed and probably revealed elsewhere? Our fieldwork suggests an answer. LU studies at 3M did not find complete ideas for breakthrough products from single lead users. Instead, LU project teams assessed ideas from a number of lead users and used Phase 4 of the LU process to combine those ideas. For example, a 3M LU study designed to identify better ways to prevent infections associated with surgery created a breakthrough product concept by combining insights from, among others, an expert in wound healing, a leading veterinary surgeon, and a specialist in theatrical makeup with special expertise in adhering materials to skin. These compound ideas were then novel intellectual property that could be protected by 3M. (In 3M's LU process, lead users retain rights to ideas generated prior to Phase 4 LU workshops, but assign rights to ideas generated *at* LU workshops to 3M.)

Finally, note that LU projects can and do fail. Because we restricted membership in both our cross-sectional and longitudinal samples to *funded* ideas, we did not include any LU or non-LU ideas that failed to cross this initial evaluation hurdle. We do know, however, that only five of the seven LU projects initiated during our period of study at 3M generated ideas that were considered worthy of funding by management. We have no data about the number of non-LU idea-generation projects failing to cross this hurdle, but our fieldwork suggests that the non-LU failure rate was at least as high as the LU failure rate.

Relying most heavily upon our cross-sectional results, we suggest that the question that motivated this study is answered in the affirmative: The LU idea-generation method does appear to generate better results than traditional methods. It therefore appears to merit further investigation and development.[3]

[3] 3M top management seems to share this assessment as two quotes collected during our fieldwork suggest:

> We were using traditional methods of marketing research in our division, and were able to achieve our corporate growth targets. However, we found that traditional techniques are not able to identify newly emerging breakthroughs in a rapidly-moving field like Telecoms. Now the LU process has been made the centerpiece of our new idea generation activities for product breakthroughs, and we have an abundance of radical new ideas. The challenge now is finding resources for all of them. –Roger Lacey, VP of 3M Telecoms Division.
>
> This is probably the best process I've seen for replicating what originally made this company great. What made 3M was our people going out and creating solutions with leading-edge customers. I think that, for a period of time, we lost a lot of that. It's very hard to create a process that will do it. But this [the LU Process] is the closest that I've seen... I'm glad that it's being adopted across the company.—Bill Coyne, 3M Senior VP of R&D.

7. Suggestions for Future Research

The LU paradigm opens up a number of research opportunities, including: (1) further empirical study of the process in other organizations, (2) new method development regarding how to *identify* users holding leading-edge information of commercial value; (3) new methods to *obtain information from* lead users and build that information into commercially viable new product and service offerings, and (4) designing and studying the organizational metrics and structures that lead to successful implementation of new processes like the LU method.

With respect to Opportunity 1, we suggest that it would be useful to conduct empirical research tracing key elements of new ideas generated to specific inputs and individuals, including lead users both inside and outside the target market. Such research could determine whether there is a causal relationship between seeking information from lead users in advanced analog markets and the likelihood of identifying ideas for new products and services that will be "breakthroughs" for the target market.

With respect to Opportunities 2 and 3, consider that in the traditional idea-generation paradigm, idea generation involves first identifying and quantifying the intensity of needs shared by many users and then having internal manufacturer personnel look for a novel product that users will find responsive to those general needs. The LU idea-generation paradigm assumes that key elements of the desired creative idea for a breakthrough already exist among leading-edge users, with the problem being to find it and develop its potential. In other words, the key challenge in the traditional paradigm is *idea generation*, and in the LU paradigm it is *idea search*.

The LU process analyzed here utilizes a networking procedure to identify and learn from a few carefully selected lead users both within and outside the target market. Other possibilities exist for mining LU information that also deserve exploration, drawing on emerging evidence that LU innovation is not rare. Empirical studies of user innovation in four very different areas show a significant fraction of users, ranging from 10% to 36%, reporting that they have developed or modified products.[4] In light of this evidence, methods to process information from many lead users simultaneously could be developed and explored.

Concerning Opportunity 4, note that even given the apparent successes at 3M, diffusion and further implementation is a challenge within the firm. Recall that Olson and Bakke (2001) reported on the lack of extensive implementation of the LU method at Cinet in spite of demonstrated success, and suggest that it is "necessary to pressure or reward personnel in order to make permanent changes in established routines" (p. 380). Resistance to innovation within corporations is a well-known phenomenon. Studies of how to address that resistance and make successful new corporate practices "stick" are clearly important.

In sum, we hope that these results will stimulate other researchers to explore and develop what we see as a promising paradigm for the idea-generation phase of new product and service development.

[4] 9.8% of users of outdoor consumer products reported innovating for own use (Luthje 2000); 26% of users of library information systems reported innovating for own use (Morrison et al. 2000); 24.3% of users of printed circuit CAD software reported innovating for own use (Urban and von Hippel 1988); 36% of users of pipe hanger hardware reported innovating for own use (Herstatt and von Hippel 1992).

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Appendix: Idea Description Form

We are interested in information about: ____________________

This new product idea has the following characteristics:	
Novelty: Relative to competition our product/service will be	10-point scale, 1 = low, 10 = high
Originality/newness of customer needs addressed	10-point scale, 1 = low, 10 = high
Global market potential (all competitors) in $ millions	$________M
% Our company's global market share in Year 5	________%
Estimated company sales in Year 5: $ millions	$________M
Profit potential (estimated % profit-operating income before taxes—5 years after introduction)	________%
Probability of business success (% chance of overall success)	________%
Estimated LOSS on sales of related products/services for this business unit in 5 years (loss due to new product/service replacing existing product/service sales)	$________M
Estimated GAIN on sales of related products/services for this business unit in 5 years (gain due to increased sales of related existing products/services for this business unit)	$________M
Fit with this business unit's current sales and distribution channels	10-point scale, 1 = low, 10 = high
Fit with this business unit's current manufacturing capabilities	10-point scale, 1 = low, 10 = high
Fit with current strategic plan of our business unit	10-point scale, 1 = low, 10 = high
Strategic importance to our business unit, regardless of fit with current plans	10-point scale, 1 = low, 10 = high
Importance of projected intellectual property protection obtained	10-point scale, 1 = low, 10 = high
Potential to proliferate into an entire product line	10-point scale, 1 = low, 10 = high

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