NORTH-HOLLAND

Diffusing Against Mature Technology: Issues and Strategy

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The classic attributes of diffusion identified by Rogers—relative advantage, compatibility, complexity, trialability, and observability—are a good basis for evaluating the diffusion prospects of a new technology qualitatively. This process may be simplified by evaluating just two primary factors, the relative performance advantage and the degree of operational novelty introduced by the new technology relative to its antecedent. We introduce the concept of operational novelty as a contraction of the innovation attributes of complexity and compatibility. Challenging a mature, established technology with a product based on new technology is risky, although the risk can be moderated by high performance advantage and low operational novelty. A product's performance advantages and operational novelties should be evaluated and compared before a strategy for market introduction is planned. An oblique rather than direct challenge to the established technology may be advised when performance advantage is marginal or operational novelty is high. © *1998 Elsevier Science Inc.*

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INTRODUCTION

Diffusing a new technology is always a challenge, but it can be particularly daunting when an older, mature technology is firmly established as the market standard. Technologists are often infatuated with the performance attributes of an innovation and are likely to overestimate its appeal to customers whose current needs are satisfactorily met by an existing technology. They often overvalue the relative advantage of a new process or product while undervaluing or even ignoring other important factors of diffusion. For example, the compatibility of an innovation with the practices and requirements of its antecedent is a potent factor in product success. Observability

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of the innovation in operation is especially important for novel technologies; and complexity of design, operation, or concept can be a serious handicap.

Evaluating the diffusion attributes of a new technology can be very difficult. Many of these factors are simply too subjective to be quantifiable except in gross terms. Mathematical models of diffusion, such as the Bass Model and its many enhancements, are useful as aids to understanding diffusion in a scholarly context, but they have little practical utility for integrating diffusion attributes in an entirely prospective evaluation of a technology's chances for market success [1].

Moreover, the capabilities of greatest importance to customers are often unforeseeable by a technology's developers. The market performance of new products based on incremental improvements to existing technology is much easier to predict than that of new products based on truly new technology. As a general rule, the more unique the technology with respect to its antecedent, the more difficult it is to predict its ultimate market niche and size. To put it another way, the more exciting a technical advance, the less likely its developers will know what to do with it and how well it will sell.

THE ATTRIBUTES OF DIFFUSION

The attributes of diffusion identified by Everett M. Rogers in his classic work, *Diffusion of Innovations* [2], are now canon. Rogers' early work stimulated an era of research in diffusion of technologies that has given rise to a great volume of literature. Unfortunately, much of this literature is perceived as abstruse and of little practical interest to business practitioners. This is unfortunate, since the fundamental premises of Rogers' work are not intrinsically difficult; indeed, they are almost common sense.

Rogers identifies five attributes of innovation that affect the rate of adoption:

1. *Relative advantage*: the degree to which an innovation is perceived as being better than the idea or product it supersedes.
2. *Compatibility*: the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters.
3. *Complexity*: the degree to which an innovation is perceived as relatively difficult to understand and use.
4. *Trialability*: the degree to which an innovation may be experimented with on a limited basis.
5. *Observability*: the degree to which the results of an innovation are visible to others.

Rogers' first attribute of innovation, relative advantage, may seem obvious. But it is crucial to understand that relative advantage is a perceived rather than intrinsic quality. Objective advantages, based on quantifiable measures of performance, can enhance diffusion only to the extent that they are perceived as advantages by users. Consequently, product developers increasingly rely on consumer-preference research as an aid to developing and improving products, and manufacturers of industrial products work closely with customers to understand their business.

Compatibility and complexity are also perceived attributes. Compatibility is a murky entity that is influenced by the established practices, values, traditions, and expectations of a user community. It can be mystic or mundane. Some communities will shun an innovation because it doesn't feel right: their psychic foundations reject it. Rogers cites several cases where societies in developing nations rejected or misadopted Western innovations because they were incompatible with cultural mores. On a different level, compatibility can also be a matter of oper-

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ational familiarity. Users become habituated to the operational requirements of an established technology, and a different protocol of operation can be disconcerting.

Complexity is less subjective than compatibility (design engineers have ways to measure complexity objectively). But perceived complexity is not a function of design alone. New operating requirements—even if measurably simpler than those of an established technology—may be perceived as complex simply because they are different. Thus, complexity may arise from incompatibility with the established protocols and procedures of an antecedent technology.

Trialability is simply the ability to "try out" an innovation before adopting it. It is an important feature for an innovation because it provides a means for prospective adopters to reduce the uncertainty they feel toward an unfamiliar technology or product. Often a new technology offers superior capabilities that can provide substantial benefits to customers, if only they can be persuaded to switch from the established technology. The inhibitions can be formidable, however. Companies seeking to deploy a new technology in commercial products and services must bridge a chasm of mistrust, habit, and risk-aversion before they can begin to realize revenues (Figure 1). These and other factors stem from product differentiation features such as brand loyalty, confidence in established manufacturers, and operational familiarity [3]. Trialability helps defeat such inhibitions.

Unfortunately, trialability is not always feasible. It is a simple matter to offer 30-day probationary sales for many consumer products. On the other hand, industrial process technologies may require substantial capital investment and changes to plant and equipment; or the benefits of the new technology may be of a long-term nature and not appreciable during a short-term trial.

In such cases, it is crucial to enhance the observability of the innovation. But observability (Rogers' fifth and final attribute of innovations) may be difficult to establish in a market that is already dominated by an established technology. Therefore, it will be important to establish observability in a niche market or a new application of the technology before attempting to challenge the dominant technology in its native market and application.

INNOVATION ATTRIBUTES CAN BE VIEWED FROM DIFFERENT PERSPECTIVES

If we think of Rogers' universe of attributes as a multivariant space of independent variables, these variables can be mapped against alternative coordinate spaces in which the same underlying concepts are seen and treated from different perspectives. By examining diffusion attributes from many directions, much of the literature has done just that [4, 5].

A principal hypothesis of this article is that—without changing Rogers' universe—we can visualize a "coordinate space" in which the attributes of complexity and compatibility are cross-coupled to create a variable we term *operational novelty*. The total number of independent variables in the space remains the same. In addition, we view relative advantage in its objective sense (measurable by performance indicators), and we regard the complexity variable as a narrower concept of complexity of operation rather than of general "differentness." We do not assert that our synthesis is more significant than other approaches, but rather, that it provides one useful and un-

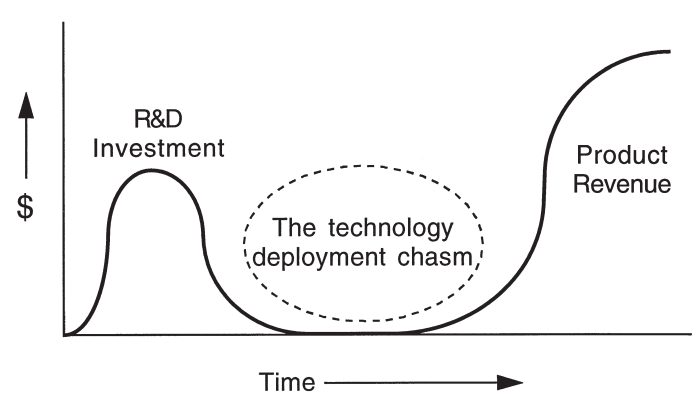

FIGURE 1. The technology deployment chasm.

. . . complexity and compatibility are cross-coupled to create . . . operational novelty.

derstandable analysis of the parameters of new-technology product diffusion.

OPERATIONAL NOVELTY

An often-overlooked factor influencing customer acceptance is the operational compatibility of a product relative to its antecedents. Operational novelty is a contraction of Rogers' innovation attributes of complexity and compatibility (or rather, its inverse, incompatibility). Considering these classical variables from the perspective of operational novelty can be helpful in a qualitative market analysis. In our redefined "coordinate space," relative advantage and operational novelty independently influence adoption of a new technology. They can be used together to help evaluate a prospective product.

Throughout this article, we use examples drawn from the professional experiences and observations of the authors. We are practitioners, and we believe it is important that theory be based on observation of the experiential world before being abstracted. Our conception of operational novelty first resulted from an effort to provide an explanation of our experience base.

We can illustrate operational novelty with the case of digital compact disc players for music reproduction. These devices are based on a technology that differs completely from that of its predecessor, the analog LP phonograph. However, the radical technical difference is largely transparent to the user, who operates the new device in a fashion very similar to the old one. Even though the technical uniqueness of the new product was great, it offered a high level of operational compatibility; or, to put it inversely, the operational novelty of the CD player when introduced was minimal. Operational compatibility creates comfort; its opposite, operational novelty, generally creates anxiety. Had the CD player introduced unique operational requirements, market acceptance would have been more difficult to predict.

Another factor with a substantial influence on customer acceptance is, of course, the relative advantage and expansion of capability of the new product with respect to products based on existing technology. One could say, for example, that the relative advantage represented by the videocassette recorder was infinite because the device had no commercial antecedent and it provided consumers with a capability previously unavailable to them. The market demand for this new capability grew so quickly that the original estimates of market size for the VCR underestimated the device's ultimate popularity.

However, one negative characteristic of the VCR was its rather high degree of operational novelty. Although it was similar in some ways to tape recorders for audio recording, the VCR presented novel programming requirements that intimidated many users. This high degree of operational novelty, arising from the complexity of the programming procedure and its incompatibility with previous user experience, was a complicating factor in the marketing of the product. Had the VCR been like the CD player and introduced virtually no new or special operating requirements, market penetration rate and ultimate market size could have been predicted with greater confidence. Illustrating this point was the surprisingly rapid though brief success of RCA's video disk technology, which was introduced at about the same time as the VCR. Although the RCA disk produced an inferior image and did not have a recording capability, it was quite successful in the marketplace, largely because it presented little operational novelty: To users it was just a video record player.

Some literature has asserted that complexity and novelty can actually enhance a perception of relative advantage in some products, particularly consumer electronics. For example, a study by Holak and Lehmann [6] found "a significant positive effect of complexity on relative advantage" for entertainment and electronics-based products. There is no doubt that some segment of the consumer population relishes the high-tech complexity of a new device. This might be expected to be especially true of college students, for example, who are a prime market for sound systems and other electronic entertainment

products. The sample population of the Holak and Lehmann study was dominated by college students and non-students living in university communities. We contend that their research did not adequately differentiate between the impact on people who are likely to be early adopters and the general population. We believe that for most products, the bulk of the consumer population responds to complexity by coupling this attribute to the compatibility variable rather than to relative advantage.

For example, the digital video disk technology being introduced into the U.S. market is intrinsically more complex than the VCR technology it will displace, or for that matter, the video disk described earlier. However, we predict this new technology will receive rapid, widespread acceptance because it offers tangible performance advantages, its operational novelty is small relative to VCRs, and its introduction price will be low. The fact that this device will provide the user with a wide range of complex options not presently available with any other device (for example, the ability to block violent and/or sexually explicit scenes) will factor only modestly as relative advantage. Indeed, it is likely that most adopters will ignore the new features or will use just one or two of them. Rather, the device will succeed on the relative advantage of superior image quality at a price equal to or lower than the price of pre-recorded VCR tapes. Because the new, complex features are ancillary to the primary function of the device, the operational novelty they introduce need not be an obstacle to immediate and intuitive basic operation.

RELATIVE ADVANTAGE AND OPERATIONAL NOVELTY INTERACT

Two major factors, operational novelty and performance or capability relative to product antecedents, conspire to make product market forecasting a very tricky endeavor. The three-dimensional plot in Figure 2 illustrates how these terms in the marketing equation create uncertainty for new technologies and products. Operational novelty increases the uncertainty associated with the introduction of a new-technology product, with that uncertainty increasing with greater operational novelty. A relative performance advantage tends to reduce market uncertainty. These two factors can be subjectively evaluated for any product and the result placed appropriately on a matrix. If we plot the early market estimates and the ultimate market volume for each product on a third axis, a spatial region of error for market estimation becomes discernible. Greater operational novelty does not necessarily result in failure in the marketplace. However, high operational novelty increases the uncertainty of market acceptance, thereby creating far more market and financial risk to the product developer.

For example, cellular telephones, introduced in the 1980s, offered an entirely new capability. The devices ranked high in performance advantage relative to the radiotelephony systems that existed then, even though some aspects of their performance (reliability and transmission quality, for example) remained somewhat inferior to standard telephones. However, the key to the technology's success was most likely the fact that it significantly reduced the operational novelty of radiotelephony relative to standard land-line telephones. Early radiotelephony systems were user-unfriendly and required the assistance of an operator and a long wait to obtain a clear transmission channel. The critical performance advance of cellular systems was their ability to perform as if channel capacity were virtually unlimited under most circumstances. This advance resulted in a radiotelephony system with virtually no operational novelty relative to standard telephones. The unanticipated success of cellular phones, despite their continued relatively high operational cost, can be readily explained by this combination of a relative performance advantage and low operational novelty.

From the vantage of the late 1990s, it is easy to deride AT&T's decision in 1984 to abandon cellular technology, which it had pioneered. Cellular phones were a distract-

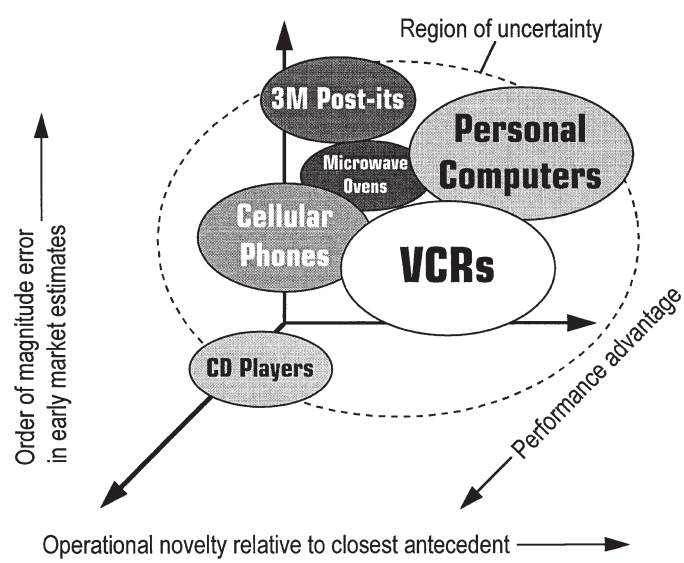

FIGURE 2. Market prediction for new technology products is filled with uncertainty.

ing issue for AT&T during the hectic days of divestiture. Given the hefty size and price tag of the device, the new requirement for some maintenance, and other performance shortcomings, one can perhaps understand why AT&T estimated that cellular phones would fill no more than a niche market. But they were colossally wrong in their market forecast (by a factor of 20 or more), and the company later had to make an enormous investment to buy back its competitive position in this technology [7]. Surely, the original decision had been made without a vision for how the new technology might itself redefine the market as it matured. But AT&T is not the only company to make such errors; many companies misjudge the market for new-technology products by orders of magnitude up or down.

IBM similarly misjudged the ultimate market volume of personal computers and consequently entered the PC market a few years late. This late entry may have been a deliberate strategy, but in any case, it indicates an initial policy of caution toward the new market. Caution was perhaps well advised in those early days. The relative advantage of PCs with respect to their antecedents (handheld calculators and typewriters) was marginal. Machines were expensive and imposed an enormous burden of operational novelty. Forecasting the long-term capacity of the microcomputer market was risky. Without a preternatural vision for how PCs would fundamentally change the work environment and how, by cultural feedback, they would cause a new generation of users to be educated with the skills necessary to fully exploit the PC, a confident forecast was hardly possible.

COMPATIBILITY AND SIMPLICITY BOLSTER RELATIVE ADVANTAGE

The enormous performance improvement of PCs in recent years has continued to propel the product to extraordinary heights of market acceptance. It is interesting to observe, however, that PC software applications that are truly operationally novel continue to be far less predictable in their success than those that merely automate traditional functions. Standard office applications still lead in home and consumer uses of computing for a variety of reasons, not the least of which is familiarity. The microcomputer application with the least operational novelty is word processing, which fundamentally is an enhanced replacement of the typewriter. It can be argued that the widespread use of office computers for word processing simply represents a further upgrade to the traditional office system of a secretary and a word processing device, be it typewriter, magnetic card system, or computer.

Consumer applications of computers have proved to be far less predictable than many other products with regard to their market acceptance. The low operational novelty of income tax preparation programs that ask a user the same questions his or her accountant always asked makes it easy to understand their success. In contrast, early home-computer programs that performed unusual tasks not normally done by most people but made feasible by the PC (for example, calculating the recipe ingredients needed for a dinner party of eleven) generally had limited success. The probability of success of Internet communications applications as replacements for long distance telephony and first-class mail will be enhanced by reducing the operational novelty of their use, even as the great technical enhancements in audio and video come along. The closer such new applications resemble their antecedents in form, fit, and function, the less uncertain will be their acceptance in the marketplace.

Another intriguing example of the uncertainty in technology/product acceptance from the “low-tech” end of the technology spectrum is found with 3M’s Post-it Notes products. It is said that a 3M employee whose hobby was singing and who was a member of a choral group identified a market need for non-damaging paper markers for musical scores. He resurrected a low-tack adhesive for this purpose that the lab had previously developed and set aside [8]. Initially, 3M did not anticipate that this invention would ultimately become one of the most popular office supply products ever. It is true that it offered a great performance advantage relative to alternative approaches (e.g., tape, paper clips), but it was also quite novel in its operation. But since it eliminated the complexity of tearing paper scraps and affixing them with tape or clips, one can argue that the antecedents of the ubiquitous “yellow sticky” were so cumbersome that their use was restricted to those circumstances where they were essential. Not recognized was the true unmet need to be able to place a non-damaging comment or marker anywhere in a document. Operational novelty can be offset if the new process significantly reduces complexity.

LOW OPERATIONAL NOVELTY IS NO GUARANTEE OF SUCCESS

It should be recognized that even with low operational novelty, new products and technologies can fail in the

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marketplace if they do not offer a sufficient performance advantage over their antecedent technologies.

An example can be found in the slow acceptance of microwave ovens. Initially, in the late 1940s, the product was marketed as a replacement for conventional-oven cooking. However, performance and capability improvements were marginal, and for some foods, negative. Even though the product did not introduce significant operational novelty, the lack of a substantial performance improvement tended to reduce the predictability of market acceptance. By the middle 1970s only a limited number of these ovens were in consumer use, mostly in the homes of early adopters. Only when the product was remarketed as a way to heat foods conveniently and fast (a new capability and hence a perceived performance improvement) did the product achieve the market volume that had been anticipated [9].

Microwave clothes dryers are likely to pose similar marketing uncertainties. The product, which may soon be introduced, imposes few operational novelties. But overall improvement in performance or capability may be judged to be marginal [10]. Some improvement may be evident in the treatment of wool and delicate fabrics. However, the potential problem of metal objects and ornaments scorching holes in clothes may present a performance decrement. In such a case, the perceived advantage of the product will suffer.

The microwave oven, it will be recalled, achieved a market presence not by displacing, but rather by supplementing, conventional thermal ovens. The microwave clothes dryer, in contrast, must successfully displace an existing, satisfactory, mature technology. (Few households will accept the presence of two clothes dryers.) This is by far the tougher task. Attempting to directly displace a mature, satisfactory, and dominant technology is extremely problematical and is rarely a viable strategy.

The market strength of established technologies increases with longevity. An old technology is generally a mature technology, easy to use, and possessing the comforting attributes of consistent performance and predictable life-cycle costs. A technology's longevity confers formidable advantages that are extremely difficult to challenge directly: customer trust, an established distribution infrastructure, and a history of incremental improvements that has resulted in very stable products. Introducing a new technology is difficult under any conditions, but it can be very risky when challenging a well-established technology head-on.

CHALLENGING ESTABLISHED TECHNOLOGY: THE SOLAR EXPERIENCE

The recent history of solar power offers perhaps the best example of a direct challenge to established technology. During the late 1970s and early 80s, solar power was aggressively promoted by both government and industry as a replacement for several well-established energy technologies. Rarely in the history of business and technology have we seen such a coordinated assault on an established technology, and rarely have we seen such a profound failure of strategy. But the solar episode is only partly a story of flawed government policy. It offers several important lessons for any company contemplating a campaign to unseat an established technology today.

The technology of mechanical solar power (the conversion of solar radiation into useful heat by mechanical means) has been explored and extended by various individuals and entities for more than a century [11]. In the 1970s, the United States Department of Energy joined the historical parade of solar entrepreneurs by sponsoring solar thermal power as a substitute for gas and oil-fired water heaters. The technical feasibility of solar power for this application was well established, and the economics of energy in the 1970s seemed to ensure cost feasibility as well. A federal tax credit subsidizing new solar instal-

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lations attempted to increase the cost-feasibility of solar power as a matter of policy.

Numerous commercial solar hot water system concepts and products quickly emerged for both residential and industrial use. Some of these systems were undoubtedly very good. However, the established technology for water heating—oil or gas-fired heaters—was a very formidable incumbent. The relative advantage of solar systems was largely one of lower total projected costs during the system's service life. But this advantage was diminished by its purely prospective character. To realize the cost advantage, a purchaser would have to have high confidence in the longevity of the system and some assurance that his up-front capital expense would be reflected in a higher resale value for his property. Such confidence was hard to instill.

Moreover, the new solar systems introduced some exotic operational novelties that were not present in the established water heater technology. Maintenance of the collector system was an entirely new operational requirement that did not exist with contemporary water heaters. For all intents and purposes, residential water heaters are maintenance-free devices. Therefore, the requirement to perform any maintenance on a solar water heater was new. This maintenance could be quite onerous in some cases. It was a new requirement, and it had the effect of creating uncertainty in market acceptance.

In the end, the strengths of the established technology—reliability, technical maturity, abundant service support, and predictable system costs—were simply too formidable for the challenger. Domestic solar hot water systems failed to take root as a competitive alternative to the established technology. And when the tax credits were removed, the industry simply collapsed.

The Department of Energy's strategy for photovoltaic technology is a similar story, but it may turn out to have a happier ending. Originally, DOE focused on grid-connected photovoltaic power plants. For this application, a cost advantage for photovoltaics over conventional forms of power generation was never demonstrated. DOE planners may well have expected that such an advantage would materialize as the result of relentlessly increasing prices for fossil fuels. But of course, fossil fuels did not continue to dramatically increase in price beyond the early 1970s. A relative performance advantage over contemporary power-generation technologies was not evident; indeed, perceived advantage was adversely impacted by the obvious problem of how to store energy for use at night and during extended cloudiness. In addition to these problems, the novelty of operating a photovoltaic installation was quite large. No experience base existed for defining the requirements for maintenance and operation of such a facility. Grid-connected photovoltaic power plants never got off the ground.

SOLAR THRIVES IN NICHES WHERE IT DOES NOT CHALLENGE ESTABLISHED TECHNOLOGY

This is not the end of the photovoltaics story, however. Small, stand-alone applications of photovoltaic systems are experiencing a renaissance. Security lighting, billboard lighting, and roadside emergency call stations are examples of photovoltaic applications that are doing rather well [12]. The international market for larger photovoltaic systems is especially promising [13]. Power grids do not extend to most rural regions of the world. Photovoltaic systems are now being developed and marketed to provide power for village-size requirements in remote areas.

The emerging market success of photovoltaic power systems is a stark contrast to the failure of photovoltaics in the original DOE program. The photovoltaic manufacturing companies experiencing success today are doing so without government subsidies, sponsorship, or plan-

The market strength of established technologies increases with longevity.

ning (although many of the advances in photovoltaic technology they employ resulted from R&D originally sponsored by DOE). Their strategy differs significantly from DOE's original strategy. They have avoided the problems one encounters when competing directly against an established technology in its area of strength. They are entering the market through a "back door" by addressing a market need which has gone unfilled by the dominant technology or antecedent product.

This strategy is analogous to the 3M Post-it Notes example in that technology insertion occurs in a previously unrecognized marketplace outside the established mainstream. In such cases, the market uncertainties introduced by high operational novelty appear to be largely neutralized by the enormous performance advantage provided by a system which satisfies heretofore unmet needs. Furthermore, by inserting the new technology in a manner that avoids direct confrontation with the established technology, the new product can avoid direct price competition. Because they are less subject to price competition from an established technology, it is possible to charge a price that will permit profitability and attract investors. This is, of course, an essential milestone for the long-term viability of any new industry.

Thus, the future of the photovoltaic industry looks brighter, at least in the neglected market niche of remote power installations. If the industry achieves stability and long-term viability in this market area, it will have established a beachhead from which it may someday again challenge the conventional technology in its area of dominance (grid-connected power plants). As stand-alone systems are designed and deployed for larger applications, such as large villages, they begin to look like small power plants with local grids. Over time, the experience base developed from such installations will reduce the operational novelty of the technology and enhance industry's receptivity. Through this oblique approach to the market, photovoltaics may ultimately succeed in usurping the dominance of the established technology, whereas the direct approach utterly failed.

ISSUES TO CONSIDER WHEN DEVELOPING A STRATEGY

Challenging an established technology with a product based on a new technology can be perilous. To evaluate the risk, two sets of questions should be asked and objectively answered before a product introduction strategy is determined.

First, what are the performance differences of the new product vis-à-vis the dominant technology? Will the performance advantages be tangible and substantial ones from the point of view of the customer? Do negative performance differences exist that can neutralize those that are positive? Regarding cost as a facet of relative advantage, is the cost structure of the new product (including pay-back profile, if applicable) an improvement?

Second, what are the operational novelties of the new technology relative to the operation of products based on the dominant technology? Is the operation of the new product different in perceivable ways, and to what degree? (Remember that novelty is not simply a question of complexity, but also of compatibility.)

The answers to these two sets of questions should be compared against each other. The matrix in Figure 3 illustrates a framework for this evaluation. Relative performance advantage and operational novelty must both be considered when planning the introduction of a new-technology product. Ignoring or discounting either of these factors may contribute to a poor forecast of market receptivity.

As a general rule, we would expect products with a high score for relative performance advantage but low marks on the scale of operational novelty to have rather good chances for acceptance in the market (quadrant 1 in Figure 3). In such cases, a direct confrontation against an established technology, while still risky, may not be foolhardy. An aggressive marketing campaign with creative pricing and advertising strategies may do well.

Products that score in quadrant 4 (low performance advantage and high operational novelty) may face very

Relative advantage and operational novelty must both be considered . . . [for] new technology product.

rough going. Rechargeable battery systems offer an example of such a product. Rechargeable batteries for flashlights, toys, and portable tape and CD players have been available for many years, but they have never achieved significant market share. When charged, these batteries can be used just like conventional dispensable batteries, but they do not offer a clear performance advantage; rather, for most applications, they actually suffer reduced performance compared with disposable batteries. Furthermore, they introduce high operational novelty because the customer must purchase a battery charger and periodically perform the process of recharging. When these factors are coupled with high initial capital cost (compared with disposables), it is not difficult to see why rechargeables have made only limited penetration of the marketplace when promoted as replacements for conventional batteries.

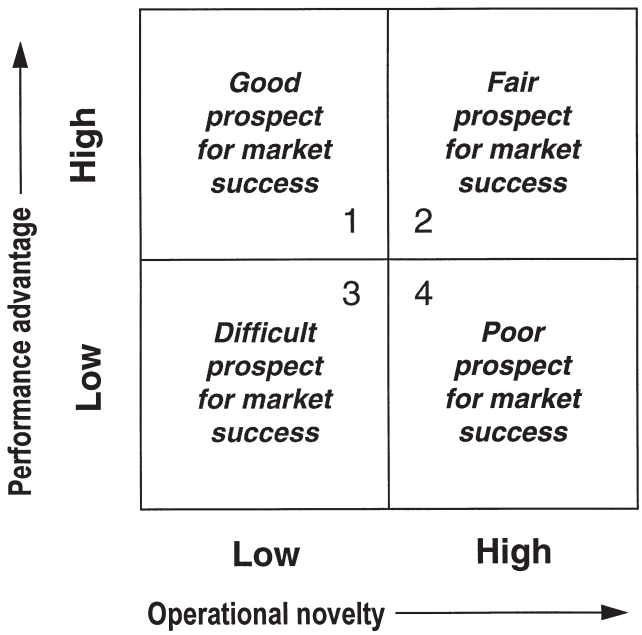

FIGURE 3. **Evaluation of market risk for new technology products.**

In contrast, rechargeable power tools have achieved very broad market acceptance in the last few years because they offer substantial relative advantage over corded tools. The operational novelty associated with recharging appears to be more than offset in customers' minds by the convenience of not being limited by a power cord. Rechargeable batteries, as an alternative to disposables, have recently been reintroduced to the market with improvements. Notwithstanding the environmental advantages of rechargeable batteries, it will be interesting to see whether the product does better this time.

Products falling within quadrant 3 (low performance advantage and low operational novelty) have little to show to stand out from the dominant market technology. However, because their functions are compatible with the existing technology, they may be viable as an average-quality alternative to the market standard if their prices are competitive. This is unusual, however, since normally it is older technologies that fill this role as their costs fall and as quality and performance standards are raised by newer technologies.

MANAGERIAL ACTIONS FOR ENHANCING ADOPTION

Those products that fall within quadrant 2 of the matrix shown in figure 3, where relative performance advantage and operational novelty are both high, are more promising of success but are still problematic. Actions that mitigate or compensate for the operational novelty will be helpful. It is always a shame to abandon an exciting new technology that can provide real performance improvements merely because customers may be put off by having to learn a new process or maintenance regime.

If a product developer recognizes the challenge and takes appropriate action, it is quite possible that adoption reluctance may be reduced significantly. For example, a

product developer may recognize the need to offer training along with the purchase of the product to help overcome potential resistance to high operational novelty. Alternatively, the product developer may consider small but significant modifications of a product that can increase the perceived compatibility with previous practice (for example, relabeling the "Send" button as "Dial" on cellular telephones).

For industrial products and technologies, the attributes and actions of both supplier and adopter firms will also affect diffusion [14, 15] and may reduce the resistance to adoption created by high operational novelty. Certainly, a highly competitive environment should stimulate changes in corporate culture and generate actions that will enhance a firm's marketing performance. On the other side of the coin, a highly competitive environment among adopters may make firms open to change and more willing to tolerate substantial operational novelties associated with new technologies.

The perceived attributes of the supplier firm can enhance or discourage potential adopters. For example, new technologies are often brought to market by new companies with no track record of customer support and no established reputation for continuity and accountability. A strategy for overcoming this perception may include joining forces with a more established firm (perhaps even a former competitor), licensing an established brand name or licensing the technology to an established firm, bundling the hardware product with a service product, or offering pricing and financing options that share investment risk (such as flexible leasing arrangements).

It is also important to understand the pressures and culture of the adopter industry. An industry that is hypercompetitive may be more interested in technology that can reduce design cycle time rather than add end-product enhancements. But an industry that is relatively secure and set in its ways may not have any compelling reason for investigating a new technology, particularly when operational novelties are involved that will require changes in the established way of doing business. In such cases, product managers should seek to gain a toe-hold and then turn up the competitive heat. For example, a strategy of low introduction pricing to create competitive advantage for the adopter may be necessary in the early years. If the technology can quickly introduce differentiating features into the look, feel, or performance of an adopter's product, or increase shareholder value by realizing efficiencies in productivity, it may create a competitive challenge that will force an adjustment by the entire industry.

In a mature industry with little incentive for innovation, the biggest challenge may be finding a toe-hold. It is for these cases that a strategy of oblique entrance to the market may have greatest merit. It is important to explore many possible applications of the technology or product and identify an unfilled market need that can be exploited. Rather than challenging the established technology head-on, it will be important—if at all possible—to identify a niche or unmet need that can serve as a basis for a longer-term, oblique challenge to the dominant technology.

SUCCESS OF THE OBLIQUE STRATEGY: FUSION SYSTEMS CORPORATION

The story of how Fusion Systems Corporation of Rockville, Maryland, established itself as a dominant developer and manufacturer of industrial process light and radiation sources is a tale of entrepreneurial success in the proud American tradition of initiative and hard work [16]. It is also a very instructive example of the oblique approach to challenging an established technology when the challenger is burdened with high operational novelty.

Fusion Systems began as a entrepreneurial venture in the early 1970s by three physicist-engineers who left service in the United States government to form their own company. Their product, a high-power, microwave-driven, ultraviolet light source, was based on a novel technology that had not previously been applied outside the laboratory. The target market was the chemical and materials industries. It had been demonstrated that high-power ultraviolet light could be used to excite or stabilize a variety of chemical reactions more effectively and with fewer problems than chemical catalysts. In principle, photo-induced reactions offered substantial performance advantages.

The entrepreneurs were surprised to receive no orders from their target customer group in the first several years. The fact that the established technology was satisfactory constituted a substantial barrier, regardless of the performance advantages offered by the new technology. In addition, using the new ultraviolet lamps instead of chemical catalysts introduced a high degree of operational novelty in a technical area that chemical engineers were not used to operating in.

Fortunately for Fusion Systems, a market for ultraviolet-radiation-cured paints, inks, and coatings was emerging at about the same time, offering a different avenue for their product that did not require challenging an established technology. These paints and coatings were for-

mulated to cure almost instantaneously on exposure to intense ultraviolet light, thereby increasing production capacity. The process avoids lengthy drying time, and the new materials eliminate altogether the problem of volatile organic compounds polluting the air. Thus the technology offered both cost and environmental advantages. With their new product, Fusion Systems Corporation was in an advantageous position to meet the need for robust, efficient ultraviolet lamps in this emerging market where no established competition existed. The company's first order was to supply lamps for curing painted can labels on a brewery production line.

This oblique entry into the ultraviolet-light curing industry established a market presence that helped create familiarity and acceptance of the new technology. It enabled the technology to demonstrate its advantages in a live production environment. It also permitted the company to generate earnings and run an R&D program to adapt its product to other applications. After a few years, the company was able to open a second product division supplying photostabilizers to the semiconductor fabrication industry, a line of products similar in concept to those they had planned for their original target market. Ashers (reactors that remove deposition residues from semiconductor wafers) employing microwave-generated plasmas were another product they were able to introduce using the same fundamental technology. Today, Fusion Systems Corporation is a robust high-technology company with a worldwide presence and a strong market position.

SUMMARY AND CONCLUSION

Challenging an established technology with a product based on a new and unfamiliar technology is difficult under the best conditions. Entrepreneurs should objectively analyze the relative performance advantages and operational novelties introduced by their product and evaluate the likely success of a direct challenge. A more effective strategy for many products may be to challenge the incumbent technology obliquely by first establishing market acceptance in an area that has been overlooked by the dominant technology or in an emerging market need that has not yet been colonized by any single technology.

Superior technology is no guarantee of market success. Acceptance must be cultivated through establishing a customer experience base and generating familiarity and trust with the technology over a period of time. Once a new technology has established a base of acceptance, it may then be realistic to mount a direct challenge to the traditional technology in its area of dominance.

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