CHAPTER 7

Producing Value via Innovation

CHAPTER OBJECTIVES

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A. Introduction

Watching a movie on a mobile phone screen can be somewhat of an eyesore, and it is quite difficult to watch the movie with someone else. A new breed of projectors, however, is ushering in a new age for mobile phones, mp3 players, and other devices. For example, 3M's MPro120 Pocket projector is a handheld device that can project high-quality images from 8 to 50 inches (Figure 7-1). A device that is approximately the size of a small TV remote control, this innovative product uses LED lamp technology that enables the device to run without any internal cooling system. Moreover, this technology enables the projectors to run for four hours while still keeping the total weight at 5.6 ounces.[1] Compatibility with personal computer formats, DVD players, iPods/iPhones, and other mobile phones ensures that this product will be enjoyed by many consumers.

The development of all new 3M products follows a long-established commitment to the environment by 3M. The company's Pollution Prevention Pays (3P) program, which is now in its fourth decade, underscores the company's high visibility regarding environmental management systems and eco-efficiency. The company continues to reduce emissions, and the eco-design of its products responds to customer demand for environmentally lean products.[2] 3M employs a life cycle management program that requires all business units to conduct life cycle management reviews for all new products.[3] This strategy enables the firm to commercialize new products like the MPro projector that incorporate environmental advantages in component procurement, production, customer use, and product disposal.

FIG. 7-1 3M's MPro 120 Projector

Source: *Courtesy of 3M Company*

As the 3M example illustrates, innovative companies are incorporating sustainability concerns into the design of new products. The purpose of this chapter is to identify strategies that enable firms to develop innovations that offer sustainable competitive advantages. We view **innovation** as the effort to create purposeful, focused change in an enterprise's economic, social, and ecological potential.[4] If organizations are to attain sustainability, it is essential for them to develop innovations that attend to each facet of the triple bottom line. They must recognize that focused change can occur to meet a variety of sustainability needs. Firms invest in new ideas in order to address growing populations, provide affordable products and services, serve growing unmet needs, and reduce environmental influences.[5]

As emerging markets mature and mature markets continue to develop, the need for sustainable innovations continues to escalate. Current estimates, for instance, suggest that if per capita consumption rates in the developing economies mirror the rates in developed markets, it will take the equivalent of three Earths to support resource consumption.[6] Innovations are necessary that promote sustainability by finding new ways to do old things as well as new ways to do new things.[7]

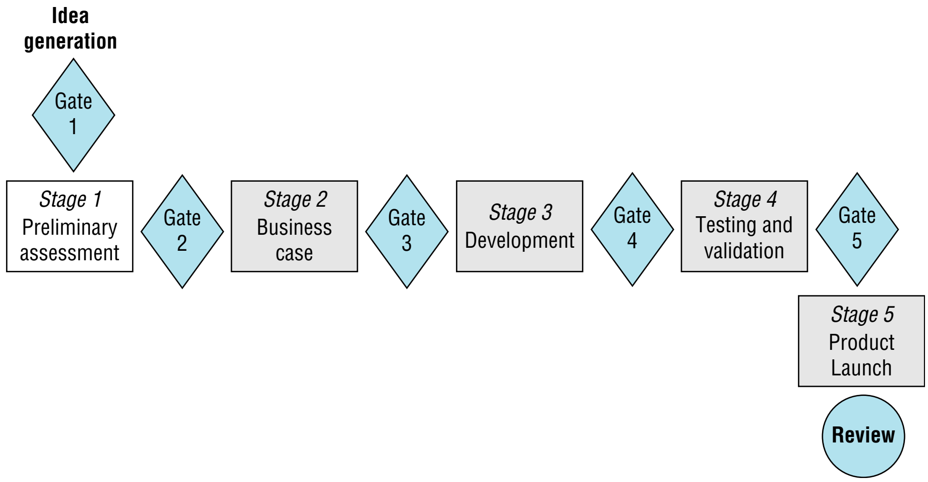
We focus our analysis of innovation on practices associated with developing innovative new products. It is essential, however, to recognize that firms innovate in a number of ways that include new channel development, new business models, and novel product ideas.[8] We distinguish between product and process innovation as two components of development. **Product innovation** refers to new goods and service that offer improvements in technical abilities, functional characteristics, ease of use, and other dimensions.[9] By contrast, **process innovation** refers to novel techniques for producing goods and services. These production enhancements are often designed to yield higher levels of triple bottom line effectiveness. Understanding of the innovation process demands consideration of both activities within the firm. In many cases, the process innovations developed by one firm become the product innovations of a second organization. For example, the innovations that UPS has made in its package tracking technology have enabled the firm to market these capabilities to its clients.[10]

In the following text, we begin by outlining the new product development process. We subsequently address the preliminary assessment, business case analysis, product development, and marketability of innovative product offerings. We then provide an overview of process development. Consider first a general framework for the development of new products.

B. Product Innovation Framework

Firms engage in an interactive process in their efforts to develop new product and service offerings. The stage-gate process outlined in Figure 7-2 elucidates the series of activities involved in designing new products.[11] *Stage-gate* recognizes that firms engage in a number of activities between idea conception and the market launch of a product. These phases are multifunctional and require interaction among marketing, R&D, production, and other activities internal and external to the firm.[12] Research indicates that technical flaws account for about 20% of product failures, whereas marketing- and management-related deficiencies account for 75% of product failures. The last 5% is not addressed in the reviewed literature. The various

FIG. 7-2 Product Innovation Framework



Source: *Robert G. Cooper, "Stage-Gate System: A New Tool for Managing New Products,"* Business Horizons *(May–June, 1990): 44–54.*

departments within the firm must work together to increase the likelihood of new product success.[13]

Each phase and stage of the development framework is accompanied by a complementary gate. **Gates** are the points in the development process at which the firm evaluates the potential for a product. The gates are predetermined and specify *must meet* requirements of a project and *should meet* requirements of a product. At each stage in the process, firms deliberate whether to *kill* the project or allow it to *go* forward to the next stage. Firms make substantial investments in new product development, and the benefits of successful new products and the costs of failure are staggering. Estimates indicate that products released in the past three years account for at least 25% of a firm's revenue.[14] By contrast, failed product launches in the electronics industry are estimated at more than $20 billion per year.[15] By devising an appropriate series of gates or checkpoints, firms increase the likelihood of success and reduce the potential for failure. As the product develops toward full market launch, the costs associated with the product increase. Consequently, each stage of the process demands more stringent gates that serve as barriers to advancement of the new product project. Decisions that are made to *kill* products should be made as early as possible in the development process. The early elimination of products destined for market failure prevents the firm from spending valuable resources needlessly. Nevertheless, the decision to eliminate a known unsuccessful project benefits the firm regardless of the stage at which the project is killed.

We next outline the various phases of the new product development process. We begin with a discussion of idea generation.

C. Product Innovation: Idea Generation

The initial activity in the new-product development process is the generation of an idea. The stakeholders associated with an organization are at the forefront of this phase of the new-product development process, and it is essential to treat stakeholders as partners throughout product innovation. New ideas can emerge from virtually any aspect of the environment, and it is important to work with stakeholders to understand their vantage points for innovations. Participation in product development should therefore include employees, consumers, vendors, government, nongovernment organizations, and the general public.

Employees are often valuable sources of information because they have the potential to understand the market as well as the production and strategic objectives of the firm. Note, however, that this understanding can also be limiting to employees. The logic of "business as usual" may detract from the ability to offer ideas that genuinely challenge current operations. In many situations, organizations develop teams of employees involved in new-product development. These individuals come from the marketing function as well as from other technical areas of the firm.[16]

If these teams are to generate ideas successfully, it is imperative for them to recognize some of the inherent challenges in group development. The group process may generate **production blocking** characterized by the inability to offer opinions simultaneously. In addition, the firm should recognize that the group process may be hindered by employee concerns about evaluations drawn from the idea generation process. Research indicates that the influence of these problems can be quelled by electronic idea generation sessions. Asynchronous interaction enables multiple responses without blocking, and anonymous participation precludes management from using the idea generation sessions in employee evaluations.[17] The organization must also contend with the possibility that some team members free-ride in the development process by failing to offer ideas. This failure to participate in idea generation can be lowered by offering employees incentives for their participation.[18]

Beyond the organization, it is also clearly essential to poll the activity of consumers of the firm's product. Although the typical process in the firm has been to survey the breadth of consumers in a market, recent studies emphasize the need to look at lead users. **Lead users** are consumers that expect attractive innovation-related benefits from a solution and experience needs for an innovation earlier than most participants in a target market.[19] A representative sample of the target market customers that is familiar with existing product uses may have difficulty conceiving of novel product uses and attributes. By contrast, future-oriented lead users are more inclined to face issues today that most users will face in the coming months.[20] These lead users tend to have more consumer product knowledge and experience than other consumers. Relative to other users, they more frequently commit to risky, innovative, and difficult tasks, and they are more likely to be predisposed to innovation.[21]

Vendors, the organizations that market to one's firm, can also be a source of new product ideas. Competitive suppliers operating close to the firm provide shortened communication lines that facilitate the exchange of ideas that yield innovations.[22] Furthermore, sales organizations can take the innovative ideas generated in one context and adopt this logic in a novel setting. Nevertheless, vendors operate in a mixed-motive model and may not have the best interests of the seller in mind. In some cases, firms have therefore elected to develop teams of personnel including vendors as well as users.[23] These interfirm teams can increase the quality of new product ideas by reducing the misunderstanding that arises from working across corporate boundaries. Similarly to their intrafirm counterparts, cross-functional teams that share information early and throughout their operations can identify problem areas early in the development process.[24]

Government at all levels—from local operations to multinational alliances—is also a valuable source of new ideas. For example, the United States Department of Commerce supports efforts to bring new technology to market via the National Institute of Standards and Technology (NIST). NIST promotes innovation in the United States through high-risk, high-reward research in areas of critical national need.[25] Scientists affiliated with NIST conduct breakthrough research that leads to the innovations, but the range of NIST effort does not extend to product development in any of its research areas. The work needed to exploit NIST technologies for commercial viability requires innovation on behalf of the private sector. Commercially promising patents are identified together with the technological gaps that impede their direct transition to the marketplace. For example, recently supported NIST research has fostered the development of flexible computer chip technology. Innovators that gain an understanding of this technology can develop marketable processor chips for a variety of applications.[26]

Nongovernment organizations (NGOs) are similar to government in the sense that they serve as sources of information for the development of new ideas. Organizations such as McDonald's, IBM, and Walmart have recognized that interaction with these organizations can provide a wealth of information that is relevant to the generation of new ideas.

While it is insightful to examine the source of an innovation, it is also illuminating to examine the events that serve as the impetus for developing an innovation. Prior research suggests seven possible sources of innovation that vary based on whether they are associated with events occurring within or outside of an industry.[27] Internal events that yield innovation include:

Unexpected occurrences Unexpected occurrences are situations in which customers find novel unanticipated uses for a product. For example, backpackers that hike long distances are reluctant to carry many items in their backpacks because each item increases the burden of the journey. Many backpackers will therefore forego the use of a pillow when a makeshift one can be made from clothing and a nylon bag. When the utility of an item can broaden to include multiple functions, a new use for a product emerges. In addition, by enabling a single product to do the work of multiple items, the economic and ecological costs associated with the activity decline.

Incongruities Incongruities are situations in which there is an inconsistency concerning the prevailing logic in the industry. These incongruities can be associated with manufacturing processes as well as with economic incongruities. For example, the personal computing industry has been characterized by an incongruity between market growth and falling profits. The introduction of netbook computers is partially attributable to the desire to overcome this incongruity.[28] These netbooks enable firms to generate revenue and profits at price levels lower than most personal computers equipped with a hard drive.[29]

Process needs Process needs are modifications in the operations of a product to enhance its performance. For instance, the QWERTY typewriter keyboard was developed in response to the cost of fixing typeface machines that were jammed. Because users of the alphabetic keyboard often jammed the machines at substantial cost, the new keyboard design was developed to slow down users.[30]

Market changes Market changes are situations in which the nature of the industry or market changes. In the television industry, for instance, the basic operation of the product changed from an analog to a digital device in 2009. This change in the product requirements occurred despite recognition that more than 3.5 million American homes were not ready for digital broadcasting.[31]

External events refer to factors happening outside of the industry that prompt innovation. These include:

Demographic changes Demographics is the study of vital statistics such as race, age, gender, and income. Changes in these factors within a population can have a dramatic effect on innovations. In the developing world, for instance, many countries face a situation in which rapid population growth yields higher levels of poverty, and poverty yields higher levels of population growth. These demographic changes are being partially addressed through innovations in irrigation and water recycling.[32]

Changes in perception Changes in perception occur when consumers modify their opinions about some factor in the marketplace. For example, grocery shoppers have begun to modify their perceptions of the environmental costs associated with disposable paper and plastic bags. Consumers are increasingly using reusable canvas bags that are less harmful to the environment.[33]

New knowledge New knowledge is the use of new technical, scientific, or social information that can be instrumental in addressing a market problem. For example, the advent of hybrid automobile engines was prompted in part by new knowledge associated with fuel cell and electric motor technologies.[34]

After the initial generation of an idea, the firm implements its first assessment of the viability of the topic. Throughout the development process at each stage of the model, many firms use checklists or scorecards to determine the degree to which the idea fulfills "must-meet" and "should-meet" criteria. The product development evaluations are a *funnel rather than a tunnel* used to assess products that move toward the market.[35] Thus, the initial screening of the product is less stringent than later in the process. Although there are must-meet and should-meet criteria at this stage, there are no financial criteria at this juncture. The evaluation focuses on project feasibility, strategic alignment, synergy, market attractiveness, and synergy with the company's core resources and business. If the decision is made to move forward, the firm begins the preliminary assessment.[36]

D. Product Innovation: Preliminary Assessment

The preliminary assessment is the first stage of the new-product development process. At this stage, the firm performs an initial market assessment in which the organization determines the market potential and size. The firm will ordinarily perform a online and library search for related products and use focus groups and interaction with key users to assess the likelihood of marketplace acceptance of the product.[37] The market analysis is complemented by a preliminary technical analysis in which the firm assesses the manufacturing and development feasibility of a project. The organization will seek to quantify the time and costs associated with manufacturing the product.[38]

Because the firm will move forward in multiple directions that may include marketing, procurement, logistics, manufacturing, and R&D, it is essential to build effective project teams at the beginning of the development process. Effective new-product teams must have clear goals and unified commitment among the team members.[39] Team members should collectively possess the capabilities to achieve the project's objectives, and they should be supported by resources and psychological support needed to maintain a high level of motivation and focus. Furthermore, the team structure should emphasize a collaborative work environment that promotes effective communication. Team leaders should provide a consistent focused message that directs all team members to achieve high levels of performance.[40]

Gate 2 is the screen used to evaluate potential products at the end of the first stage. Although the *Go/Kill* decision will not be markedly different from the initial screen, the should-meet criteria now incorporate considerations brought to the process by customers and sales representatives. Financial criteria at this point are not substantial, but they do address the potential break-even point for the venture. If the project adequately addresses the should-meet and must-meet criteria, the project moves forward to the business case preparation.[41]

E. Product Innovation: Business Case Preparation

The business case preparation phase is the last stage in the process before substantial investment is made in product development. Consequently, it is essential for the firm to identify the attractiveness of the product associated with manufacturing, marketing, legal, and financial constraints.[42] The manufacturing assessment must address the investment required to engage in production as well as the costs of manufacturing. Since organizations that do not address sustainability concerns face increased social and economic liability, it is important for the manufacturing cost analysis to consider triple bottom line costs associated with manufacturing and the supply chain.[43]

The marketing component of the business case requires the organization to assess consumer needs and wants to determine customer expectations for the ideal new product. In addition, the firm will propose new products to customers to determine their likely acceptance of a new product. Firms that engage in dialogue with potential consumers gain input that enables them to make product enhancements prior to the product development stage.[44] This dialogue enables the firm to identify the economic, social, and ecological merits of the product as they relate to potential consumers. The marketing analysis will also require a competitive analysis to determine the relative advantage of a new product. Similarly, the firm will assess the patentability of a new product as well as a review of legal and regulatory constraints. Increasingly, the legal requirements are embracing technologies that are more beneficial or less harmful to the environment. For example, prevailing EU law prevents firms from marketing electrical or electronic components made from mercury, lead, cadmium, and hexavalent chromium.[45]

The third gate in the new-product development process is critical because it is the last chance to eliminate the idea prior to a sizeable investment. Research within the stage-gate model indicates the need to incorporate the following considerations before advancing to product development:[46]

Product competitive advantage The value proposition for the new product must be compelling and superior with respect to some facet of the triple bottom line. This benefit should be recognized and viewed as favorable by the consumer. If the value proposition is based on ecological merits, then the trade-offs associated with this benefit should be greater than any associated limitations with respect to the social and economic benefits of the product.

Strategic fit It is essential that the new product be consistent with the firm's business strategy. Furthermore, the importance of the product to the business strategy must be recognized.

Market attractiveness The attractiveness of the market includes consideration of the market size and growth potential. The margins realized by competitors in this market should be established, and the intensity of the competition in the market must also be determined.

Core competencies relatedness New projects should reflect the core strengths in the firm. The attractiveness of new products should increase when they enable a firm to leverage strengths in marketing, production, technology, and distribution.

Technical feasibility The feasibility of the technology is addressed by identifying the results to date of a technology and the complexity of the technology associated with a new product. The firm should also identify the degree to which it is familiar with the technology inherent to a new product.

Financial risks and rewards The financial assessment should consider the level of risk associated with a product as well as the ability of the firm to address the risk. The organization should also examine the financial reward in terms of the net present value, productivity index, and size of the financial opportunity.

F. Product Innovation: Product Development

When a product concept successfully passes through the third gate in the development process, it then moves into product development.[47] Marketing and manufacturing activities move in parallel at this stage. The marketing function must continue to track the potential for the product and continue to obtain customer feedback concerning the ecological, social, and economic value associated with the new offering. It is essential to determine the extent to which consumers understand, recognize, and value the benefits derived from the product. On the manufacturing side, the firm develops a product prototype. In the process, the firm assesses the technical feasibility of the new product.

At the close of this stage, the firm faces Gate 4 in the development process. The criteria outlined in Gate 3 are reviewed to evaluate the attractiveness of the product. Although the evaluative criteria do not change much from the previous gate, new information concerning the marketplace attractiveness and financial merits of the project are incorporated into the decision calculus. If the decision is made to go forward, the firm mobilizes to perform a market test.

G. Product Innovation: Test Market and Validation

In the final stage before full market launch of the product, the firm examines whether the product can be manufactured and marketed in a profitable manner. The firm will engage in pilot production during which it will determine the production rates and costs.[48] Importantly, the triple bottom line criteria identified previously must be observable in the test runs of the production process. The firm cannot determine the total amount of by-products that emerge from production, but it will be able to observe which by-products are provided by manufacturing. The firm can determine whether these products can be used in alternative operations as well as the costs and returns associated with the by-product. For example, steel manufacturers identify the amount of slag produced that can be marketed to the cement industry. The assessment of by-products should also examine the amount of greenhouse gases produced in the manufacturing process. Firms that identify greenhouse gas production can act to offset the cost of this operation by making carbon dioxide available to industry or via carbon offset trading.

The marketing activity at this stage focuses on determining the level of interest and acceptance among consumers. If the firm can adequately determine demand, it can accurately determine the resources needed in production and marketing. Test marketing of the product is one activity that provides substantial insight into resource constraints. In a test market, the firm implements a complete market strategy in a single market over a short-term horizon. The test market provides new information about consumer responses to products, and it provides an estimate of sales and profitability.[49] For example, in October 2006, Procter and Gamble began test marketing its concentrated liquid laundry detergent in Cedar Rapids, Iowa.[50] When used in the proper amount, concentrated detergents produce fewer chemical by-products than traditional-strength detergents.[51] The test also provided the opportunity to learn about consumer acceptance and use of this new technology. Thus, the firm could observe whether consumers used the proper dose of the product and the proper water temperature.

Gate 5 at the end of the test market is a crucial point at which to assess whether the product should go into full production. Given the overall costs of producing and selling the product, it is important to be frank in the evaluation at this stage. Many organizations grapple with the desire to be objective at this stage because many individuals have dedicated substantial effort to product development.[52] Projects that will not obtain profitable levels of sales that are eliminated at this stage save the firm sizeable investments. Financial projections are paramount at this stage, and the market test and pilot production provide great insight into these projections. The market test illuminates the potential sales, whereas the market test and pilot production inform the firm about the ecological, social, and economic costs of the product. Consequently, the firm is poised to offer a more precise prediction of the sales and profit potential of a product. This information is essential because it enables the firm to project human resource needs for production and marketing. This information further enables the firm to estimate its resources requirements as well as the by-products of production. If the profit potential of a product is sizable, then the firm begins full product production.

H. Product Innovation: Full Production and Follow-up

When the product reaches the commercialization stage, the production staff commits resources to full-scale manufacturing. Similarly, marketing and sales must be fully committed to the product. Review of operations, regardless of the level of performance germane to this stage of operations, must be performed. Despite the detailed analysis associated with the new-product development process, roughly half of all new products still fail to achieve commercial success.[53] It is incumbent on the firm to review the product development process to reconcile marketplace and production realities against the projections. Sustainability assessments associated with the ecological and social returns of a project necessarily should augment the economic costs and benefit considerations.

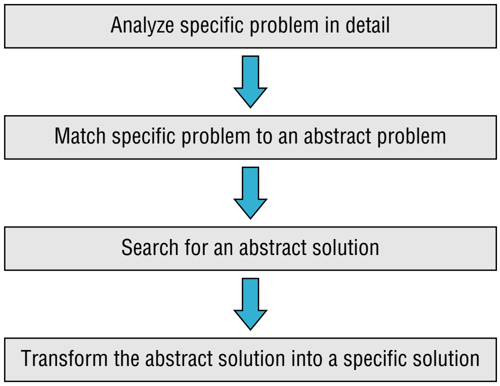
Data associated with expenditures, revenues, profits, and timing should be compared to related projections so that the firm can identify opportunities to learn from the new-product development process. This exercise should be performed regardless of the degree of success with the project. Recognizing individuals that made high-quality projections and evaluations likely reinforces their predisposition to continue to perform adequately. Critiques that identify potential areas for improvement similarly enable members of the new-product development team to refine their evaluation and assessment of future projects.

I. Process Innovation

Process innovation refers to a technical system that generates value by transforming resources into products. These products contain physical and service components.[54] Several factors contribute to the desire to develop uniform, standard processes.[55] Standardized processes enhance communication and information systems operating across departments and firms. In addition, standardized processes provide the opportunity to hand off subcomponents and products more efficiently between functional groups. The standardization of processes also enables organizations to outsource activities associated with a process more easily. For example, specification of component requirements enables Dell to focus its internal operations on final assembly and pass component-related production to its suppliers.[56]

Organizations that develop operational standards may evaluate the operations associated with the process in three ways.[57] First, standards emerge due to the simultaneity of this activity in numerous organizations and locations. The movement toward standardization is occurring simultaneously across multiple organizations, and as this transformation occurs, process standards and performance guidelines for these standards are emerging. The Supply Chain Council, for example, has developed the Supply Chain Operations Reference (SCOR) model.[58] This model provides detailed visibility of how work is accomplished. It promotes team building and facilitates process improvement by addressing the entire supply cycle. Second, the development of standards facilitates **process performance evaluation**. When companies in an industry develop consensus about the activities and flows associated with a process, they can begin to compare their results to external service providers and competitors. Version 9.0 of the SCOR standards, for instance, incorporates industry best practices with respect to the environment. The standards address energy consumption and efficient resource utilization, and they identify environmental metrics such as carbon footprint, energy costs, and emissions per unit of production. The emerging standards also identify procedures for the management of waste and other by-products of manufacturing.[59] These standards enable the firm to compete more effectively while lowering costs, reducing cycle times, and enhancing reliability. Third, **process management standards** provide the opportunity to assess how well processes are managed. By outlining the key activities and resource demands of a process, a firm can evaluate the performance of alternative providers of a process. For example, firms can decide whether it is more efficient to have a process performed in-house or by a third-party vendor.

FIG. 7-3 Framework for Examining Process Innovations



Source: *Martin G. Moerhle, "What is TRIZ? From Conceptual Basics to a Framework for Research,"* Creativity and Innovation Management *14 (1, 2005): 3–13. Wiley-Blackwell Publishers.*

Given the potential to augment efficiencies and raise performance via innovation, firms continue to evaluate the processes associated with production and supply. The *theory of inventive problem solving* recognizes that action dedicated to solving one issue often has negative outcomes for another aspect of the system.[60] A **contradiction** includes anything that limits the performance of a system relative to its goal. For example, increases in the number of functions performed on a computer likely yield higher costs of computer maintenance. When such contradictions are managed effectively, the overall performance of a process should increase. The evaluation of a process to enhance its productivity can be achieved via a four-phase procedure outlined in Figure 7-3.[61]

Analyze specific problem in detail In the initial phase, the firm begins by illustrating how the present process addresses a problem. The firm identifies how a process works, and it identifies the materials, information flows, and energy associated with a process. Importantly, the firm specifies the input materials used in a process as well as the tool that transforms the process and the action undertaken by the tool. For example, the removal of impurities from water involves a water source (input), a gauze filter (tool), and purified water (output). The action of the tool can be expressed in terms of the operations it performs on the input material. The output materials may be useful or harmful, and in many cases the analysis of the process examines the utility of the outputs. Whereas some outputs are likely harmful, firms are increasingly searching for useful purposes for all output materials. For example, the steel production process outlined in Chapter 14 underscores efforts made within this industry to use most outputs from each production stage. Note that the desired and harmful outcomes associated with a process may reflect different performance outcomes associated with the economic, ecological, and social outcomes sought in a process. For example, the social returns from having mobile telephone service must be weighed against the economic and ecological cost incurred in production and service.

After the operation of a process and its associated inputs and outputs have been identified, one can determine whether there are resources within the process that are not fully exploited. Resources include the materials endemic to operations (e.g., input materials, desired outputs, by-products), but they also include spatial requirements (e.g., physical footprint of the tool), temporal considerations (e.g., just-in-time considerations), energy demands, and information requirements. Since all of these resources influence productivity, firms that consider each of these factors have greater potential to raise productivity.

Analysis of the resources associated with an operation enables the firm to evaluate the productive use of currently employed resources as well as alternatives to current operations. In the evaluation of their refinery operations, Shell isolates substantial levels of carbon dioxide that they market to Dutch greenhouses. Note that this evaluation of manufacturing processes also enables firms to assess whether there are available external resources. The carbon dioxide provided by Shell, for instance, is an external resource made available to the floral industry. Sale of this compound reduces emissions by 325,000 tons per year and saves greenhouses from having to burn millions of cubic meters of gas.[62]

In addition to identifying the resources in a process, this initial evaluation also examines the goals of the operation. This consideration demands that the firm balance the best possible solution against conditions that restrict one from recommending the best solution. Consider, for example, the design of computers used to verify production quality of automobiles rolling off an assembly line. The design of these machines must consider the trade-off between the convenience of uninterrupted power versus the weight of the device. Efforts to enhance power capabilities must be assessed in light of the market attractiveness of a relatively heavy computer.

Match specific problem to an abstract problem After the current operations have been clarified, the organization then matches the specific problem associated with a process to an abstract problem. Theory of inventive problem solving calls for the inventor to develop a **contradiction matrix**.[63] According to this approach, a series of 39 factors represent the potentially favorable or harmful outcomes associated with a process. These factors include weight, length, area, power and energy considerations, operational issues, and productivity. The matrix matches each of these factors against all other factors in the matrix. At 39 factors, the number of potential constraints is 1,482 ($39^2 - 39$). A partial contradiction matrix is provided in Figure 7-4. By developing this matrix, the inventor identifies all trade-offs between desired and harmful outcomes. In the personal computer example, the desired outcome of uninterrupted power is treated as a component of the need to limit the amount of energy lost. By contrast, the weight of the batteries within the computer is represented by the *weight of the moving object* in the contradiction matrix. Note that at this point in the analysis, the contradiction (in the specific problem) between power convenience and computer weight has been transformed to an abstract problem between loss of energy and weight of a moving object.

Search for an abstract solution In the third phase of process innovation, the firm searches for technologies that enable them to overcome the constraints identified in the prior phase. In the development of theory of inventive problem solving, researchers observed that 40 abstract principles have previously been applied to address the series of contradictions in the matrix. Importantly, these principles have historically been successfully associated with selected contradictions in the matrix. For example, firms and inventors that have faced the trade-off between loss of energy and weight of a moving object have used the principles of dynamics, universality, periodic action, and mechanics substitution. By shifting the problem to the abstract, the inventor gains the ability to consider the multiple ways in which others have successfully addressed this type of issue. Thus, the computer developer for quality control at the

FIG. 7-4
Contradiction Matrix

Worsening feature →	1. Weight of moving object	…	22. Loss of energy	…	39. Productivity
Improving feature ↓					
1. Weight of moving object	+		6, 2, 34, 19*		35, 3, 24, 37*
…					
22. Loss of energy	15, 6, 19, 28*	,	+		28, 10, 29, 35*
…					
39. Productivity	35, 26, 24, 37*		28, 10, 29, 35*		+

*The numbers represent 40 abstract principles previously used to address the 1,482 abstract problems in the matrix:[63]

2. *Taking out*
Separate an interfering property or part from an object.

3. *Local quality*
Change an object's structure from uniform to nonuniform, or make each part fulfill multiple functions.

6. *Universality*
Make a part or object perform multiple functions, or eliminate the need for other parts.

10. *Preliminary action*
Before it is necessary, perform the required change of an object; or arrange objects so that they can come into action from the most convenient place and without time loss.

15. *Dynamics*
Design characteristics of an object to be optimal; divide an object into parts capable of movement relative to each other; or make inflexible objects adaptive.

19. *Periodic action*
Use periodic or pulsating action instead of continuous action.

24. *Intermediary*
Use an intermediary process or an intermediary carrier article, or temporarily merge one object with another.

26. *Copying*
Replace unavailable, expensive, fragile objects with simpler and inexpensive copies.

28. *Mechanics substitution*
Replace a mechanical means with a sensory means, or use magnetic and electric fields to interact with the object.

29. *Pneumatics and hydraulics*
Use liquid or gas parts of an object instead of solid parts.

34. *Discarding and recovering*
Eliminate or modify objects that have fulfilled their functions, or restore consumable parts during operations.

35. *Parameter changes*
Change an object's physical state (e.g., to a liquid); change the concentration, consistency, flexibility, or temperature.

37. *Thermal expansion*
Use thermal expansion and contraction of materials.

Source: *Based on Features of the Contradiction Matrix, by Ellen Domb, Joe Miller, and Ellen MacGran.* TRIZ Journal, *(November 1998.), http://twin-spin.cs.umn.edu/files/matrixwordversion.pdf (accessed June 10, 2009).*

end of an assembly line may elect to investigate the degree of universality as an abstract solution to the contradiction. This principle suggests that objects associated with a process perform multiple functions. When components offer multifunctional versatility, other components can be reduced or eliminated.

Transform the abstract solution into a specific solution In the final phase of the process, the abstract solution is transformed into a specific solution. The computer developer pursuing the principle of universality may consider increasing the functionality of selected components. Thus, photovoltaic cells placed on the back of the display add marginal weight, but they also add a source of energy.

The theory of inventive problem solving provides a strong framework for the analysis of enhancements to production processes. The breadth of the favorable and unfavorable outcomes associated with the contradiction matrix enables the organization to apply this logic across elements of the triple bottom line. Organizations must augment consideration of social and economic returns with consideration of ecological returns from these processes. When all three outcomes are considered, the potential for sustainable processes and designs should increase.

Summary

A. Introduction

The goal of this chapter has been to develop strategies that enable firms to develop innovative products and product strategies. New products are important to success, yet many products fail to enhance the performance of the firm. We presented the stage-gate model of new-product development as a framework for product development. We augmented the discussion of this framework by outlining a process by which firms can enhance process innovations.

B. Product Innovation Framework

The *stage-gate process* refers to a series of activities involved in designing new products. Stage-gate recognizes that firms engage in a number of activities between idea conception and the market launch of a product. These phases are multifunctional and require interaction among marketing, R&D, production, and other activities internal and external to the firm.

C. Product Innovation: Idea Generation

The initial activity in the new product development process is the generation of an idea. Since new ideas can emerge from virtually any aspect of the environment, it is important to work with stakeholders to understand their vantage points for innovations. Participation in product development should include employees, consumers, vendors, government, and other stakeholders.

D. Product Innovation: Preliminary Assessment

The preliminary analysis is the stage in which the firm performs an initial market assessment to determine the market potential and size. The firm will ordinarily perform an online and library search for related products and use focus groups and interaction with key users to assess the likelihood of marketplace acceptance of the product. The market analysis is complemented by a preliminary technical analysis in which the firm assesses the manufacturing and development feasibility of a project.

E. Product Innovation: Business Case Preparation

The business case preparation phase is the stage in which the firm evaluates the attractiveness of the product given manufacturing, marketing, legal, and financial constraints. The manufacturing assessment must address the investment required to engage in production as well as the costs of manufacturing. The marketing component of the business case requires the organization to assess consumer needs and wants to determine customer expectations for the ideal new product. The firm also assesses the patentability of a new product and reviews other regulatory constraints.

F. Product Innovation: Product Development

During this stage, marketing and manufacturing work in tandem to bring the product closer to market. The marketing function tracks the potential for the product and obtains customer feedback concerning the ecological, social, and economic benefits derived from the product. On the manufacturing side, the firm develops a prototype and assesses the technical feasibility of the new product.

G. Product Innovation: Test Market and Validation

In this final stage before full market launch of the product, the firm examines whether the product can be manufactured and marketed in a profitable manner. The firm will engage in pilot production during which it will determine the production rates and costs. The marketing activity at this stage focuses on determining the level of interest and acceptance among consumers. When the firm adequately determines demand, it can accurately determine the resources needed for production and marketing.

H. Product Innovation: Full Production and Follow-up

At this stage, the production staff commits resources to full-scale manufacturing, and marketing similarly commits to the product. Review of operations, regardless of the level of performance germane to this stage of operations, must be performed. It is essential for the firm to review the product development process to reconcile marketplace and production realities against the projections. Sustainability assessments associated with the ecological and social returns of a project necessarily should augment the economic costs and benefit considerations.

I. Process Innovation

Process innovation refers to a technical system that generates value by transforming resources into products. The theory of inventive problem solving enables firms to examine whether enhancements to one process influence other outcomes associated with a system. The evaluation of a process includes analysis of a specific problem in detail, matching the specific problem to an abstract problem, searching for an abstract solution, and transforming the abstract solution into a specific solution.

Keywords

Questions

1. How is sustainability relevant to new product development?
2. Figure 7–2 outlines a series of processes that precede the development of new products. Why is it necessary for the firm to pass through each phase?
3. What are gates, and why are they important to new-product development?
4. Explain why the decisions made at each gate should involve sustainability considerations.
5. Who are the stakeholders that should be consulted during idea generation, and how does each inform the development process?
6. Describe a situation in which internal events lead to the development of an innovation.
7. What are the potential consequences to the firm that does not adequately engage in business case preparation?
8. What critical decision is made after test marketing, and what information contributes to this decision?
9. Distinguish process innovation from product innovation, and explain why both forms are necessary.
10. What are the four stages of the theory of inventive problem solving, and how do these phases help to develop process innovations?

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